Forest Health Assessment and Plan for the 2006-2007 project area of Mount Spokane State Park

Pacific Biodiversity Institute

Washington Park staff discussing forest health issues at Mt. Spokane

Forest Health Assessment and Plan
for the 2006-2007 project area of
Mount Spokane State Park

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Forest Survey Crew, October 2006 Sampling Period

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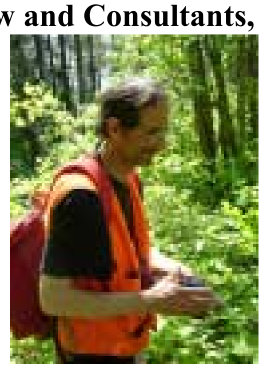
Forest Survey Crew and Consultants, May 2007 Sampling Period

Don Stragis and Hans Smith



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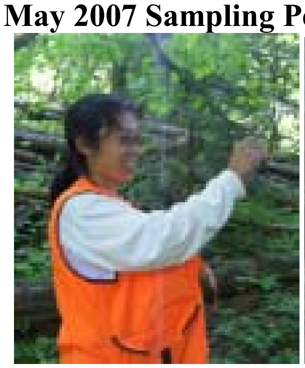
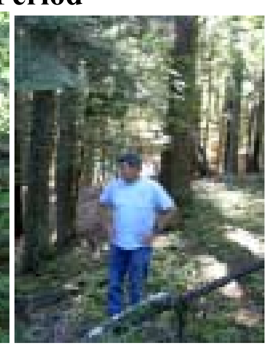


Juliet Rhodes



Tom Leuschen

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Executive Summary

The goal of this project is to protect and enhance the health of a portion of Mount Spokane State Park's forested lands through creating a forest mosaic rich in structure and diversity; reducing the risk of catastrophic wildfire; protecting and creating habitat for a diversity of native plants and animals; protecting cultural resources; and, providing a safe and aesthetically pleasing environment for visitors. In addition to these goals, the project will encourage the redevelopment of more fire-adapted forests.

Mt. Spokane State Park is the largest state park in Washington State (13,919 acres) and is located in the northeastern corner of the state, near the city of Spokane. Mt. Spokane is the highest peak in Spokane County and is a local icon visible from the surrounding populated valleys. The park is a heavily forested, semi-natural area popular throughout the year with a variety of recreation opportunities. It was established in 1927 and grew to its current acreage by 1993 through land acquisitions and subsequent land donations.

Pacific Biodiversity Institute undertook this project under contract with Washington State Parks. Our work on this project has focused on providing information on forest health and habitat conditions in the project area at the State Park. In this report, we also provide management direction via a forest plan that gives guidance on forest management and specific treatments that will assist Washington State Parks in meeting the project goals.

We intensively studied about 4,250 acres of the park in 2006 and 2007. This area was determined to be the most important part of the park to assess for forest health issues and was selected from an initial 6,000-acre potential treatment area. The mean elevation of the project area is 3,921 feet and most of the mountain slopes exceed 20% in steepness. The project area receives about 38 inches of mean annual precipitation a year – about the same as Seattle. The top of the mountain receives over 300 inches of snow on the average year. Deep, volcanic, ash-derived soils capture and store much of this moisture, leading to lush forests, which cover most of the mountain.

We surveyed and conducted a comprehensive analysis of ecological data from 406 systematically located forest condition assessment plots across the project area. We used these data to evaluate, at a fine spatial scale, many factors influencing fire hazard, forest health condition, and wildlife habitat condition. Using this information, we were able to draw objective conclusions about the ecological condition of forests in the project area, and draw conclusions about the magnitude and spatial distribution of forest health elements across the landscape.

Each forest condition survey plot consisted of a nested fixed radius (1/20th acre) plot to measure understory characteristics and a variable radius plot to measure tree characteristics. We located the plots that were established on a fixed grid system using GPS. At each plot we took a final GPS location calculated by waypoint averaging. We measured the overstory and midstory trees in each plot using prism sampling. We recorded the species, diameter, height, height to live crown and dominance of all "in trees". We also recorded the species, height, diameter, and decay class for each snag that was "in". We recorded the forest canopy closure measured with four readings of a spherical densiometer. In the fixed radius plot we identified and visually estimated the percent cover and maximum height for the 3 most abundant understory and shrub species. We estimated, using an ocular count, the total number of shrub species present. We also recorded the ground cover, number of pieces and decay class of coarse woody debris in each plot. We counted the number of small trees (less than 4 inches DBH) in each plot and estimated their percent cover.

We characterized each plot to one of 40 fire behavior fuel models that best described the fuel conditions for that plot. We assessed the overall vegetation in each plot and classified it to a forest plant association.

Once the data were transferred into a database the data values were automatically converted to a per acre basis and we calculated the following forest stand indices for each plot: canopy cover, quadratic mean diameter, canopy bulk density, canopy height, canopy base height, trees per acre, stand density index, basal area per acre, and understory mean height. We also calculated the maximum diameters of trees meeting potential old-growth criteria, tree diameter distributions, information on tree species composition and dominance classes, information on the distribution of snags, coarse woody debris, shrub cover, frequency of small trees and Shannon diversity indices. The generated statistics were used to help understand potential fire behavior, predicted fire effects, wildlife habitat suitability, and forest health issues.

A closed canopy coniferous forest interspersed by a few small meadows and some larger shrubfields covers most of the project area. We found 14 different plant associations in the project area during our forest survey. Most of these plant associations are in the grand fir zone. However, there are some in the wetter western hemlock zone. The other categories fell into the subalpine fir zone, Douglas-fir series, western redcedar series, or non-forest plant associations. Three plant associations were ranked as either globally imperiled or state rare and vulnerable. The ecological diversity of the project area was relatively high, both in terms of composition and structure. We also found 14 of the 40 fire behavior fuel models in the project area. Timber litter and timber understory fuel models dominated. Most of the project area had relatively light to moderate fuel loadings. The canopy based height of the forest in much of the project area was surprisingly high, leading to our conclusion that the potential for torching and passive crown fire initiation would be low in many areas. Likewise, the canopy bulk density of much of the forest is below the threshold where active crown fire spread is likely.

There is a diversity of habitat for many wildlife species in the project area. Many coniferous forest types and forest succession stages are represented, and non-forested shrubfields, herbaceous meadows, and riparian wetlands add ecological complexity. Important structural elements of habitat such as large snags and downed logs, varying in size, density and distribution, occur throughout the project area. Given these factors, we believe that the general habitat suitability of the project area for a wide range of wildlife species is currently good and not of major concern. To better understand habitat conditions, we performed a wildlife habitat analysis for a select number of sensitive wildlife species. The wildlife habitat analysis had three components: 1) habitat suitability index (HSI) modeling for northern goshawk, Canadian lynx and American martin; 2) a general literature and habitat needs review of nine additional sensitive wildlife species occurring in the project area; and 3) a review of the potential impacts of forest prescriptions on all twelve species. We also considered the overall condition of habitats for a wider range of wildlife species and the potential impacts of forest treatments on these conditions.

Our comprehensive wildlife analysis revealed that good habitat for sensitive species does exist in Mount Spokane State Park. Given the protected status of the park versus the surrounding landscape matrix of heavily managed timberlands and residential developments, the significance of the Park increases greatly in terms of providing priority forest habitats for sensitive species and a suite of other wildlife species. One of the key habitat elements is mature and old-growth mixed conifer forests. While historic logging and fires have created a rich mosaic of diverse forest conditions throughout the landscape, there still exists a considerable amount of large patches of late-successional forest. It is unlikely that similar forest conditions exist in the surrounding lands; hence from a wildlife conservation perspective, the park should consider these forests as high conservation priorities.

We conducted a comprehensive assessment of wildfire hazards and fire behavior in the forests of the project area. This assessment included the following elements:

- Examination of fire history and occurrence in the project area and surrounding landscape.
- Review of fire ecology literature and information on forest types.
- Characterization of forests in terms of fire behavior fuel models and development of fuelbeds for selected stands.
- Characterization of fire weather data for the area, including information on wind, temperature, humidity, precipitation, and fuel moistures.
- Modeling of fire behavior of plot sets using NEXUS and BehavePlus software.
- Characterization of fire effects using FOFEM software for a variety of stand and fire behavior conditions.
- Spatial fire modeling using FlamMap and FARSITE software to predict fire behavior characteristics for the entire landscape, and predict dynamic fire behavior as simulated fires spread across the landscape.

From our assessment of fire occurrence and history in and around the project area at Mt. Spokane, we determined that relatively few fires have started in the project area in recent times. The fires that occurred did not get very large. Our review of fire history and fire ecology of forest types found in the project area revealed that the moist grand fir and western hemlock forests had a mixed severity, pre-settlement fire regime with fire return intervals often exceeding 100 years. The drier grand-fir forests in the project area are characterized by a fire regime with more frequent (compared to the moist forest areas), low intensity surface fires. The assessment of fire behavior fuel models and fuelbeds for the stands in the project area lead to a better understanding of how both wildfires and prescribed fires will burn under a variety of weather and fuel moisture conditions. In most parts of the project area the fire models show that fires will not achieve high flame lengths and fire intensity, nor will they become crown fires except under the most extreme fire weather conditions. The spatial fire models (FlamMap and FARSITE) confirmed this result and proved useful in the design and characterization of forest health treatment units that will slow the spread of both surface and crown fires during extreme fire weather conditions.

When evaluating the health of the forests in the project area and formulating management approaches to maintain and enhance the health of these forests, we carefully reviewed the field survey and model results, with a focus on considering and addressing:

- Wildlife habitat conditions.
- Fire hazards and fire behavior.
- Vegetation diversity (both in composition and structure).
- Persistence and resilience of plant communities.
- Presence of rare plants and rare plant communities.
- Presence and abundance of non-native plant species.
- Presence and abundance of non-native animal species.
- Presence of forest insects and diseases.
- Departure of the current landscape condition from known or hypothesized historic conditions.
- Persistence of pre-settlement tree species diversity.

- Persistence of fire-resistant trees.
- Densities and cover of understory trees.
- Current rates of tree mortality.
- History of human disturbances.
- Persistence of natural disturbance regimes.

Then we specifically worked to be sure that within the project area, and in many of the treatment units themselves, our treatment recommendations would:

- Reverse the trend of forests, which are moving toward significantly denser grand fir forests.
- Encourage the development of more fire-resistant forests through gradual conversion of grand fir dominated forests into ponderosa pine, western white pine, western larch and Douglas-fir forests.
- Encourage the development of forest stand conditions that can be easily maintained by regular use of prescribed fire with little need for pre-treatment.
- Create opportunities for recruitment of ponderosa pine, western white pine, western larch and Douglas-fir.
- Protect existing legacy trees of ponderosa pine, western white pine, western larch and Douglas-fir.
- Reduce the risk of catastrophic stand replacement wildfires in Mt. Spokane State Park.
- Further the development of late successional forests.
- Reduce possibilities for large lodgepole pine dominated stands forming in the park after prescribed fire or wildfire.
- Increase the number of large snags in identified snag augmentation priority areas to improve habitat for snag-dependent species.
- Augment coarse woody debris to improve wildlife habitat in areas where CWD is currently deficient.
- Encourage the growth of lush deciduous shrub and tree species (e.g. Douglas maple, Sitka alder, Scouler's willow, aspen, birch, cottonwood) in stands. These species have a fire-retardant effect due to their high live fuel moisture content. Increasing their prevalence in forest stands at the park will reduce fire hazard. Deciduous trees are important for browse and provide nesting and denning habitats.

Overall, the forest of the project area exhibits many attributes associated with a healthy forest (e.g., diverse species composition and structure), and if we were to use a “report card” approach to evaluating these attributes, many would receive “A’s” and “B’s”. However, we did find that this forest had several health problems, including lack of regeneration associated with fire-resistant trees, high densities of understory trees (principally grand fir), and altered natural fire regimes. These conditions in-turn work against the long-term quality of wildlife habitat and overall forest health. They also place at risk three sensitive plant communities in the project area, western hemlock/bear grass (*Tsuga heterophylla/Xerophyllum tenax*), western hemlock/rusty menziesia (*Tsuga heterophylla / Menziesia ferruginea),* and subalpine fir/cascade azalea/beargrass (*Abies lasiocarpa / Rhododendron albiflorum / Xerophyllum tenax*). These are listed as either imperiled globally or rare and vulnerable in the state. While their presence is in part a testament to the good ecological condition of much of the project area, the long-term prognosis for these communities, in the wake of forest succession and possible large-scale fires, is somewhat in question. The presence of these communities is a good reason to manage the project area, judiciously, so that these rare plant communities and other habitats can persist.

Probably the single greatest issue working to degrade the forest's health in the project area is the dense regeneration of grand fir. High levels of grand fir regeneration create the potential for: the loss of fire-resistant, shade-intolerant tree species; loss of vegetation diversity in the understory and subsequent impacts on wildlife cover and food sources; the possibility of increasing susceptibility of canopy trees to fir engraver mortality; and the potential for development of ladder fuels that could carry a surface fire into the tree crowns. Many parts of the project area have small grand fir saplings in excess of 800 stems per acre.

We developed a GIS-based method to map areas that are of moderate to high risk of losing fire-resistant ponderosa pine, western larch, and Douglas-fir due to grand fir encroachment. These are areas where forest health might be improved through treatments to suppress competition from grand fir. Two zones were mapped based on presence of fire-resistant legacy tree species and presence of small grand fir encroaching and competing with the legacy tree species. This map was used in combination with other information to develop a plan to maintain and improve the forest health. We identified areas where forest health can be improved, wildlife habitat elements supplemented and fire hazards reduced, and addressed these issues in our treatment option recommendations for specific treatment units.

To address the grand fir regeneration and other forest health issues in the project area, such as regeneration of fire-resistant species like ponderosa pine and western larch, augmentation of snags and CWD, and habitat improvement of sensitive wildlife species, we developed ten treatment options applied to 45 treatment units comprising 1,470 acres (about 35% of the project area). In the near-term, the balance of the project area was not targeted for treatment, owing to the overall high quality of forest health and wildlife habitat in of much of the interior of the project area, abundant areas covered by steep slopes, and/or the need to construct new roads (often across steep terrain) for access. We initially identified six general treatment zones as the most feasible areas to treat and highest priority areas from the standpoint of reducing the spread of catastrophic wildfire while minimized any potential negative environmental consequences of treatment. We also propose a schedule for treating each of the 45 units during a 15-year timeframe. Treatment of all the proposed units is not mandatory for the overall forest health plan to succeed. Many areas require only minimal or no treatment. It is also important to note that forest conditions in many of the treatment units are quite diverse and, thus, any particular treatment option may not necessarily be applicable for uniform application across a given unit. In many cases, in a given unit, some areas should remain untreated. In some units the majority of the unit is to be left untreated, with only localized treatment in specifically targeted areas.

Other considerations in the location of treatment units and treatment options include the influence of park infrastructure, such as roads (a source of human fire-starts), electrical transmission lines and buildings. Aesthetic and recreational issues are also considered: those that will enhance wildlife habitat are given priority. Finally, achievability, which is a function of costs and technical capability to successfully implement the treatments, were considered.

Most of the treatment options use prescribed fire either alone or in conjunction with some limited mechanical treatments. It is our professional opinion that forest health issues, which have largely resulted from fire exclusion policies, are best addressed by the reintroduction of prescribed fire. The ten treatment options developed for application in the treatment units are:

1. Minimal active management – relies on natural successional processes and natural disturbance processes.
2. Prescribed fire with minimal pretreatment.
3. Prescribed fire with significant manual pretreatment.
4. Limited piling and burning of fuel accumulations.
5. Protection of legacy trees through focused thinning of small grand fir around legacy trees and pile burning in a limited area.
6. Extensive non-commercial thinning of small grand fir with protection of largest trees and all legacy trees (ponderosa pine, Douglas-fir and western larch) followed by pile burning and/or prescribed fire.
7. Extensive non-commercial thinning of small grand fir with protection of the largest trees and all legacy trees (ponderosa pine, Douglas-fir and western larch) followed by mechanical chipping and/or mastication of treatment slash.
8. Combined non-commercial thinning of small trees and commercial thinning of grand fir, western hemlock, and lodgepole pine followed by pile burning and/or prescribed fire.
9. Road zone treatment - designed to create shaded fuel breaks along roads through commercial harvest of selected species, reduction in canopy bulk density, thinning of young grand fir and use of prescribed fire.
10. Chipping and/or mastication - mowing and chipping and/or mastication of small trees in accessible areas along roads and trails.

In addition, we recommend that some general restrictions be applied to all treatments occurring in the project area except under exceptional circumstances. These restrictions are:

- No cutting of large diameter (exceeding 24 inch DBH) mature and old-growth trees.
- No cutting of ponderosa pine, western larch or western white pine unless dense patches occur where inter-tree competition would impede development of a mature stand composed of these species.
- No cutting of Douglas-fir, unless Douglas-fir stems occur at a density over 100 trees per acre, and then, no cutting of trees over 12 inch DBH.
- No construction of new roads.
- No use of mechanized harvesting equipment on slopes greater than 20%.
- No skidding of logs on slopes greater than 30%.
- No skidding of logs on any slope where long-term soil damage could result.

Each treatment unit was designed to help achieve one or more of the more general objectives of the planning effort (maintaining good habitat for a number of wildlife species; protecting aesthetics and recreational values associated with the forest; reducing the risk of catastrophic wildfire; limiting tree mortality from insects and disease to the historic range of variability; maintaining diverse and resilient plant communities). Many treatment units help to achieve multiple objectives. We provide extensive tables and maps that describe and illustrate the characteristics of each treatment unit. Each treatment unit is assigned a preferred treatment option. Alternative treatment options are also assigned to each treatment unit. These alternative treatment options can be used if the first option is rejected for some reason. We provide information rational behind each treatment unit and its expected effect on wildlife habitat and fire behavior. It is important to remember that we are treating only a portion of the park and thus any treatment impacts are likely to be limited in both time and space.

Our conclusion from the assessment of the forest condition of the project area is that forest health in the project area is relatively good. Some of the concerns about forest health that prevail throughout the eastern portion of the Columbia Basin may be less relevant at Mt. Spokane because of the more mesic conditions that resemble forested landscapes west of the Cascade Range. Therefore, there is no “forest health emergency” at Mt. Spokane that requires desperate actions. Rather, a steady and thoughtful approach to treating the relevant forest health issues that do exist in the park is recommended. We envision that if the recommendations we have outlined are adopted, eventually it will be possible to use prescribed fire alone to maintain vibrant, diverse and resilient forest in the project area with minimal effort.

In addition, this forest health plan should not be considered a rigid plan of action. Our intent is that adaptive management approaches will be implemented through the plan period and that Washington State Parks will learn from the experience of implementing this plan, and will modify timing or treatments to best achieve the objectives outlined below. Careful monitoring of treatment areas before, immediately after and in the following years will be necessary to better learn what works and how to fine-tune treatments in the future.

In all cases, we recommend that existing forest canopies be left largely intact. Reductions in canopy cover and canopy bulk density are limited except where it is necessary to break canopy fuel continuity to impede the potential spread of crown fire. Intact forest canopies provide shade and mitigate the effect of wind in a fire event. They also help prevent lofted embers from igniting dry fuels on the forest floor, since the embers are intercepted by the live canopy, which is difficult to ignite. Intact forest canopies are often an important component of wildlife habitat for many species and add to the aesthetic and recreational experience of park users.

Lastly, it is essential for Washington Parks to utilize highly qualified and experienced crew managers to oversee implementation of the treatments outlined in this plan so that the learning curve is not too steep. Forest health treatments that are not carefully designed and implemented can result in forest stands moving along unintended successional pathways. Our approach to conducting forest health treatments is conservative, as we believe that many treatments can easily do more harm than good. More aggressive forest health treatments can increase fire hazards and the risk of unintended changes in forest stand composition and structure.

Introduction

Project Statement

This report was produced at the request of the Washington State Parks and Recreation Commission. The field work, analysis, and forest planning associated with this report were developed to answer general questions about forest health and fire risk in Mt. Spokane State Park, and to help guide Park staff in implementing forest health, wildlife habitat improvement, and wildfire prevention treatments.

Pacific Biodiversity Institute (PBI) has undertaken this project to assist the managers at Mt. Spokane State Park build a well-defined forest plan that balances the issues of forest health, wildlife habitat, and wildfire risk. Our approach was to collect highly detailed data on forest conditions and to use state of the art analysis techniques to process the data into logical inputs for creating a successful forest plan. The concept of the plan is to find and focus on areas of the park where management treatments can reduce wildfire risk, improve forest health, and preserve or enhance wildlife habitat.

Project Goals

The goal of the project is to "protect and enhance the health of the Mount Spokane State Park's forested lands. Specifically, the project seeks to:

- Create a forest mosaic rich in structure and vegetation diversity, where the vast majority of stems are healthy;
- Reduce the risk of catastrophic wildfire;
- Protect and create habitat for a diversity of native plants and animals;
- Protect cultural resources of statewide or regional significance;
- Provide a safe and aesthetically pleasing environment for visitors; and,
- Inform the public of these forest health efforts."

Our work on this project was focused on providing information on forest condition in the project area at the State Park. We also provide management direction via a forest plan that gives guidance on forest management and specific treatments that will assist Washington State Parks in meeting these goals.

Project Area Details

Mount Spokane State Park Details and History

Mt. Spokane State Park is located in northeastern Washington State, near the Idaho border and northeast of the city of Spokane. The 13,919-acre park encompasses the peak of Mt. Spokane (elevation 5,883 ft) and much of the mid-mountain slopes and some adjacent smaller mountains as well. Mt. Spokane is the highest peak in Spokane County and is a local icon visible from the surrounding populated valleys.

The park is a heavily forested, semi-natural area where recreation seekers go to do snow sports in the winter and hiking and mountain biking in the summer. Camping is a minor recreational use in this particular park, with only a few, small, designated campsites open during the summer. Considerable infrastructure exists in the summit area and the downhill ski area of the park, but most of the rest of park has very limited infrastructure. There is very little urbanized development surrounding the park. A majority of the private lands around the park are owned by Inland Paper Company and are used for timber production purposes.

Mt. Spokane State Park was established in 1927 as a 1,500-acre recreation area. Through land acquisitions during the great depression and subsequent land donations, the park grew to its current acreage by 1993. Land use in the pre-park era varied, but many acres were intensively logged and both man-made and natural fires burned in much of the forest. Many of the current forest conditions occurring in the park can be attributed to disturbance events caused by human influence in the last 150 years.

Project Area Boundary and Field Survey Timeline

For this project Washington State Parks initially proposed five potential forest health treatment areas to be surveyed and analyzed in Mt. Spokane State Park. These original five areas total around 6,000 acres, or 43% of the park's area. During contract negotiations and inventory planning these areas were subsequently subdivided into six potential forest health treatment areas (see Figure 1). Due to weather and time constraints, assessment priority was focused on the four lower elevation treatment areas in the southern end of the proposed project area (areas 1c, 2-4).

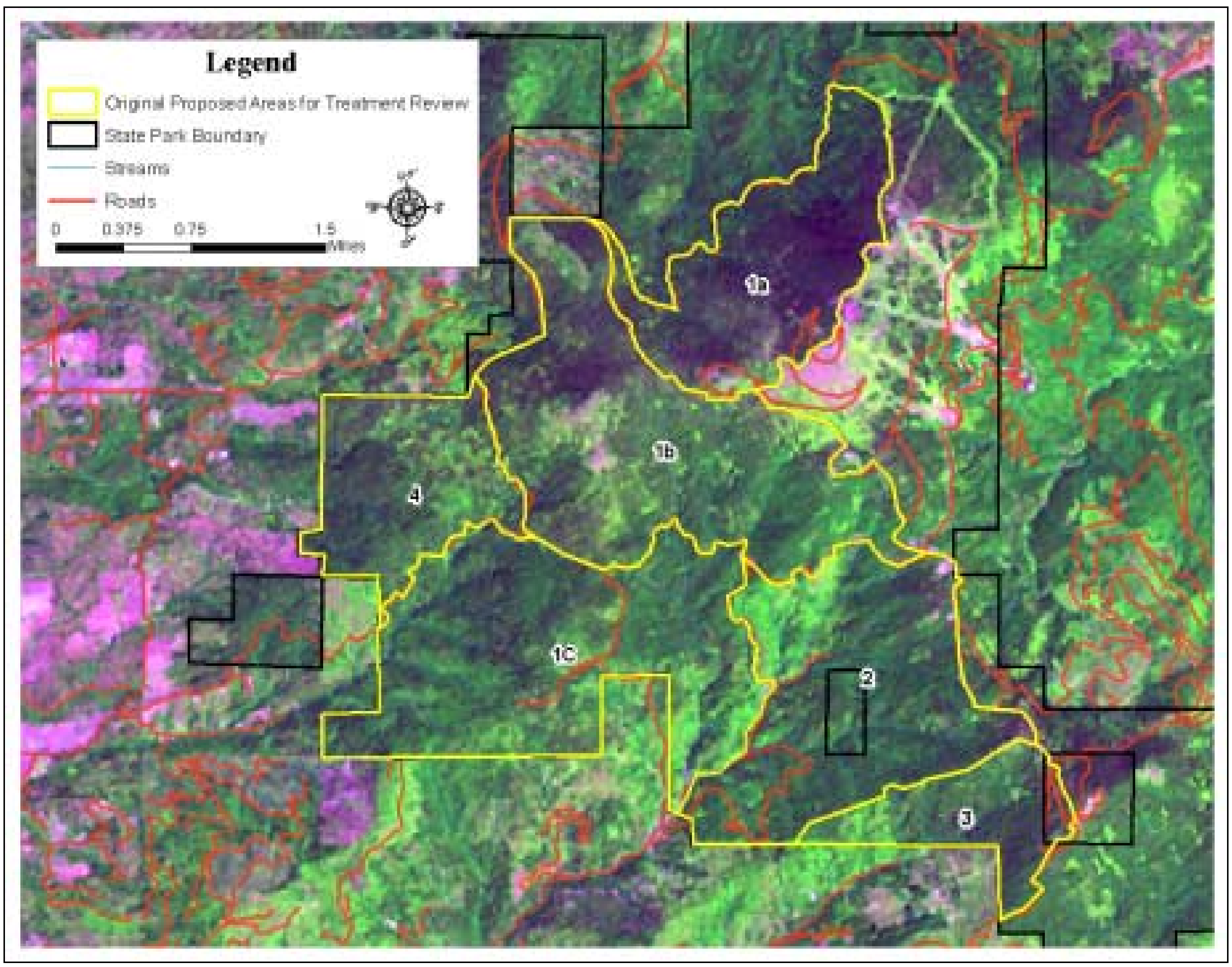

Figure 1. Layout of the original six proposed forest health treatment areas in Mount Spokane State Park.

PBI began forest surveys of the four lower elevation treatment areas and part of treatment area 1B on October 8, 2006. We completed our surveys of these areas by the end of October 2006, when fieldwork had to be halted due to snowfall and the onset of winter conditions. Another forest inventory entity, Maurice Williamson & Associates, began work on surveys of the upper treatment area (1A) in late October 2006. Snowfall and the onset of winter conditions terminated this work in early November. PBI field crews resumed survey work in the lower parts of treatment area 1B in late May 2007 and finished surveying targeted stands on June 1, 2007. In total, 4,250 acres of the park, excluding areas done by Maurice Williamson & Associates, have been intensively surveyed. The data collected by Maurice Williamson & Associates was analyzed and will be used in a subsequent study. From here on, all areas referred to as the "project area" in this report refer to the 4,250 acres surveyed by PBI in 2006 and 2007. Figure 2 provides a map detailing the layout of Mt. Spokane State Park, the original four proposed survey areas, and the resulting actual project area detailed in this report. Figure 3 provides a more detailed look of the actual project area.

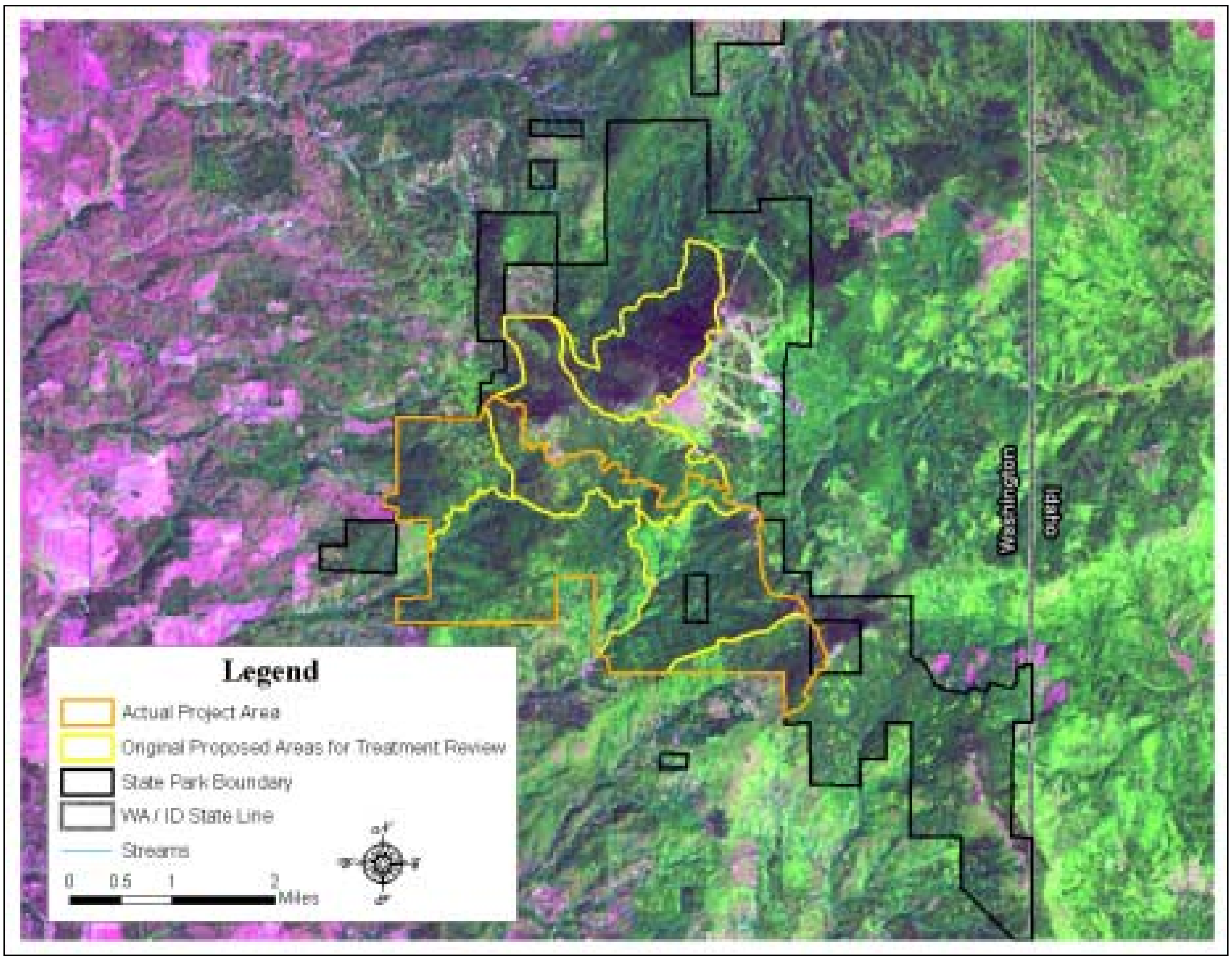

Figure 2. Map of Mount Spokane State Park and proposed and actual project areas analyzed in this report.

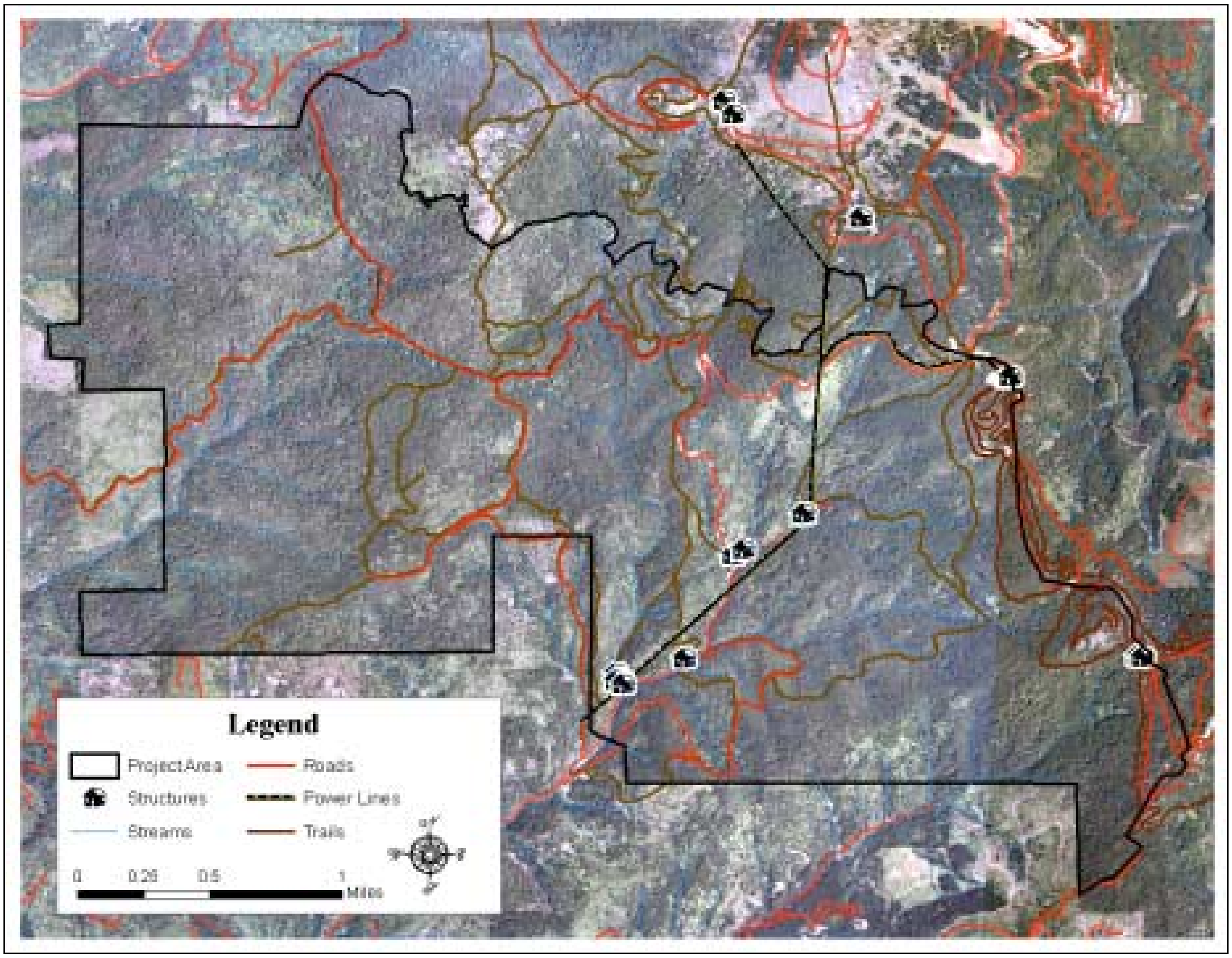

Figure 3. A more detailed look at the project area, including roads and infrastructure.

Topography of Project Area

Given that Mt. Spokane is a mountain, it goes without saying that the topography of the project area has many steep slopes and a variety of ridges, draws, valleys, and aspects. The large variety of slope, aspect, and elevation combinations in the project area contributes significantly to the diversity of forest and plant association types and conditions.

The mean elevation of the project area is 3,921 feet. The lowest elevation in the project area is 3,079 feet at the park entrance and highest is 4,979 feet on the southwest slopes of Mt. Kit Carson. Much of the project area contains more or less south facing aspects due to its location on the south side of Mt. Spokane. A vast majority of the project area has slopes over 20%. Figures 4, 5 and 6 illustrate the diversity of topographic variables occurring in the project area. The aspect classes in Figure 6 are based on true north.

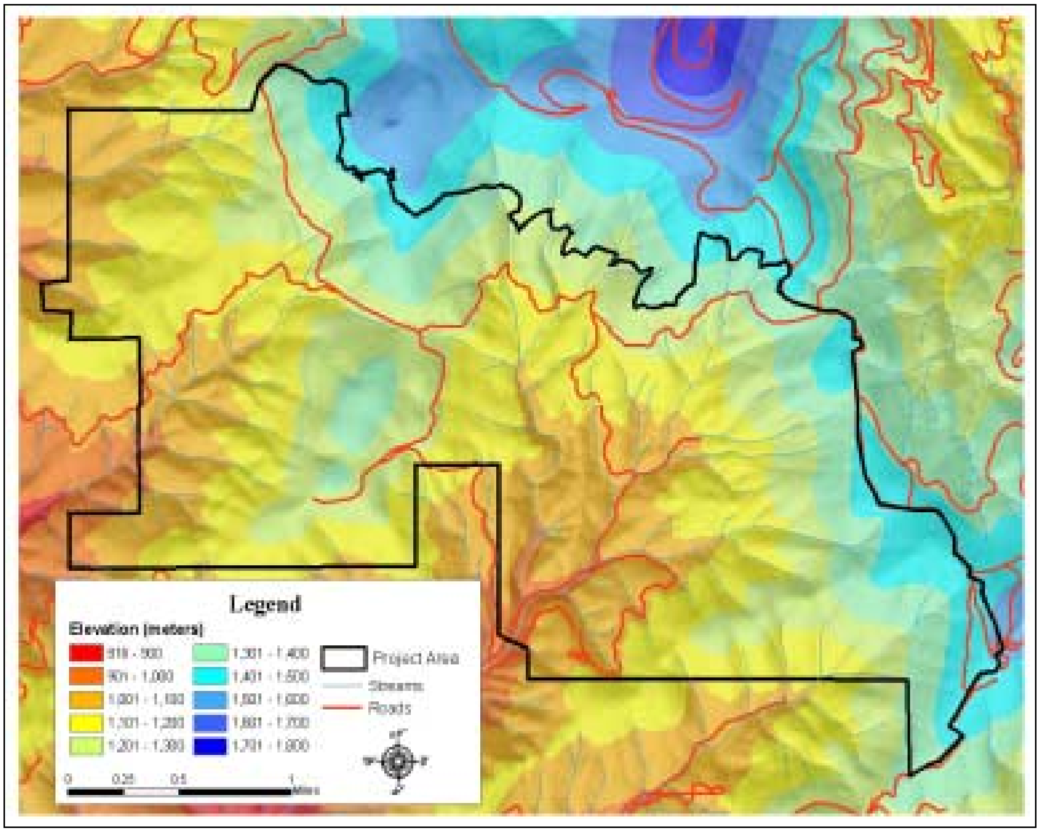

Figure 4. Elevation and topography of the project area on Mt. Spokane. (1 meter = 3.28 feet.)

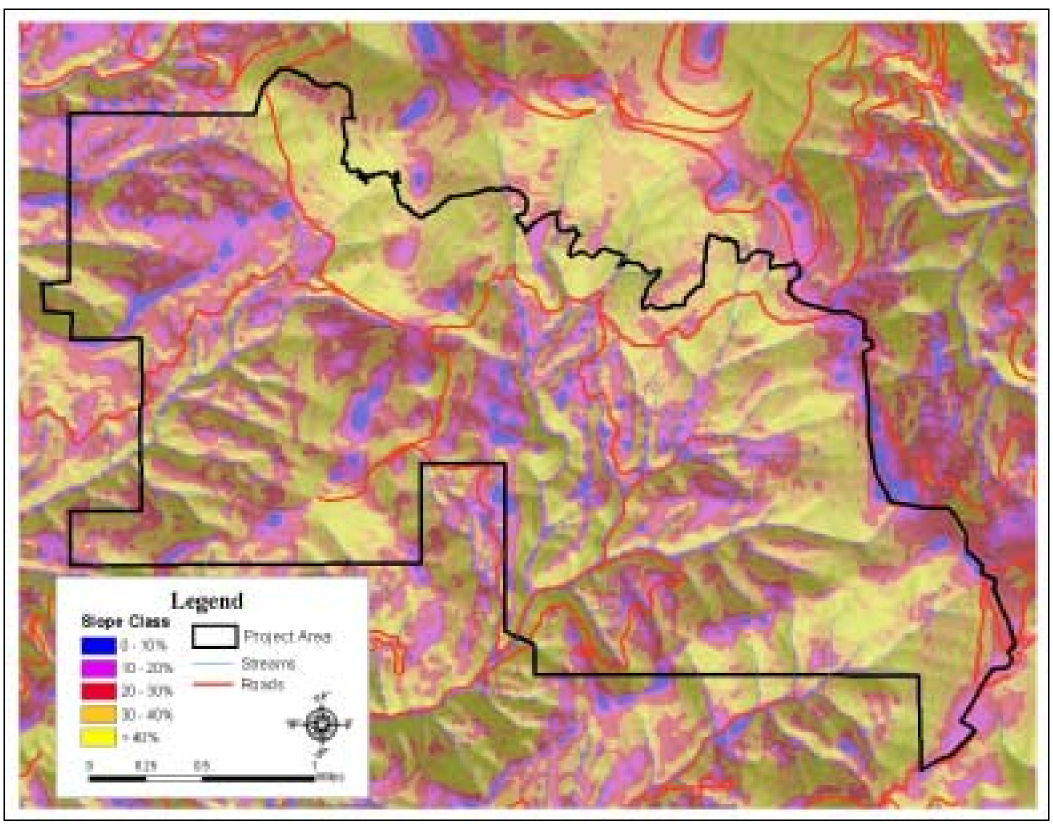

Figure 5. Slope classes of the project area.

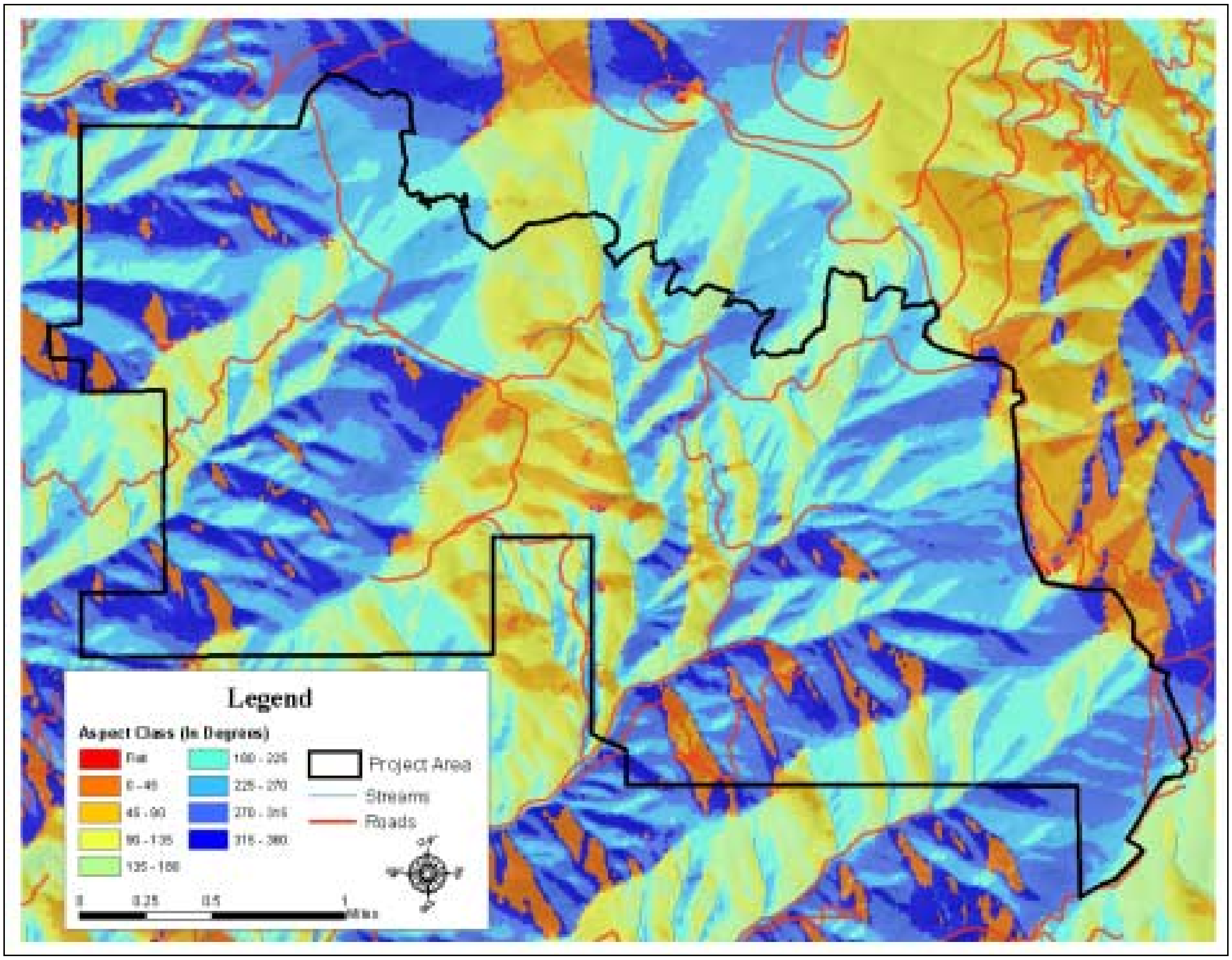

Figure 6. Aspect classes of the project area.

Precipitation in the project area

The mean annual precipitation ranges between 31 inches at lower elevations and 43 inches at upper elevations in the project area at Mt. Spokane State Park based on the precipitation record from 1971 to 2000 (PRISM precipitation data). According to the PRISM precipitation data, the mean annual precipitation for the upper part of the mountain (above the project area) is about 46 inches. For comparison, the mean annual precipitation for Seattle, Washington is about 39 inches and for Wenatchee, Washington, 9 inches a year. The precipitation in the project area is more similar to the Puget Sound region of Washington than most of eastern Washington (PRISM) (Figure 7). The elevation of the project area is relatively low and the precipitation in the project area is high compared to similar elevation areas on the east slope of the Cascade Range.

The high precipitation in the project area compared to most of eastern Washington is a very significant piece of information to consider when evaluating the forest health of the project area. The project area lies within what has been called the “inland rainforest zone” that stretches from central British Columbia, into northern Idaho and northeastern Washington. The forests on Mt. Spokane are not “dry forests” that typify the interior Columbia Basin. This is largely a function of the relatively high precipitation levels on the mountain. Most of the discussion of forest health issues that has ensued over the last 20 years has focused on “dry forests.” We should be careful about confusing the relatively wet forests found at Mt. Spokane with the dry forests that are so often the focus of forest health discussions.

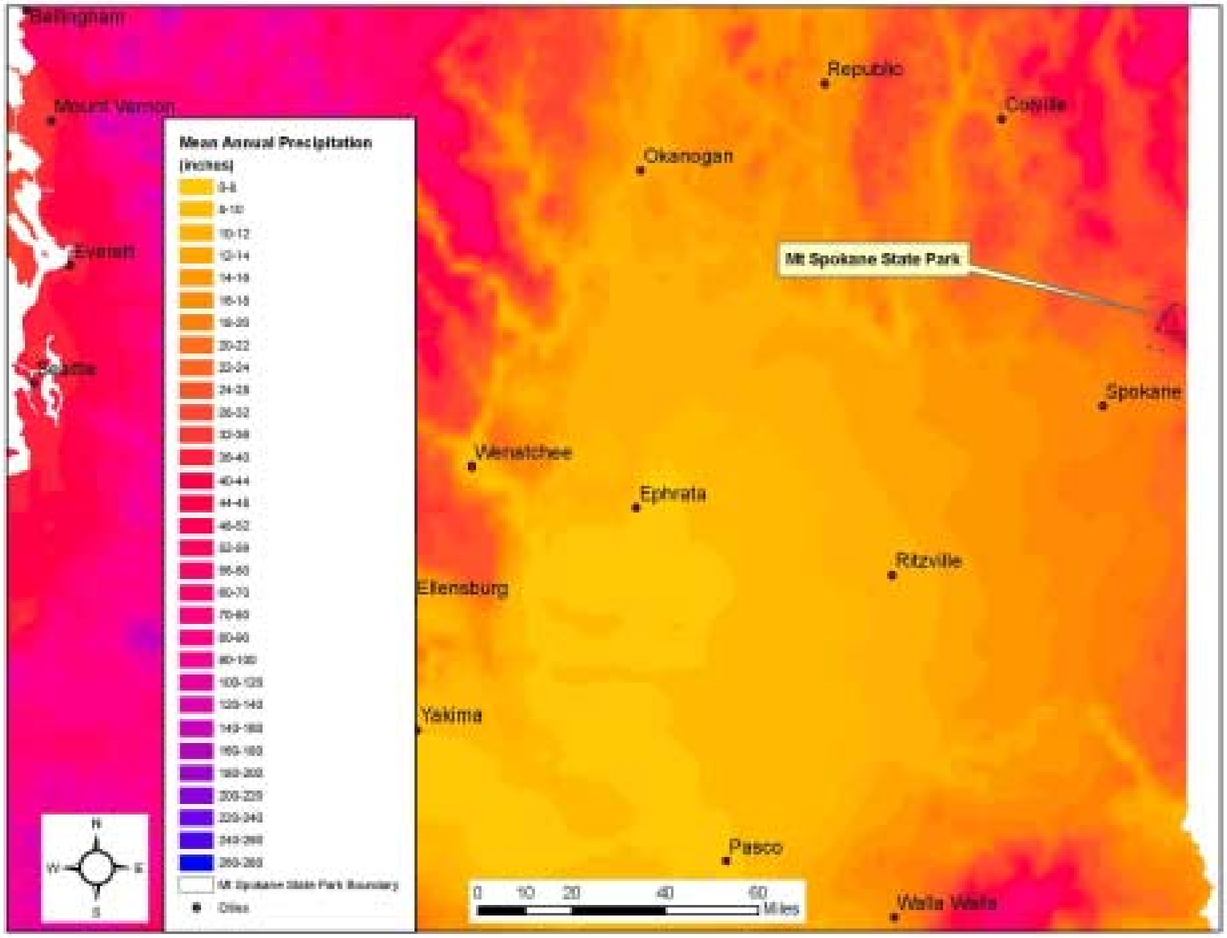

Figure 7. Regional annual precipitation map illustrating relatively high annual precipitation at Mt. Spokane State Park.

Significant Natural History Events Affecting the Project Area

During the last 100,000 years, the most significant events that have altered the physiography and ecology of Mt. Spokane are glaciations during the Pleistocene and the deposition of volcanic ash from the eruption of Mt. Mazama about 7,000 years ago. The Pleistocene glaciations affected the overall form of the mountain and dramatically altered its plant species composition. During the post-glacial period the current plant communities evolved into their current composition.

The eruption of Mt. Mazama released about 12 cubic miles of magma. Much of this was carried by the wind and deposited as volcanic ash throughout northeastern Washington and northern Idaho. In the project area at Mt. Spokane, there is an average thickness of 9 to over 15 inches of volcanic ash (Kimsey et al. 2007). These volcanic ash soils have a considerable influence on the forest ecology and management constraints in the Mt. Spokane area (Page-Dumroese et al. 2007, Kimsey et al. 2007). The deep volcanic ash soils have a high water holding capacity. This soil characteristic amplifies the effect of the relatively high precipitation found at Mt. Spokane and effects the composition of plant communities that dominate the project area.

Repeated wildfires have also burned over Mt. Spokane and influenced its forest condition. The more frequent fires that are characteristic of the lowland surrounding Mt. Spokane very likely burned up the mountain slopes on occasions. The fire history of the mountain is discussed in more detail later in this report.

Mt. Spokane is an isolated mountain massif and receives the brunt of the winds blowing off the interior Columbia Basin. As a result, large blowdown events are common. There are considerable areas of blowdown that occurred in the last 30 years scattered across various places on the mountain and in the study area. This is a normal disturbance event and should not be considered a forest health issue.

Forest Health – What is it and how is it measured?

Forest health is a frequently used phrase, but is often used without definition or explanation. Since this project was conceived by Washington State Parks to be a forest health assessment, it is important to define forest health and discuss how it might be measured.

The project goals (stated in the introduction to this report) give us some guidance with regard to the forest health issues of concern to Washington State Parks. Yet, some phrases like, "where the vast majority of stems are healthy," are open to interpretation. For example, is a dead tree (a snag - which might provide important wildlife habitat) a healthy stem? Likewise, is a tree dying of natural causes (and turning into a snag, which will provide wildlife habitat) a healthy or an unhealthy stem? It is useful to examine how others have grappled with these issues and how they have defined and measured forest health. Below, we present several definitions and discussions of forest health from the recent literature. Our assessment of the forest health condition of the project area at Mt. Spokane will be addressed later in this report, but is based on these concepts.

"Forest health is a human concept, and people have different views about what constitutes a healthy forest. As demands on forests change over time, so too will people's views of forest health. Currently, two ideas are included in most definitions of forest health:
• A healthy forest maintains its function, diversity, and resiliency; and
• A healthy forest provides for human needs and desires, and looks the way people want it to look." (Campbell and Liegel, 1996).

A healthy forest can renew itself vigorously across the landscape, recover from a wide range of disturbances, and retain its ecological resilience while meeting current and future needs of people for values, uses, products, and services. (Adapted from: Forest Health Policy, USDA Forest Service, 1996.)

"A healthy forest is one that maintains the function, diversity, and resiliency of all its components, such as wildlife and fish habitat, riparian areas, soils, rangelands, and economic potential . . ." (Mike Dombeck, Chief US Forest Service 1997).

"Forest health" means "a condition of forest ecosystems that sustains their complexity while providing for human needs." (Sampson and DeCoster, 1998).

Sampson and DeCoster go on to say*, "We all want healthy forests. But what, exactly, is a "healthy" forest? Would we necessarily know one when we see it? The fact is, forests exist in* *various stages of physical reality, and whether or not we view different conditions as healthy is often based as much on our desires and interpretations as on any empirical evidence. So forest health is largely in the eye of the beholder, which makes for a difficult debate. How are we to agree on what constitutes a healthy forest when for all practical purposes none of us are looking at the same forest?"*

"The difficulty of defining forest health ensnares both professionals and the general public, since we all harbor feelings (often very strong ones) about what we want from them. To make things more confusing, forest conditions are complex and seldom permanent. Forests go through many stages as they become established, change through the growth and aging of the dominant trees, or are dramatically affected by a disturbance like fire, flooding, or windstorms. All of those conditions may, at one time or another, be part of the natural dynamics within a healthy forest. Or they may be a sign that something is terribly wrong. Knowing the difference may tax the best knowledge we possess."

All of these definitions and discussions of forest health have a few things in common. First, forest health is hard to define and is largely in the eye of the beholder. It is a human concept and requires careful examination to avoid a completely arbitrary definition. Perhaps the next most important point where many authors agree is that a healthy forest is one that maintains the potential for complexity, diversity and resilience. Natural disturbance events (including catastrophic wildfire and insect outbreaks) are part of the long-term history of every forest and the future trajectory of a healthy forest and must not be considered to be inherently bad.

Measures of Forest Health

From our review of the literature on forest health, we found repeated themes that can be used to determine the relative degree of forest health in a project area. These themes are:

- Ecological diversity
- Ecological resilience
- Extent of departure from historic forest conditions
- Long-term changes in forest structure
- Long-term changes in forest species composition
- Relative abundance of native vs. non-native species

All of these themes have elements that can actually be investigated and measured to some degree.

Can Forest Health be "Managed"?

Many treatments have undesired consequences and there is no silver bullet for dealing with many forest health issues. Many of the most aggressive treatment options can set things on the wrong track as easily as restore a forest to good health. Hence, ***given current knowledge of forest health processes and technologies to alter these conditions, it is the desire of State Parks and PBI to be conservative when attempting to treat forest health issues***.

One of the best strategies is to restore forests to a better condition before they depart too much from historic conditions. It is often best to apply treatments to areas that do not currently suffer from severe forest health problems (e.g., encroachment of small grand fir into stands that were historically dominated by fire-resistant tree species). These forests can often be easily treated with minimal cost. It is much better to restore forests to more fire-resistant – habitat diverse conditions than to wait until much more expensive (and potentially less successful) treatments are required.

Project Timeline and Desired Length of Time for Positive Effects

This project was initiated in October of 2006. We conducted fieldwork and held regular project meetings with Parks' staff and other interested parties according to the schedule show in Table 1.

Table 1. Schedule of Project Activities

Activity	Dates
Forest health survey of Treatment Areas 1C, 2, 3, 4 and part of 1B	October 8-31, 2006
Project meeting in Wenatchee	January 5, 2007
Project meeting in Spokane	March 15, 2007
Project meeting in Spokane	April 19, 2007
Project meeting in Spokane	May 24, 2007
Forest health survey of more of Treatment Area 1B	May 28 – June 1, 2007
Project meeting in Spokane	June 26, 2007

This report is intended to give Parks' staff recommendations on treatment options for given regions of the project area that can be executed over a ten-year timeline, with more detailed focus on conducting higher priority treatments over a five-year timeline.

As with all forest treatments regardless of type or justification, the immediate effects of a treatment are limited to a relatively short timeframe. Forests are very dynamic systems and forest management must rely on repeated monitoring and assessments of how conditions are changing to adequately address priority issues. A treatment conducted without monitoring and evaluations of the results cannot be considered a successful treatment. As such, it would be an undesirable management practice to execute the suggested treatments given in this report without directly monitoring the results. Monitoring of treatment units should begin before treatments commence to adequately define pre-treatment conditions. The data collected in this study are not site specific enough to define pre-treatment conditions for each Treatment Unit. At a minimum, additional data on specific fuel loadings in the treatment units, presence of at-risk wildlife (animals and plants) and presence and abundance of weeds should be collected. Treatments should include careful monitoring of their implementation and immediate effects. Subsequent monitoring of longer-term effects should take place after the first year and after two years. After the first five years of treatments, it is our hope that State Parks' staff will perform a formal evaluation of the results of committed treatment actions. Furthermore, Parks' staff will need to assess whether successive management activities are called for so ensure that the goals of the original treatments have been met and to optimize forest health. We estimate that the treatments proposed in this report will have a ten-year desired effect timeline after which further treatments will be necessary.

The Forest Condition Survey

Methods

During the fall of 2006 and late spring of 2007, we inventoried 406 forest condition assessment plots across 4,250 acres in Mt. Spokane State Park, or one plot for every 10.5 acres of the project area. The idea behind a survey of this intensity was to build a detailed spatial dataset realistically representing the on-the-ground conditions of the landscape in the project area. This dataset assisted us in evaluating, at a fine spatial scale, the factors influencing fire hazard, forest health condition, and wildlife habitat condition. Using these data, we were able to draw objective conclusions about the condition of forest ecosystems at Mt. Spokane, and we were able to understand the magnitude and spatial distribution of forest health elements across the landscape.

The survey methods and targeted variables of the forest inventory were initially defined by Washington State Parks. Some adaptations to the original survey protocols were made, and new protocols were added as the surveys progressed due to a better understanding of real forest conditions in the survey area. The following section details our methods and protocols in the forest condition survey as they were followed at the termination of our fieldwork sessions on June 1, 2007.

The delineation of forested stands in the project area

We delineated forest stands in the original treatment areas proposed by Washington State Parks (Figure 1) using the guidelines set forth in the original project proposal. Stand delineation was conducted remotely prior to any of our staff actually visiting the project area during this project. We used digital satellite imagery, digital elevation models (DEMs), color stereo air photographs, agency provided GIS data (including color orthophotographs, topographic maps, and priority habitat data), and a Natural Forest Inventory conducted by the Department of Natural Resources (DNR) Natural Heritage Program in 1992 to aid in the delineation of forest stands.

We were requested to delineate forest stands between 75-125 acres in size. These stands were meant to be relatively homogenous in species composition, age, structure, understory vegetation, and physical attributes (slope, aspect, soils). In some cases, stands smaller than 75 acres were delineated where the characteristics of the stand were clearly different than that in the surrounding forest (e.g. a pocket of old growth or balds). Stands in excess of 125 acres were delineated in select situations where forest conditions appeared very homogeneous.

Figure 8 illustrates the layout of the stand boundaries resulting from our remote spatial data analysis. Figure 9 illustrates the layout of stands in the actual project area pertaining to this report.

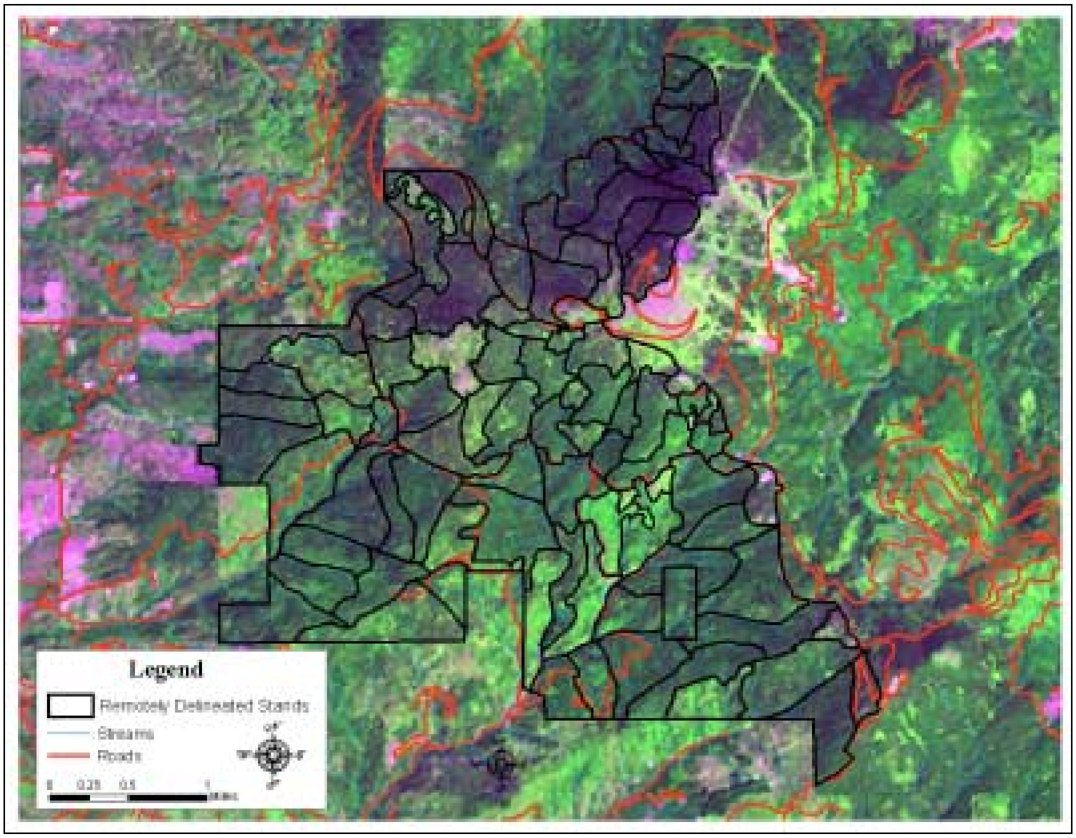

Figure 8. Location of all forest stands mapped in 2006.

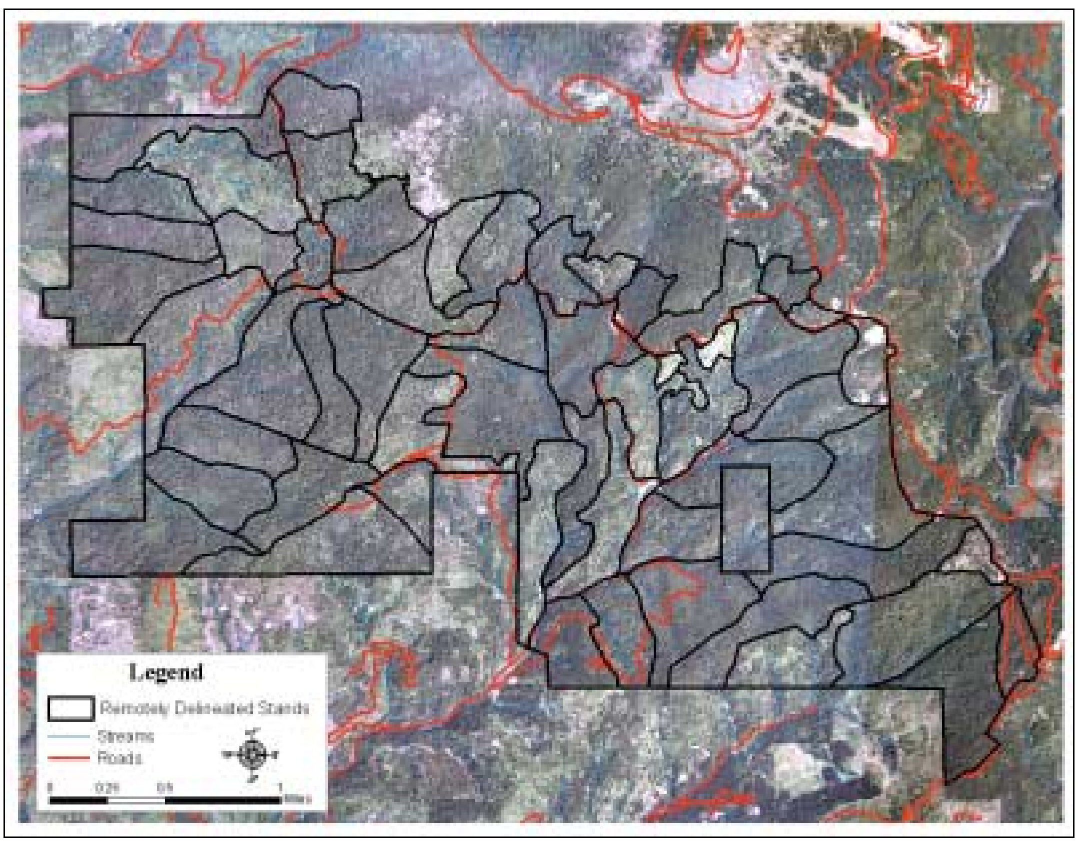

Figure 9. Location of forest stands in the project area mapped in 2006.

Field Surveys

Field surveys consisted of measuring discreet data within variable and fixed-radius plot locations throughout the project area. We also collected a standardized set of stand level data compliant with the Vegetation Polygon Forms provided by Washington State Parks and used as a vegetation community inventory field form throughout the Washington State Parks system. The guidelines used to complete all of the survey types mentioned were provided to us by Washington State Parks.

The forest condition survey plots were established along a randomly generated, systematic plot grid that covered the areas to be surveyed. This systematic grid and the approximate location of each plot were provided to PBI by Washington State Parks. Some plots in the systematic grid fell very close to stand boundaries or ownership or project area boundaries. These plots were moved from these locations (typically 100 ft towards the interior of the stand in question) so that they would fall entirely within the stand that was to be sampled. Figure 10 illustrates this situation. The initial sampling protocol called for using variable radius plot with a basal area factor (BAF) of 10, so this factor was used to determine if plots might straddle polygon boundaries. The initial sampling protocol called for in the RFP was modified to use other BAFs in dense stands (as described below), but this could not be predetermined. Therefore it was assumed for the purpose of plot layout that all plots might use a BAF 10 variable radius.

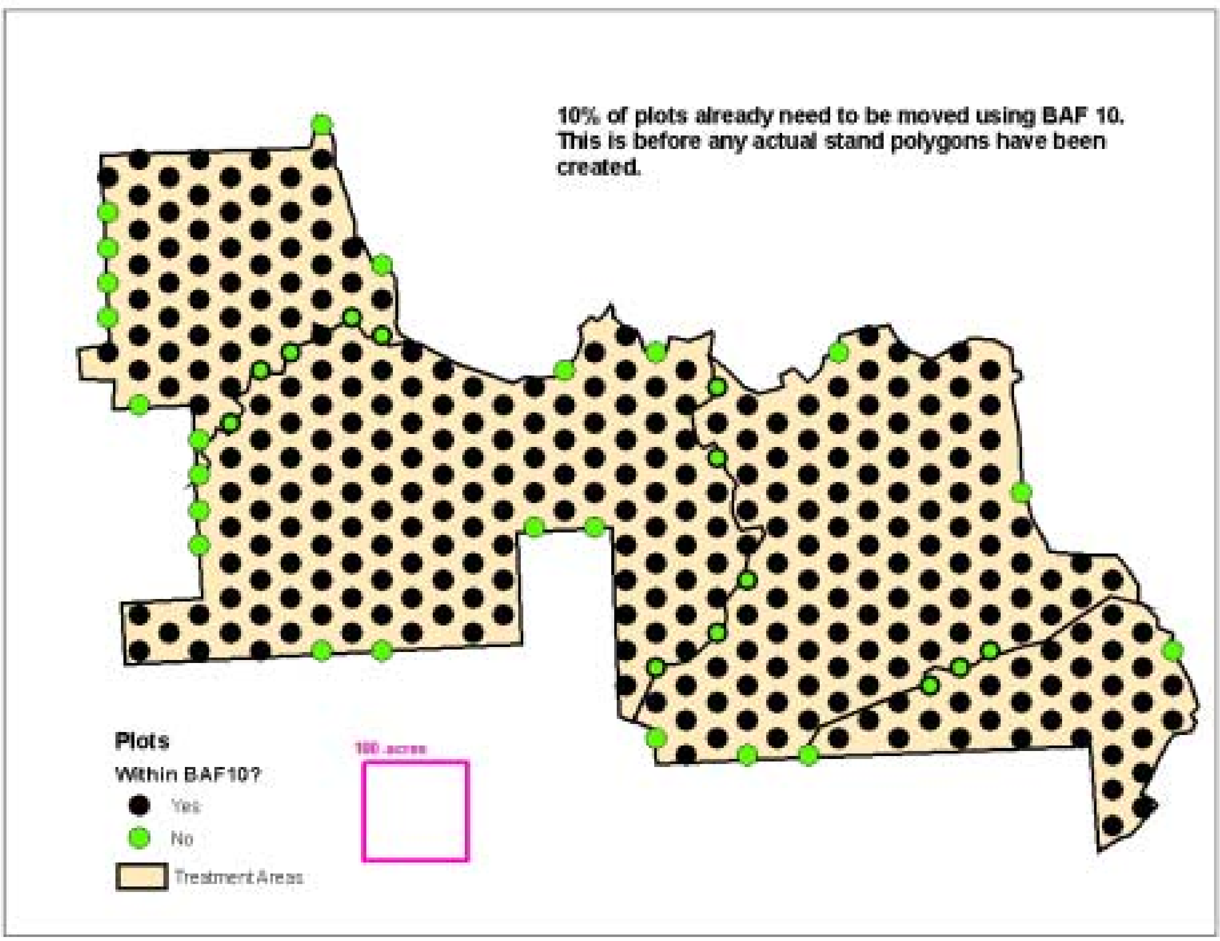

Figure 10. Map providing an example of the problem faced with ensuring that the systematic plot grid-sampling scheme didn't create "edge" plots where data would have been measured from two distinct areas.

We used topographic maps, aerial maps, compasses, and hand-held GPS units to locate the plots. Once arriving at the assigned plot, GPS accuracy was calculated by waypoint averaging. We strove to locate the plots within 20 feet of the assigned location. GPS reception was very poor in some locations due to tree canopies and obstruction from adjacent hillslopes. Figure 11 illustrates the resulting layout of the 406 plots we surveyed during this project.

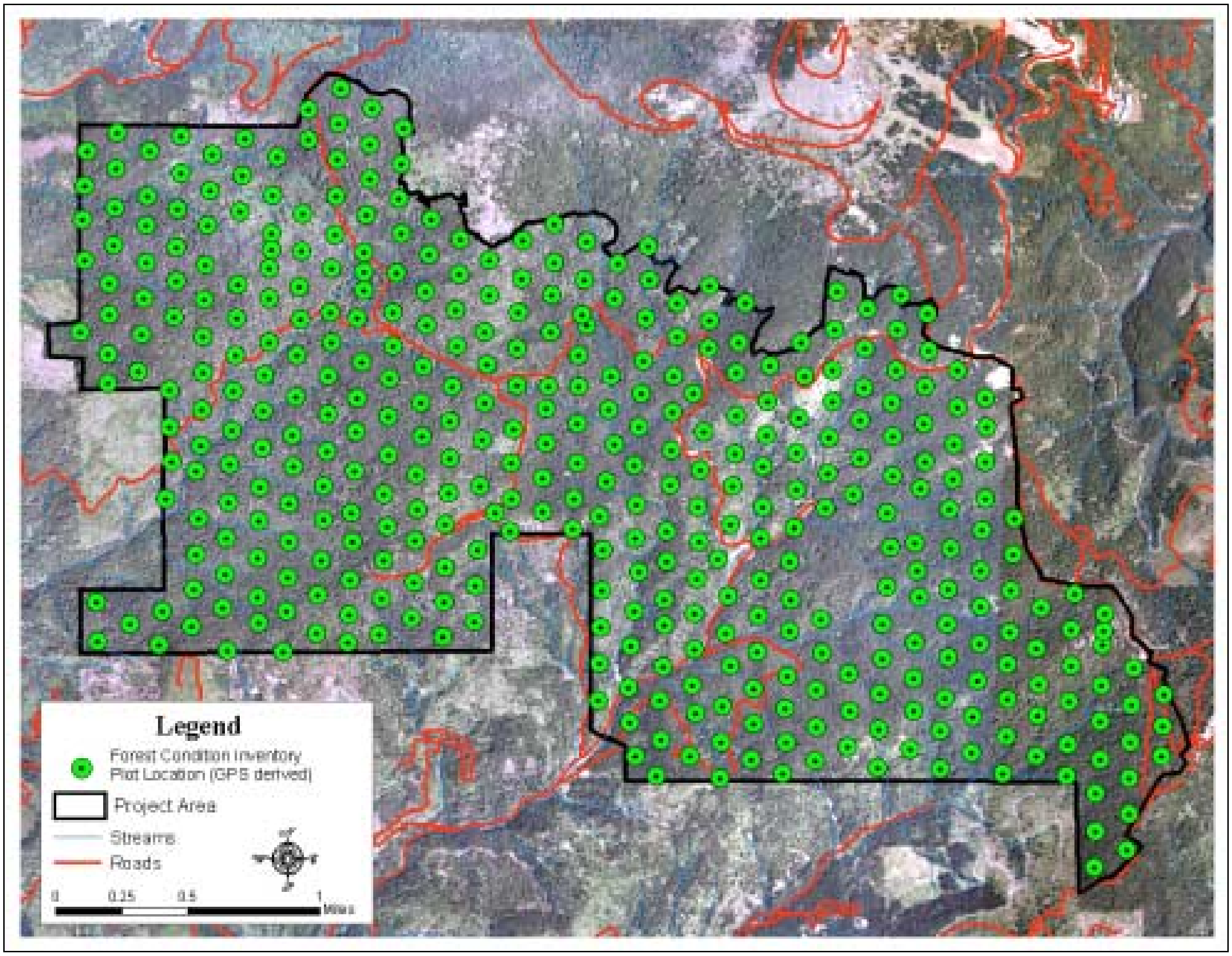

Figure 11. Layout of the 406 forest conditions survey plots inventoried by PBI staff during the fall of 2006 and late spring of 2007. The open area in the central-eastern part of this figure is a private inholding and was not a part of the study.

At each plot, we recorded information on physical characteristics, overstory characteristics, mid- and understory characteristics, coarse woody debris, fire behavior fuel model, dominant plant associations and selected vegetation attributes. We also photographed representative vegetation and noted signs of wildlife-use of the habitat in or near the plots.

We collected data on all the stand attributes specified in our contract using a combination of fixed (0.05 acre) and variable radius plots. A detailed description of the sampling methods is outlined below. For the variable radius plots, we used an appropriate Basal Area Factor (BAF) for each stand condition that we encountered. Our default BAF was 10. We used a BAF of 20 if a BAF of 10 pulled in more than 15 trees into a plot. In a few plots, a BAF of 40 was used if greater than 15 trees were in the plot using a BAF of 20. Table 2 shows the number of plots that used each Basal Area Factor prism.

Table 2. Number of plots using a given Basal Area Factor.

BAF Prism Used	Number of Plots	Percent of Total Plots
10	123	30%
20	275	68%
40	7	2%

All trees identified as being "in" in the variable radius plots were identified to species, measured to the nearest inch for the diameter at breast height (DBH), and measured to the nearest foot for the total tree height (HT). We also measured to the nearest foot the distance from the forest floor to the nearest live branches on an "in" tree to get crown heights (directly related to crown depth). Details of our surveying methods for stand characteristics are described below. A copy of the survey instructions and guidelines used by the field crew is included in this report as Appendix A.

The following stand characteristics were observed and recorded at each plot:

1. Physical attributes

- GPS location – the location of each plot center was recorded by a handheld GPS unit and given a specific waypoint name. The location accuracy was calculated by waypoint averaging. We allowed the GPS unit to run for the duration of our survey at each plot to calculate the average location of the field plot. We attempted to locate the field plot to within 20 feet of the assigned location in the systematic grid provided by Washington State Parks.
- Elevation, slope and aspect of the plot were derived via an automated ArcMap function using waypoints of our recorded GPS locations overlaid on a high-resolution digital elevation model.

2. Overstory characteristics (variable plots for all "in trees")

- Species – tree species were identified and recorded in plot forms as 4-letter alpha codes.
- Diameter at breast height (DBH in inches) – the DBH was measured to the nearest inch with a DBH tape. In cases where two trees were growing together, we measured individual trunks as two separate trees if they split below breast height (4.5 feet) or recorded a single tree if they split above the breast height.
- Total height (feet) – we used electronic clinometers to measure tree heights to the nearest foot. The distance from the trunk of the tree was measured using a logger's tape or a calibrated string and entered into the electronic clinometer. Height was then calculated automatically by the clinometer. After some familiarity with the heights in each plot measured by the clinometer, our crew was able to visually estimate some tree heights to efficiently complete plot surveys.
- Height to live crown – we measured the height to the lowest, significant live branches of each tree.
- Dominance (D, CD, I, S) – Trees were classified into four classes: Dominant, Co-dominant, Intermediate, and Suppressed. Dominant trees are usually the tallest trees with crowns emergent above the surrounding canopy. These trees have full access to light and are not shaded by any other trees. Co-dominant trees share the canopy with other trees. Trees classified as intermediate are usually shorter in height than the two previous classes,

with light limitations due to shading from D and CD trees. Intermediate and taller trees suppress the growth of smallest trees by limiting light and space.

- Canopy closure (densiometer) – overstory density was measured with a spherical densiometer. Four readings of North, East, South, and West were taken at each plot from the plot center. We assumed four equi-spaced dots in each square of the grid and counted dots that represent canopy openings. The total count was used in our analysis to calculate the percent of area covered by live forest canopy.
- Snags – we recorded the species name and measured the height, DBH, and decay class for each snag that was considered "in".
    - Species – the species of snags were identified by observations of bark and trunk characteristics.
    - Height (of those > 6 ft) – Snag height was measured by clinometers or estimated visually.
    - DBH (of those > 4 inches DBH) – the DBH of snags was measured with a DBH tape.
    - Decay class – We followed the guidelines from Washington Department of Natural Resources (2004. Natural Resources Field Procedures: Forest resource inventory system. FRIS Ver. 1.31. Feb. 04.) to categorize snags into four decay classes (1 to 4) based on characteristics such as the presence and amount of bark left on the trunk, the presence and size of twigs and branches, and the texture, shape, and color of the wood.

3. Mid- and understory characteristics (in a 0.05 ac [26.33 ft radius] plot surrounding the plot center)

- We identified and visually estimated the percent cover and maximum height for the 3 most abundant understory and shrub species. We estimated, using an ocular count, the total number of shrub species present.

4. Coarse woody debris (CWD) (in a 0.05 ac plot)

- We recorded the number of pieces that were > 6 inches in diameter at largest end (where the large end falls into the plot). The decay class was recorded based on guidelines from Washington Department of Natural Resources (2004. Natural Resources Field Procedures: Forest resource inventory system). FRIS Ver. 1.31. Feb. 04.). We also estimated the percent of each plot covered by the tallied CWD.

5. Fire behavior fuel model (Scott and Burgan 2005)

- We recorded the fire behavior fuel model, or combination of models that best described the fuel conditions at each plot.

6. Vegetation associations

- Beginning with the first plot in each stand, information was gathered about the dominant vegetation associations and select vegetation attributes found in the stand. Vegetation plant associations were assessed according to Williams et al. (1995) or Cooper et al. (1987). A key to the plant associations of the project area is provided in Appendix L.

Data Analysis Methods

PBI staff and interns entered the forest condition plot data into a Microsoft Access database. In the database suitable values were automatically converted to a per acre basis based on forest inventory statistical procedures (for example – trees per acre, tree species per acre, CWD stems per acre, etc.). The following forest characteristic indices were also calculated with the data following standardized calculation techniques.

- Quadratic Mean Diameter (QMD)
- Stand Density Index (SDI)
- Shannon Diversity Index (Shannon-DBH and Shannon-species)
- Canopy Bulk Density (CBD)
- Canopy Height (CH)
- Canopy Base Height (CBH)
- Trees Per Acre (TPA)
- Basal Area per Acre (BA)
- Understory Mean Height (UMH)

The generated statistics were attributed to each plot and incorporated into tables for processing in various models and data analysis programs used to help understand potential fire behavior, predicted fire effects, wildlife habitat suitability, and forest health issues.

The data we collected at each plot were initially assigned to a point location for the plot center. However, the plot data represent a sample of the forest characteristics of a large area surrounding the plot center. To better assess the spatial distribution of the forest characteristics of the survey plots, we converted the plot data for each point into a grid surface layer using the inverse distance weighted (IDW) interpolation method build into ESRI's ArcGIS Spatial Analyst (ESRI 2007).

"IDW interpolation explicitly implements the assumption that things that are close to one another are more alike than those that are farther apart. To predict a value for any unmeasured location, IDW will use the measured values surrounding the prediction location. Those measured values closest to the prediction location will have more influence on the predicted value than those farther away. Thus, IDW *(interpolation)* assumes that each measured point has a local influence that diminishes with distance. It weights the points closer to the prediction location greater than those farther away, hence the name inverse distance weighted." (ESRI 2007).

The maps created using the IDW technique illustrate the distribution of the most important forest condition attributes across the entire study area. To create these maps we used a power factor of 1, a cell size of 30-meters (100 feet) and a search neighborhood of 7 plots (a central plot plus six surrounding plots) (points). The resulting grids were used in subsequent analysis and assessment of forest health conditions and wildlife habitat conditions.

Results

Vegetation Plot and Polygon Data Summary

We surveyed and analyzed the data from all 406 forest-condition survey plots and collected data on the 56 remotely delineated forest stands. The results of our data collection and statistical processing are discussed below for the following forest condition attributes:

- Plant associations
- Fuel models
- Canopy cover
- Canopy bulk density
- Canopy height
- Canopy base height
- Tree density
- Stand density index
- Basal area
- Quadratic mean diameter
- Maximum diameters of trees meeting potential old-growth criteria (> 8 trees per acre)
- Tree diameter distributions
- Tree species composition and diversity
- Tree dominance classes
- Distribution of snags and coarse woody debris (CWD)
- Understory shrub cover
- Cover and density of small trees

These data were mapped based on analysis of the forest survey plot data across the study area as determined by IDW interpolation and are presented in Figures 12-34 (except for the small tree data – see Figures 97 and 98). These data are also presented in a tabular form as calculated for each plot in Appendix M.

Plant Associations

We found 14 different plant associations in the project area during our forest survey (Figure 12 and Table 3). Most of these plant associations are in the grand fir zone. However, many are in the wetter western hemlock zone. A few plots fell into the subalpine fir zone, a few were Douglas-fir series or western redcedar series plant associations and a few were non-forest plant associations. Further discussion of the distribution of plant associations is presented later in the report (see Table 15 and Figure 89). A key to the plant associations of the project area is provided in Appendix L.

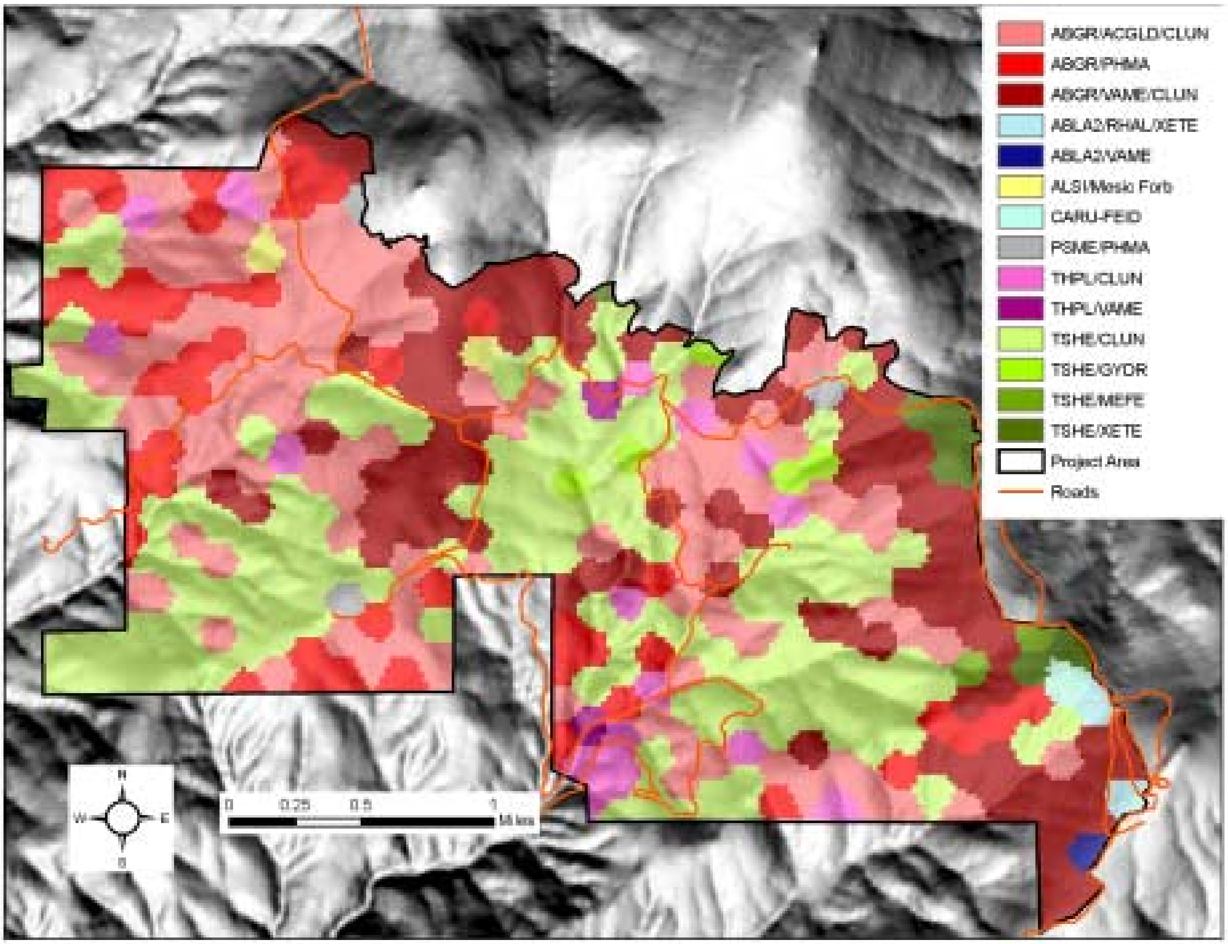

Figure 12. Plant associations occurring in the project area. (see Table 3 for key to codes)

Table 3. Plant associations found in the project area.

Common Name	Scientific Name	Abbreviation	Global Rarity Rank
Grand fir / Douglas maple / queen's Cup	*Abies grandis / Acer glabrum / Clintonia uniflora*	ABGR/ACGLD/CLUN	G3
Grand fir / mallow-leaf ninebark	*Abies grandis / Physocarpus malvaceus*	ABGR/PHMA	G3
Grand fir / thinleaf huckleberry / queen's cup	*Abies grandis / Vaccinium membranaceum / Clintonia uniflora*	ABGR/VAME/CLUN	G3G4
Subalpine fir / cascade azalea / beargrass	*Abies lasiocarpa / Rhododendron albiflorum / Xerophyllum tenax*	ABLA2/RHAL/XETE	G5-S3
Subalpine fir / thinleaf huckleberry	*Abies lasiocarpa / Vaccinium membranaceum*	ABLA2/VAME	G4
Sitka alder / mesic forb	*Alnus sinuata /* mesic forb	ALSI/Mesic Forb	G3G4
Pinegrass / Idaho fescue	*Calamagrostis rubescens / Festuca idahoensis*	CARU-FEID	no NatureServe listing
Douglas-fir / mallow-leaf ninebark	*Pseudotsuga menziesii / Physocarpus malvaceus*	PSME/PHMA	G5
Western redcedar / queen's cup	*Thuja plicata / Clintonia uniflora*	THPL/CLUN	G4
Western redcedar / thinleaf huckleberry	*Thuja plicata / Vaccinium membranaceum*	THPL/VAME	G3G4
Western hemlock / queen's cup	*Tsuga heterophylla / Clintonia uniflora*	TSHE/CLUN	G4-S4
Western hemlock / northern oak fern	*Tsuga heterophylla / Gymnocarpium dryopteris*	TSHE/GYDR	G3G4
Western hemlock / rusty menziesia	*Tsuga heterophylla / Menziesia ferruginea*	TSHE/MEFE	G2
Western hemlock / beargrass	*Tsuga heterophylla / Xerophyllum tenax*	TSHE/XETE	G2

Global Rank Codes	State Rank Codes
G2 = Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction throughout its range. (6 to 20 occurrences or few remaining individuals or acres).	**S3** = Rare or uncommon in the state. (Typically 21 to 100 occurrences)
G3 = Either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range (e.g., a single western state, a physiographic region in the East) or because of other factors making it vulnerable to extinction throughout its range. (21 to 100 occurrences)	**S4** = Widespread, abundant, and apparently secure in state, with many occurrences, but the taxon is of long-term concern. (Usually more than 100 occurrences)
G4 = Widespread, abundant, and apparently secure globally, though it may be quite rare in parts of its range, especially at the periphery. Thus, the Element is of long-term concern. (Usually more than 100 occurrences)	**Note: Global Rarity Ranks are from natureserve.org State Rank Codes are from Washington Dept of Natural Resources Natural Heritage program**
G5 = Demonstrably widespread, abundant, and secure globally, though it may be quite rare in parts of its range, especially at the periphery.	

Fire Behavior Fuel Models

In this project, we used a new set of standard fire behavior fuel models developed by Scott and Burgan (2005) for use with Rothermel's surface fire spread model. Fuel models have long been used to help predict the potential behavior and effects of wildland fire. The original set of 13 fuel models (Albini 1976) have been replaced by the new set of 40 fuel models developed by Scott and Burgan.

The fire behavior fuel models used in this project are designed as input to the Rothermel (1972) fire spread model, which is used in many fire behavior-modeling systems. "The fire behavior fuel model input set includes:

- Fuel load by category (live and dead) and particle size class (0 to 0.25 inch, 0.25 to 1.0 inch, and 1.0 to 3.0 inches diameter)
- Surface-area-to-volume (SAV) ratio by component and size class
- Heat content by category
- Fuelbed depth
- Dead fuel moisture of extinction" (Scott and Burgan 2005).

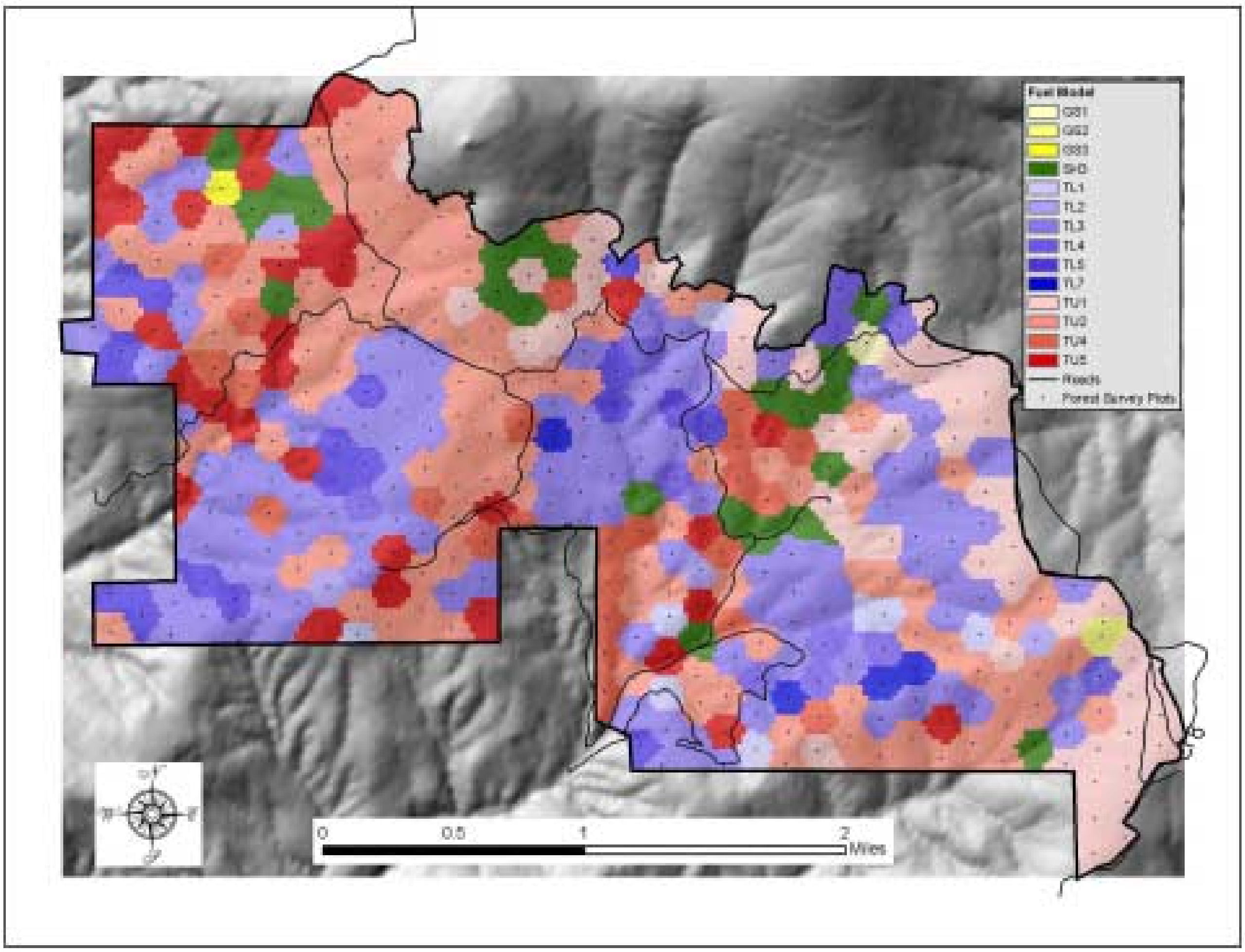

Figure 13. Fire behavior fuel models occurring in the project area. (Scott and Burgan 2005)

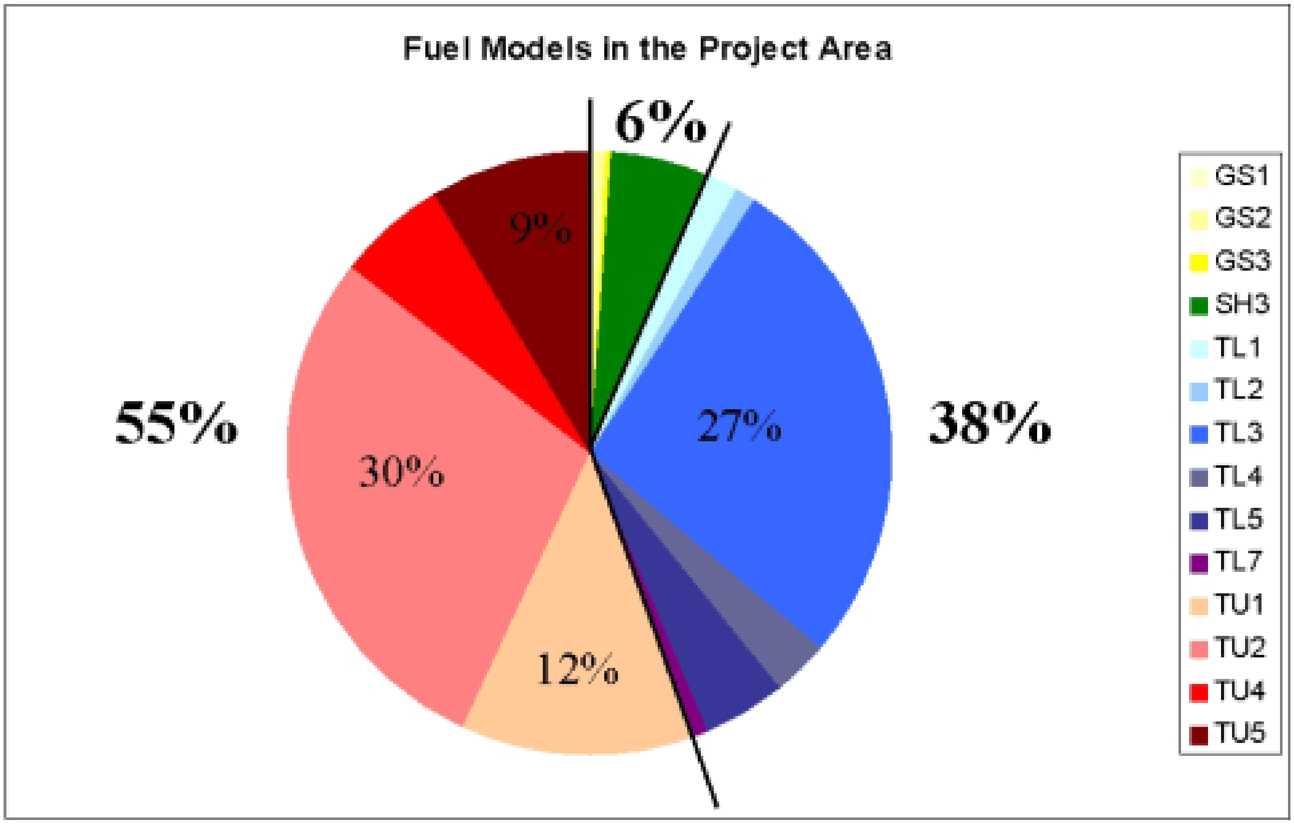

Figure 14. Pie chart of fire behavior fuel model occurrence in the project area.

We found 14 of the 40 Scott and Burgan (2005) fire behavior fuel models in the project area (Figures 13 and 14, Table 4). A little more than half the plots fit into the timber understory (TU) model types, while most of the remaining plots were deemed to fit the timber litter (TL) models (Figure 14). Scott and Burgan organized their fuel models based on major fuel type (e.g. grass, shrub, timber litter, slash) and then by two climate types. Their fuel models are split into either an "arid to semiarid climate" type (with extinction moisture content of 15 percent), or a "subhumid to humid climate" type (with extinction moisture content of 30-40 percent). This climate-based categorization leaves a gap (extinction moisture content of 15-30 percent). Unfortunately, the microclimates in the Mt. Spokane study area are often midway between a semi-arid and a sub-humid climate. In part, because of the fact that the Scott and Burgan fuel models do not cover this gap adequately, we selected fuel models from both the dry climate group and the wet climate group, depending on which fuel model best described the situation at each forest survey plot. We also often assigned the plot to two fuel models, one the dominant type and a secondary type. Table 4 briefly describes the fuel models in the project area.

Table 4. Primary Fire Behavior Fuel Model in the Project Area

Code	General Fuel Model Type	Description of General Fuel Model Type	Specific Description	Climate Type
GS1	Grass-Shrub	Mixture of grass and shrub, up to about 50 percent shrub coverage	Shrubs are about 1 foot high, low grass load. Spread rate moderate; flame length low.	Arid to semiarid climate (rainfall deficient in summer)
GS2	Grass-Shrub	Mixture of grass and shrub, up to about 50 percent shrub coverage	Shrubs are 1 to 3 feet high, moderate grass load. Spread rate high; flame length moderate.	Arid to semiarid climate (rainfall deficient in summer)
GS3	Grass-Shrub	Mixture of grass and shrub, up to about 50 percent shrub coverage	Moderate grass/shrub load, average grass/shrub depth less than 2 feet. Spread rate high; flame length moderate.	Subhumid to humid climate (rainfall adequate in all seasons)
SH3	Shrub	Shrubs cover at least 50 percent of the site; grass sparse to nonexistent	Moderate shrub load, possibly with pine overstory or herbaceous fuel, fuelbed depth 2 to 3 feet. Spread rate low; flame length low.	Subhumid to humid climate (rainfall adequate in all seasons)
TU1	Timber-Understory	Grass or shrubs mixed with litter from forest canopy	Fuelbed is low load of grass and/or shrub with litter. Spread rate low; flame length low.	Semiarid to subhumid climate.
TU2	Timber-Understory	Grass or shrubs mixed with litter from forest canopy	Fuelbed is moderate litter load with shrub component. Spread rate moderate; flame length low.	Humid climate.
TU4	Timber-Understory	Grass or shrubs mixed with litter from forest canopy	Fuelbed is short conifer trees with grass or moss understory. Spread rate moderate; flame length moderate.	Semiarid to subhumid climate.
TU5	Timber-Understory	Grass or shrubs mixed with litter from forest canopy	Fuelbed is high load conifer litter with shrub understory. Spread rate moderate; flame length moderate.	Semiarid to subhumid climate.
TL1	Timber Litter	Dead and down woody fuel (litter) beneath a forest canopy	Fuelbed is recently burned but able to carry wildland fire. Light to moderate load, fuels 1 to 2 inches deep. Spread rate very low; flame length very low.	No climate modifier
TL2	Timber Litter	Dead and down woody fuel (litter) beneath a forest canopy	Fuelbed composed of broadleaf (hardwood) litter. Low load, compact. Spread rate very low; flame length very low.	No climate modifier
TL3	Timber Litter	Dead and down woody fuel (litter) beneath a forest canopy	Fuelbed does not include coarse fuels. Moderate load conifer litter. Spread rate very low; flame length low.	No climate modifier
TL4	Timber Litter	Dead and down woody fuel (litter) beneath a forest canopy	Fuelbed includes both fine and coarse fuels. Moderate load, includes small diameter downed logs. Spread rate low; flame length low.	No climate modifier
TL5	Timber Litter	Dead and down woody fuel (litter) beneath a forest canopy	Fuelbed does not include coarse fuels. High load conifer litter; light slash or mortality fuel. Spread rate low; flame length low.	No climate modifier
TL7	Timber Litter	Dead and down woody fuel (litter) beneath a forest canopy	Fuelbed includes both fine and coarse fuels. Heavy load, includes larger diameter downed logs. Spread rate low; flame length low.	No climate modifier

Forest Canopy Cover

Forest canopy cover (Figure 15) represents the amount of the sky that is covered by a forest canopy. It is one of the most important indicators of forest condition and determines the amount of light that understory vegetation and fuels on the forest floor receive. It also is a primary determinant of wind speed and air movement in the forest understory and at the forest floor.

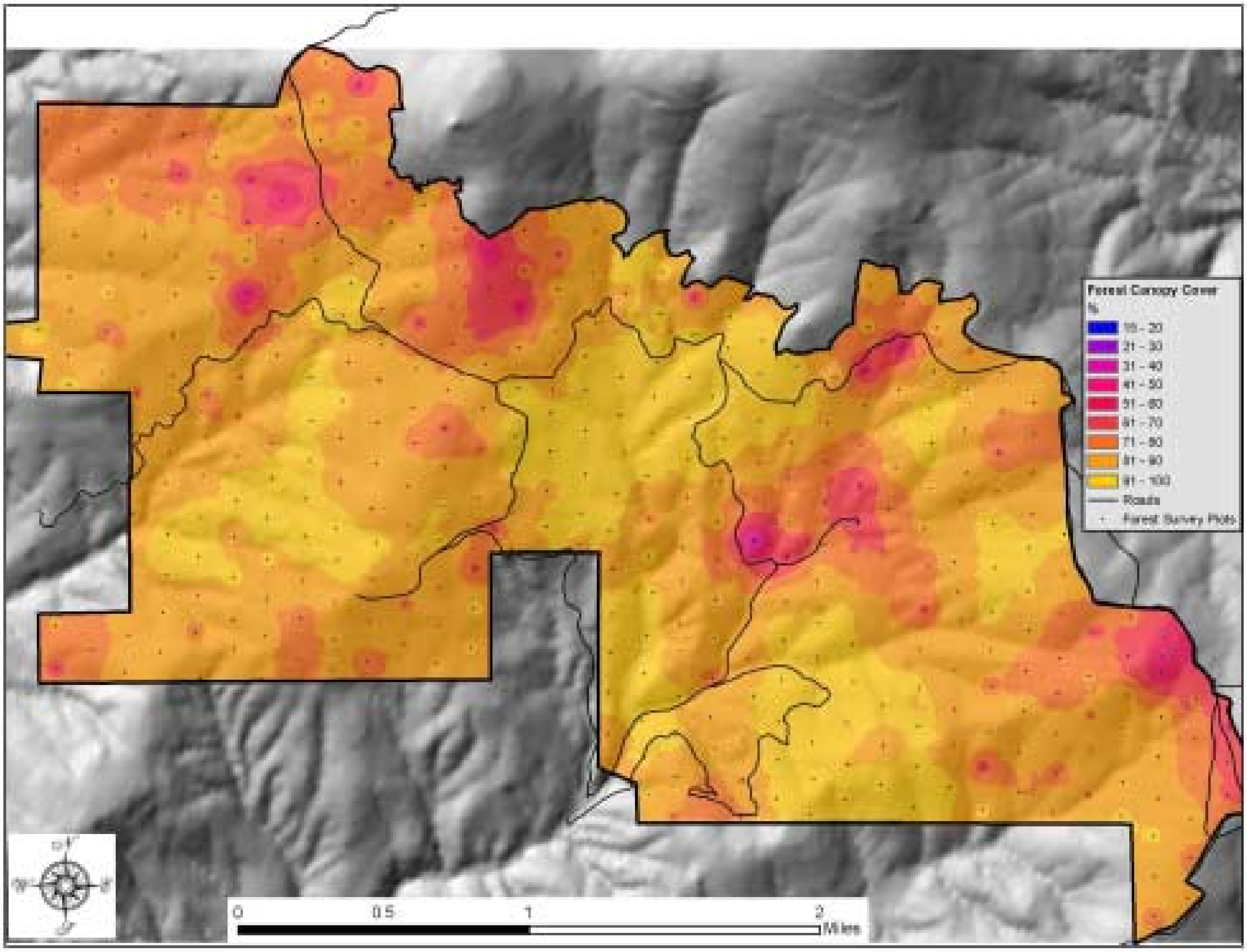

Figure 15. Forest canopy cover in the project area.

Canopy Bulk Density
Canopy bulk density is an important crown characteristic needed to predict crown fire spread, yet it is difficult to measure in the field (Keane et al 2005). Canopy bulk density is a measure of the fuel density (measured in kg/cubic meter) in the forest canopy. It is the accumulation of the crown bulk densities within a forest stand (Figure 16) that is an indicator of the canopy bulk density (and thus fuel load) in that stand.

Tree-level | **Stand-level**

Crown bulk density and Crown base height | **Canopy bulk density and Canopy base height**

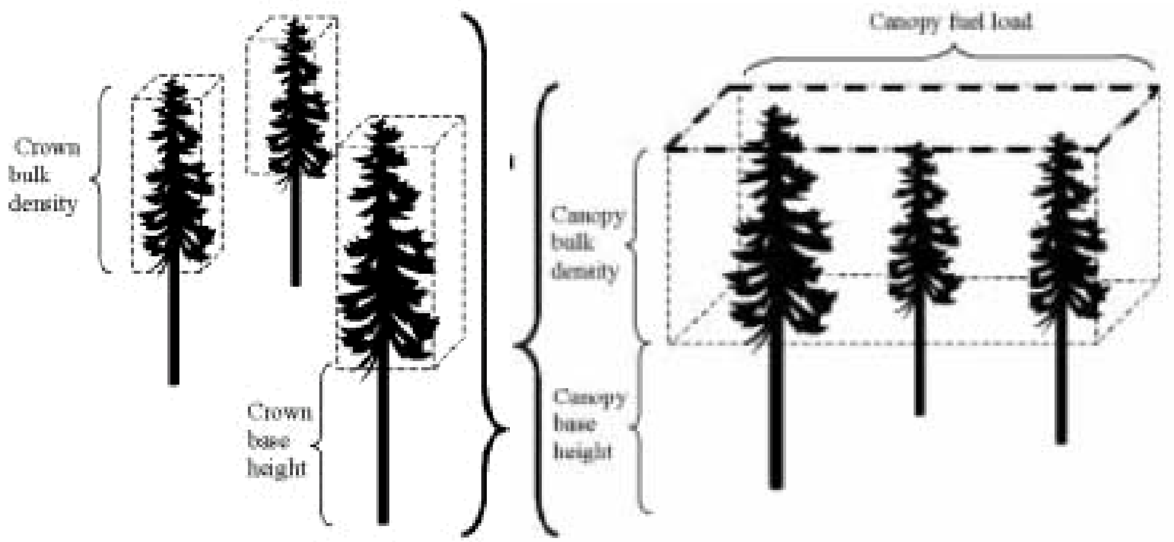

Figure 16. Illustration of crown and canopy bulk density and crown and canopy base height. (From Cruz et al 2003)

Crown bulk density is the primary factor that controls the rate of spread needed to achieve active crown fire (Figure 17). Therefore it is an important dimension of forest condition to estimate and use in wildfire modeling and prediction. We created a canopy bulk density GIS raster surface layer for the study area (Figure 18) using methods described in Cruz et al (2003) by calculating the crown bulk density of each individual tree and summing these for the stand on a per acre basis. These values were then interpolated to the entire project area landscape using the IDW technique.

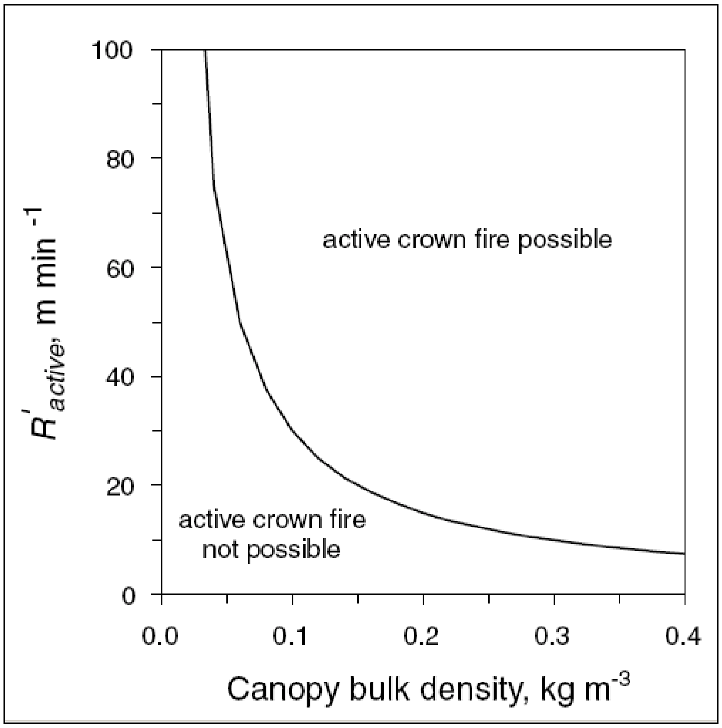

Figure 17. Van Wagner's criterion for sustained active crown fire spread based on a minimum horizontal mass-flow rate of 0.05 kg m-2 min-1. Example: a stand with CBD of 0.2 kg m-3 requires a spread rate of 15.0 m min-1 to sustain active crowning. (From Scott and Reinhardt 2001).

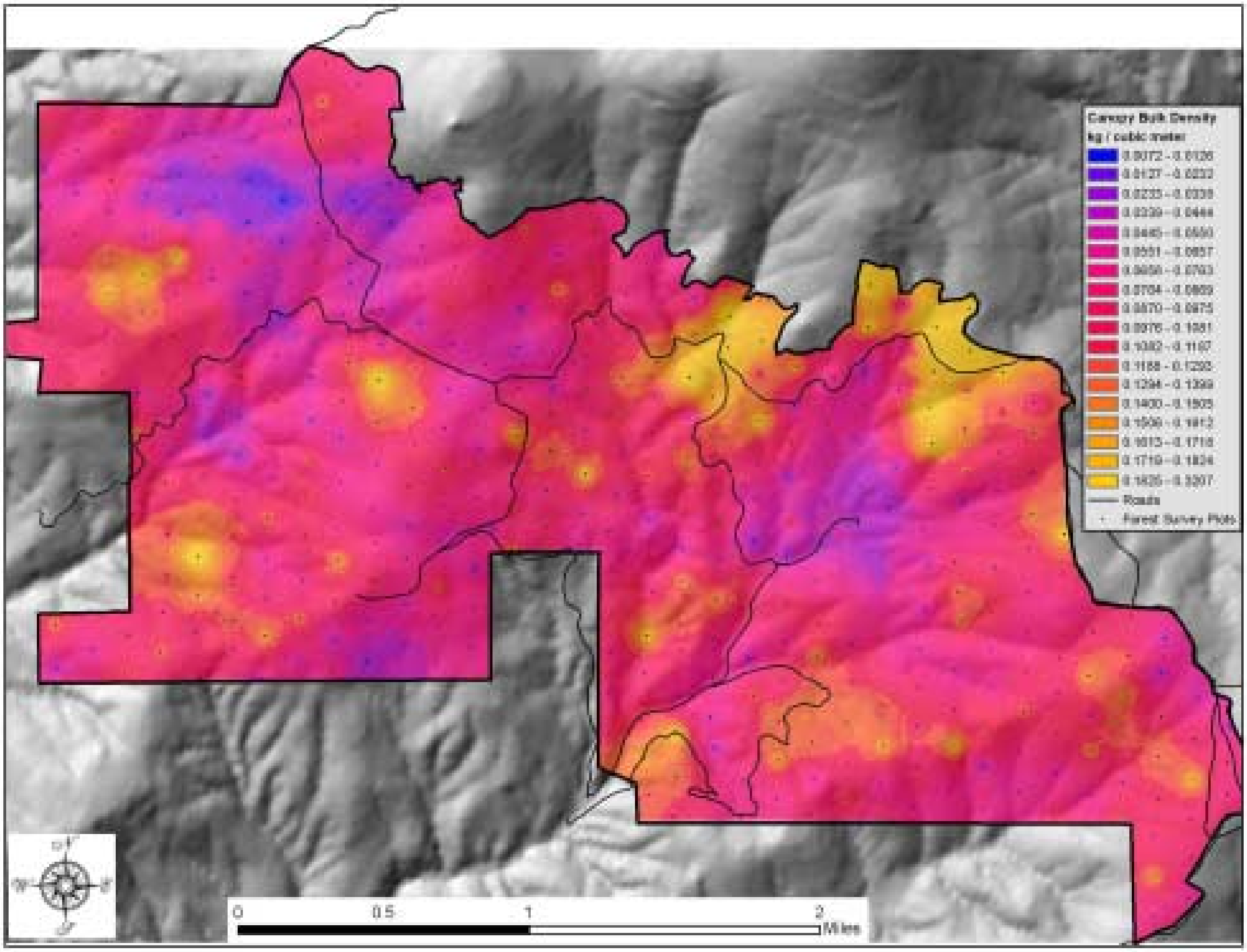

Figure 18. Canopy bulk density in the project area. (trees > 4 inches DBH)

Canopy Height

The height of the forest canopy (Figure 19) is another important forest stand attribute. It can be one of the determinants of wildlife habitat for certain species. It is also an important factor in fire behavior and forest successional processes. It is determined by averaging the height of the dominant and co-dominant trees in the stand.

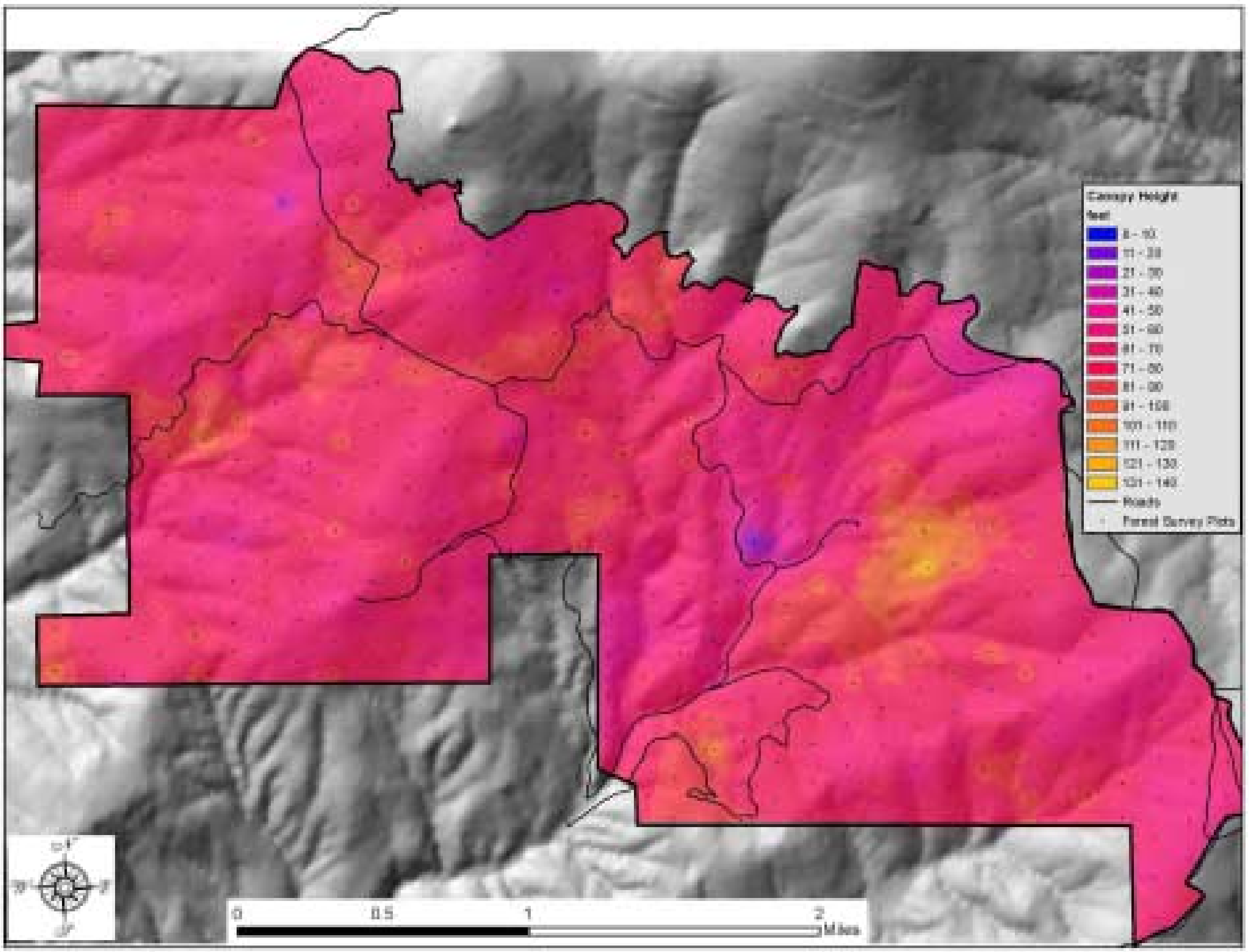

Figure 19. Mean canopy height in the project area. (trees > 4 inches DBH)

Canopy Base Height

The canopy base height (Figures 16 and 20) is another important forest stand attribute. It is also an important factor in fire behavior and forest successional processes. It can be used along with canopy height to help determine wildlife habitat for certain species. It is determined by averaging the crown base height (Figure 16) of the all the trees in the stand.

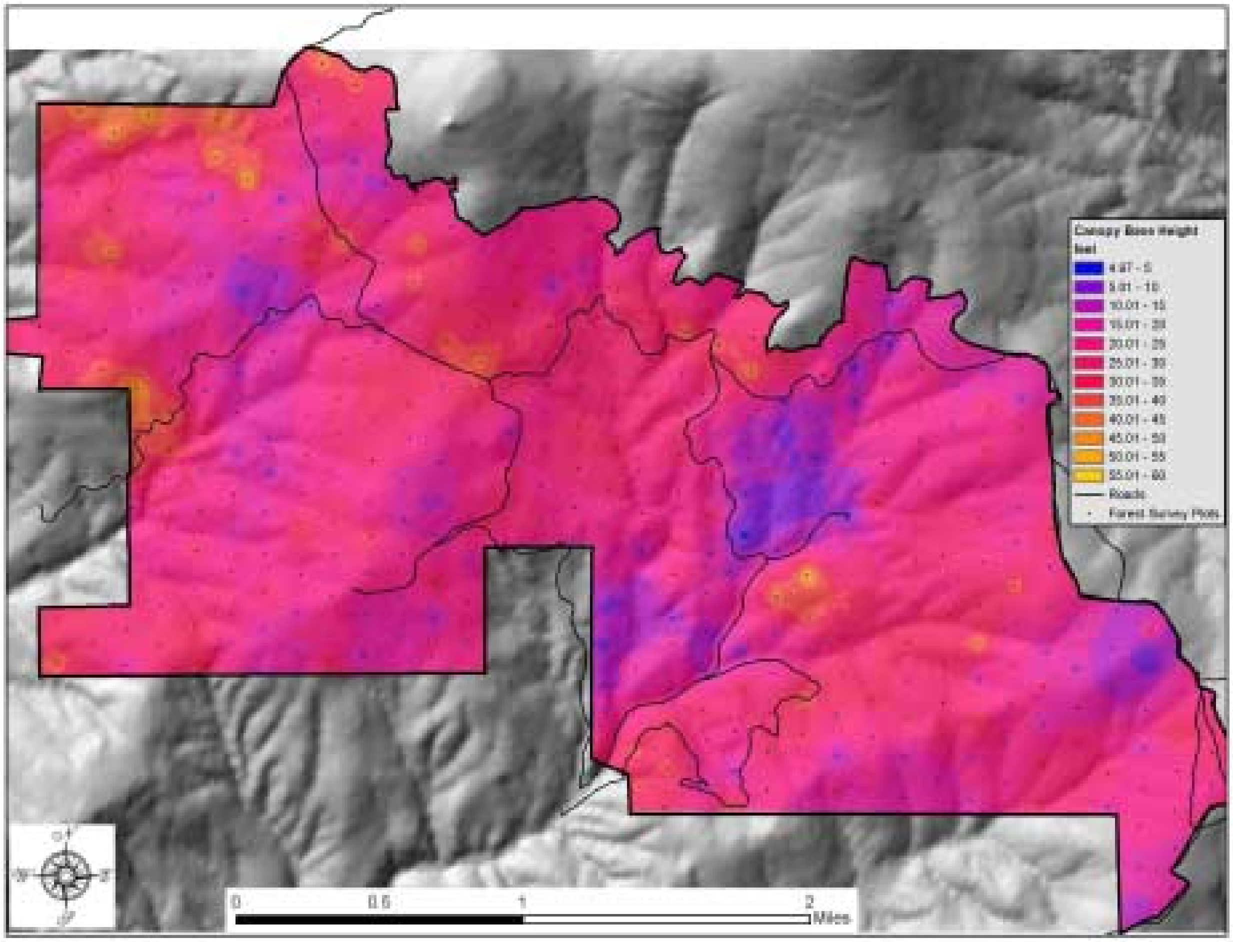

Figure 20. Mean canopy base heights in the project area. (trees > 4 inches DBH)

The following discussion from Scott and Reinhardt (2001) is helpful in understanding complexity in measuring and computing canopy base height:

"Crown base height is a simple characteristic to measure on an individual tree. Canopy base height (*CBH*) is not well defined or easy to estimate for a stand. Neither the lowest crown base height in a stand nor the average crown base height is likely to be representative of the stand as a whole. Canopy base height is difficult to measure in multistory stands and stands with ladder fuels. Van Wagner (1993) reduced (the)observed *CBH* to account for ladder fuels in a two-story stand. 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. Using this definition, ladder fuels such as lichen, dead branches, and small trees are incorporated. Sando and Wick (1972) estimated canopy base height of nonuniform stands based on the height at which a minimum bulk density of fine fuel (100 lb acre-1 ft-1, 0.037 kg m-3) is found. The Fire and Fuels Extension to the Forest Vegetation Simulator (Beukema and others 1997) uses the Sando and Wick approach in combination with Brown's (1978) equations to estimate canopy base height and canopy bulk density. Canopy base height was defined as the lowest height above which at least 30 lb/acre/ft (0.011 kg m-3) of available canopy fuels is present. Ladder fuels that increase the intensity of the surface fire, such as short understory trees, shrubs, and needle drape, are best accounted through custom surface fuel modeling or by simple adjustment of simulated surface fire intensity to include their effect."

In the Mt. Spokane project area we were conservative in our estimate of canopy base height, since we measured the crown base height of each tree at the lowest significant live branches. This places the crown base height below the level described above. Therefore, our calculation of canopy base height for the stands is lower than what would be indicated from a calculation that included consideration of the amount of canopy fuel above a given height. Those measurements were beyond the scope of our contract.

Canopy base height is one of the most important variables in determining crown fire initiation (Figure 21). When crown base heights of trees in a stand are low, then low fireline intensities and low flame lengths are sufficient to initiate crown fires under various fuel moisture conditions.

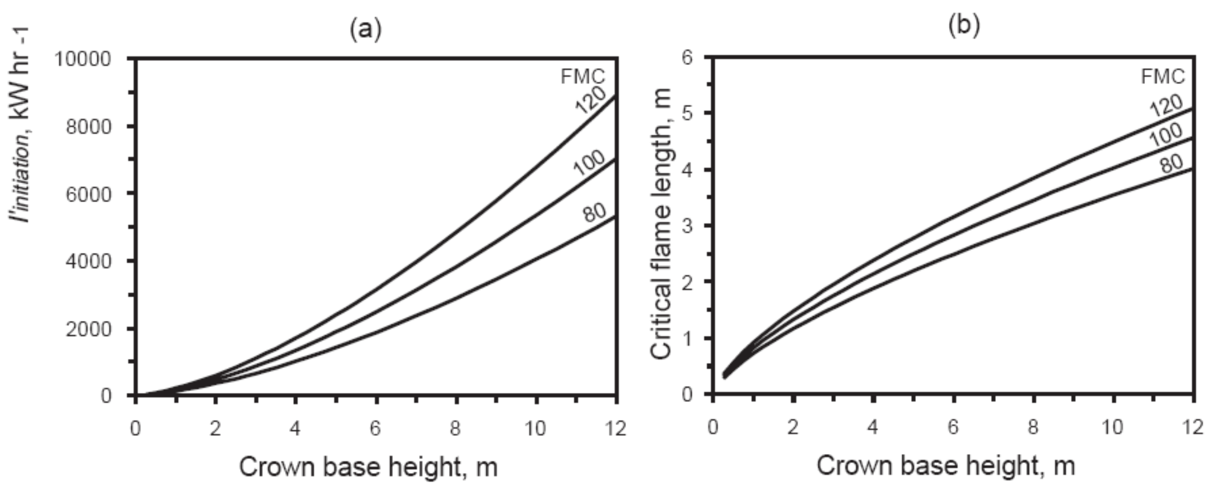

Figure 21. Van Wagner's crown fire initiation criterion (following Alexander 1988) expressed as critical surface fireline intensity (a), and critical flame length using Byram's (1959) flame length model (b). Note that critical flame length is less than canopy base height (CBH) for CBH greater than about 1 m. Example: a stand with CBH of 3 m and 100 percent fuel moisture content (FMC) requires surface fireline intensity of 875 kW m-1 (flame length 1.7 m) to initiate crowning.

Tree Density

The density of trees in a stand (stem density) is another important measure of forest condition. It is calculated by determining the number of tree stems per unit area (Figure 22). Our calculation of tree density was based on trees sampled in the variable radius plots, and so it does not include the smallest trees. These were tallied separately. High-density stands often have intense competition between trees for sunlight, water and nutrients. This often results in eventual mortality of the less competitive trees. Low-density stands often have ample room for trees to grow, however there may be very dense shrub understories and intense competition in the understory.

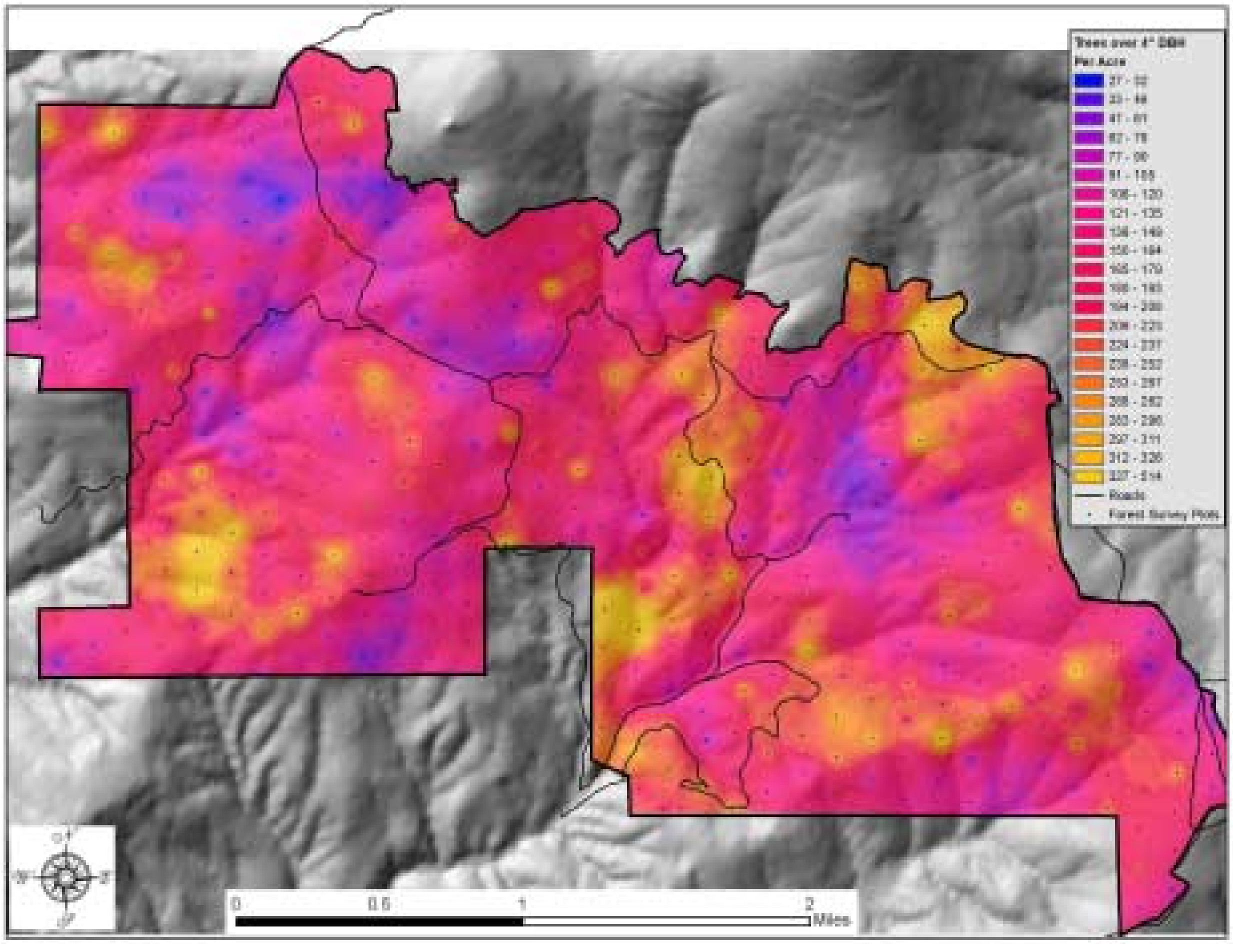

Figure 22. Tree density in the project area. (trees per acre > 4 inches DBH)

Basal Area

Basal area is simply a measure of the cross-sectional area of each stem, in this case the stems of the live trees. We calculated the basal area of each tree and then summed these values on a per acre basis for each forest survey plot. Figure 23 illustrates basal area as it varies throughout the project area as determined by IDW interpolation from the plot data. Basal area is one of the factors that determine the total biomass in a forest stand.

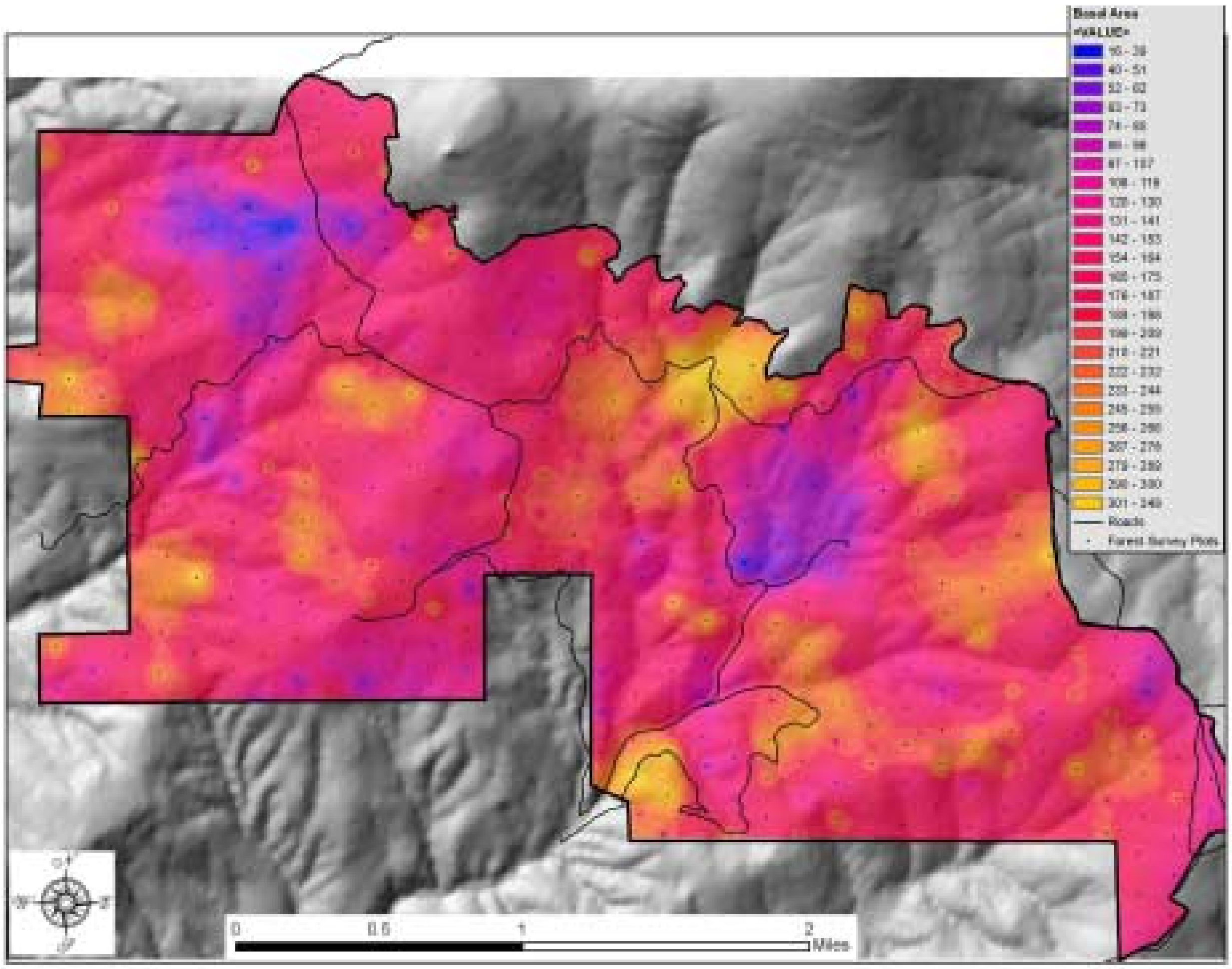

Figure 23. Stand basal area throughout the project area. (square feet/acre for trees > 4 inches DBH)

Tree Diameters

The project area has a wide range of successional stages of stands - quadratic mean diameter is one expression of the size and age of a forest stand. The quadratic mean diameter is the diameter of the tree with the arithmetic mean basal area (cross-sectional area) (Husch et al 1982). It is a more meaningful measure of the stand diameter than the simple mean diameter and is illustrated in Figure 24. Graphs of the actual diameter distribution of all the plots are provided in Appendix M.

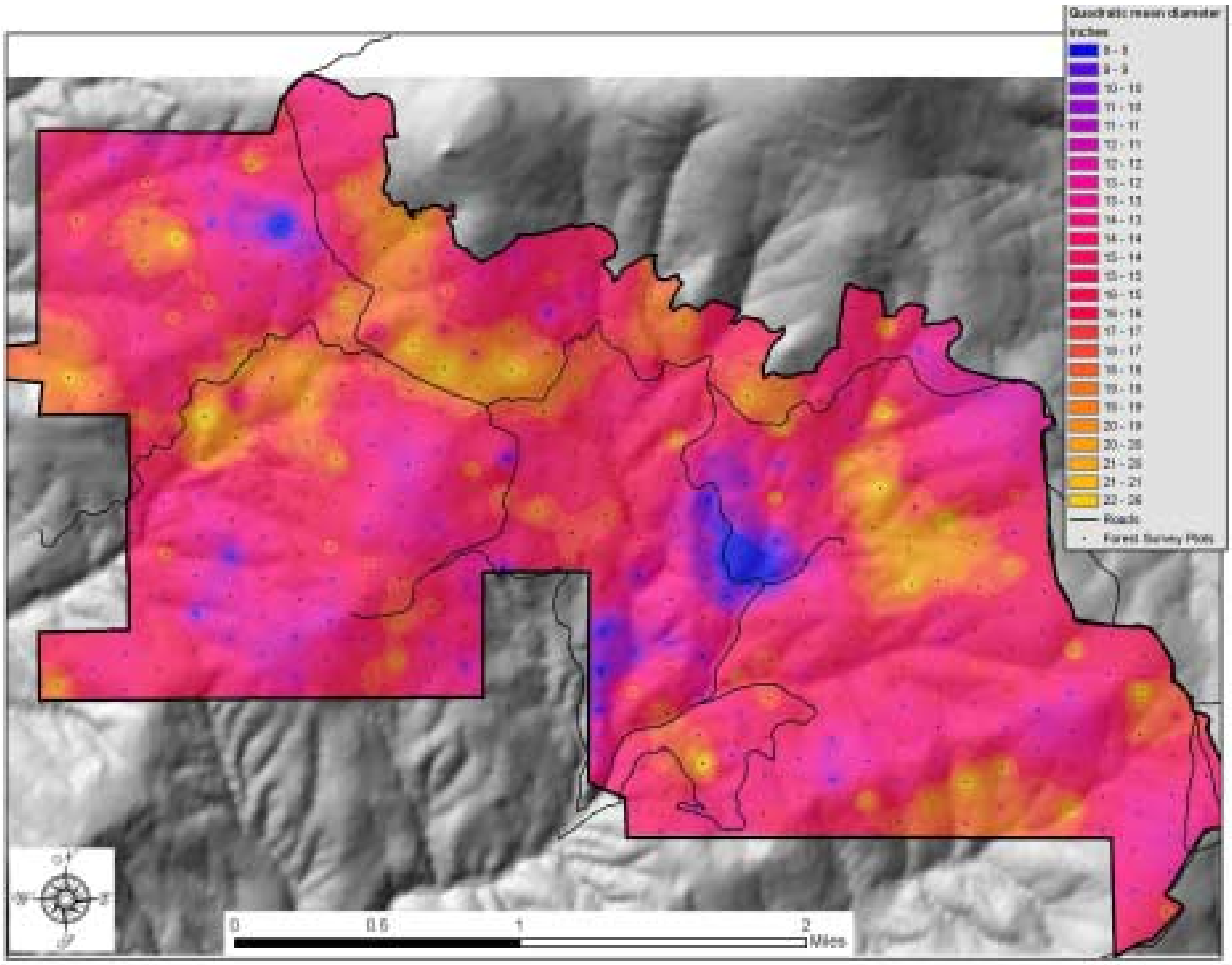

Figure 24. Quadratic mean diameter of forest stands in the project area. (trees > 4 inches DBH)

Stand Density Index

Stand density index (SDI) is a measure of relative stand density, allowing comparisons between stands comprised of different species and diameters (Husch et al 1982). We calculated SDI using a new method developed by Woodall and Miles (2004) from our plot data and the result is depicted in Figure 25. Stand density index (SDI) was originally developed for use in even-aged monocultures, but has been used more recently for stand density assessment in large-scale forest inventories. Woodall and Miles (2004) improved the application of SDI in uneven-aged, mixed species stands present in large-scale inventories, through development of a model whereby a stand's maximum SDI was calculated as a function of the stand's mean specific gravity (SG) of individual trees.

SDI is usually not strongly correlated with age or site index. This quality of independence of age and site makes SDI a valuable parameter in describing a stand. We did find that it was highly correlated with basal area in our project area.

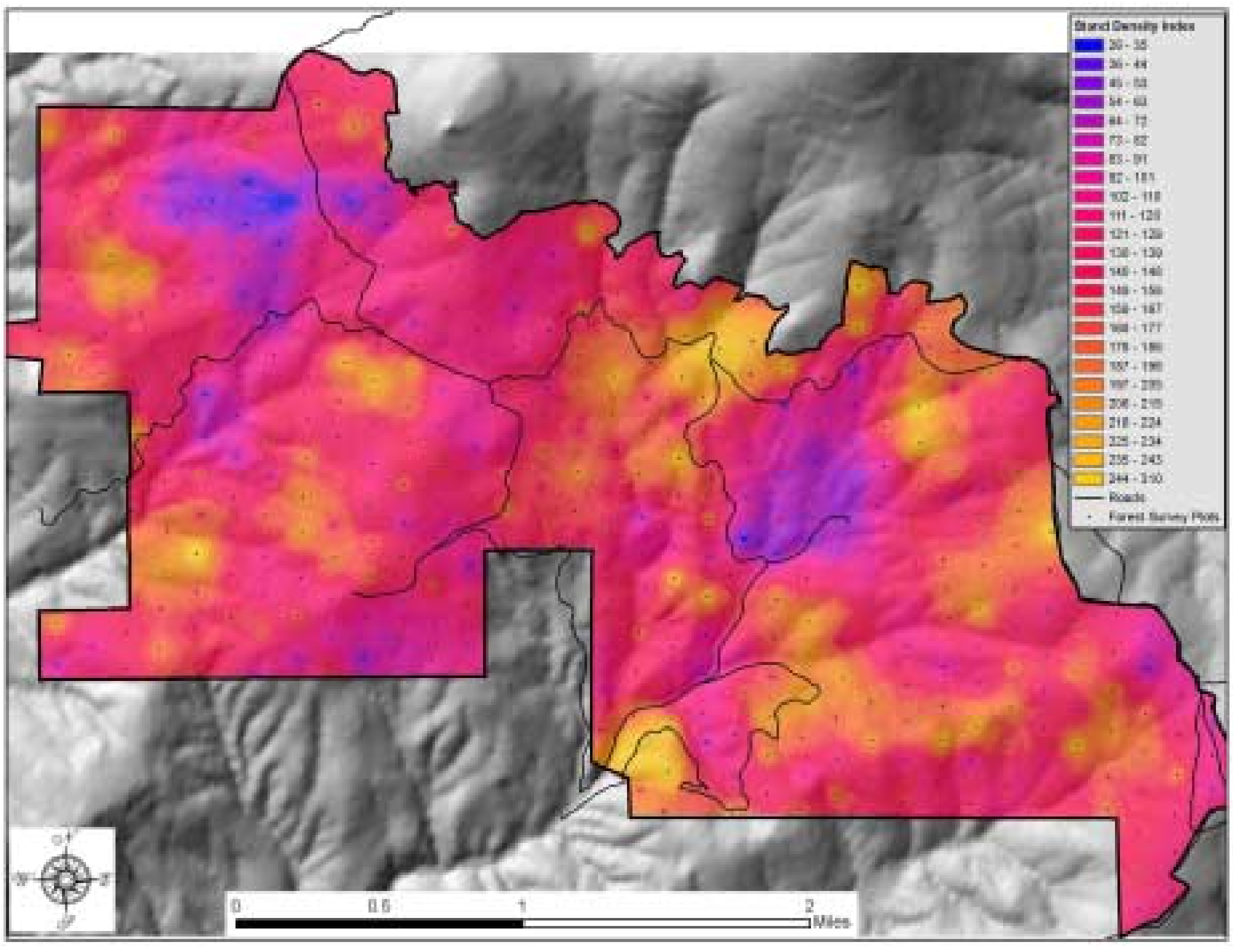

Figure 25. Stand density index in the project area. (trees > 4 inches DBH)

Tree Species Composition and Diversity

Figures 26-28 depict examples of the variation in tree density by various conifer species. The three species chosen (ponderosa pine, western larch and Douglas-fir) are the most fire resistant species in the project area. These species are also diminishing in abundance compared to pre-settlement conditions. Figure 29 illustrates Shannon's diversity index, which is a measure of overall tree species diversity. The formula for Shannon's diversity index is:

$$H = -\sum_{i=1}^{S} p_i \log p_i$$

where p_i is the fraction of individuals belonging to the i-th species. This is by far the most widely used diversity index. It is much more informative than a simple measure of species richness because it accounts for both the overall richness of species and the relative abundance of those species.

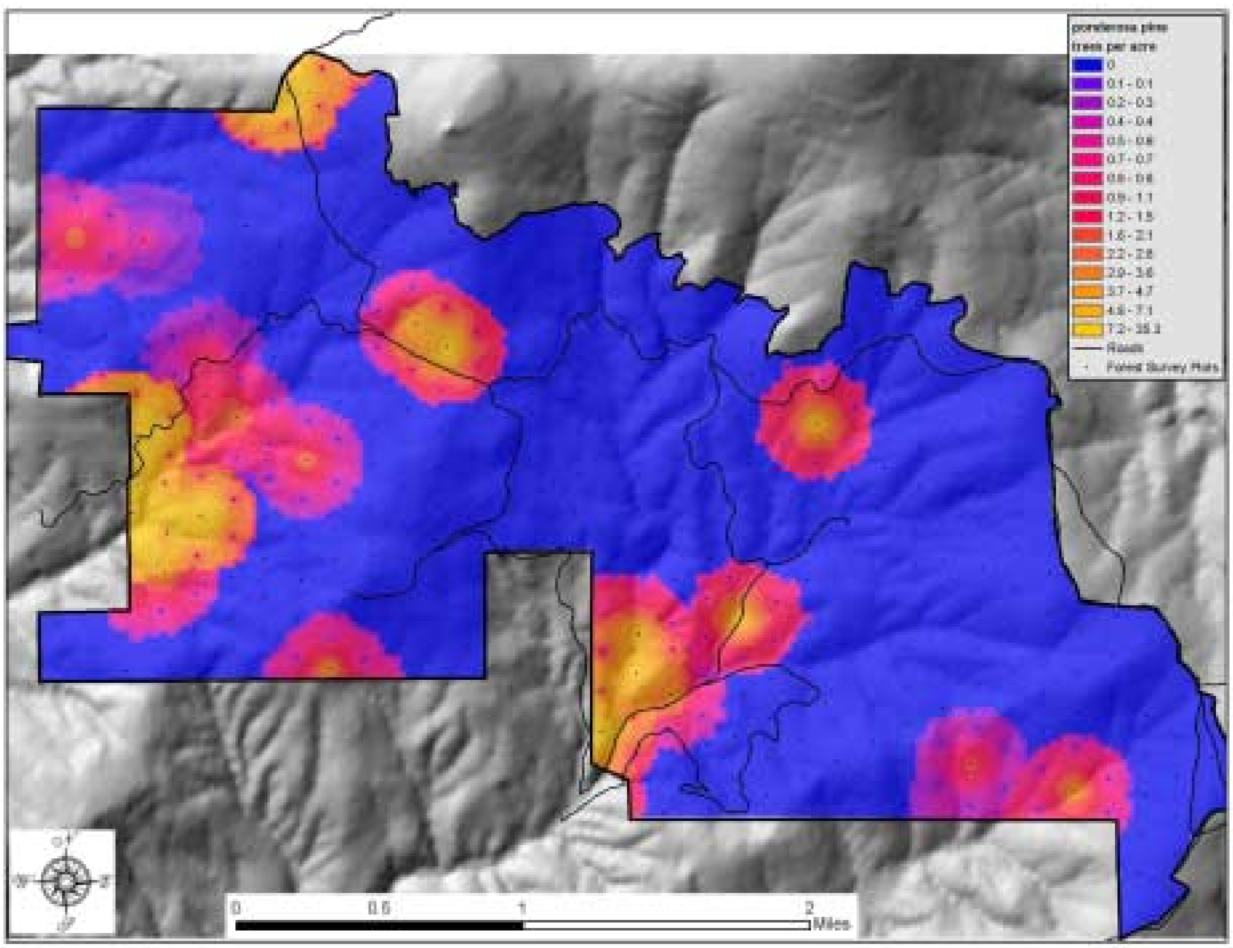

Figure 26. Ponderosa pine density (trees per acre) in the project area. (trees > 4 inches DBH)

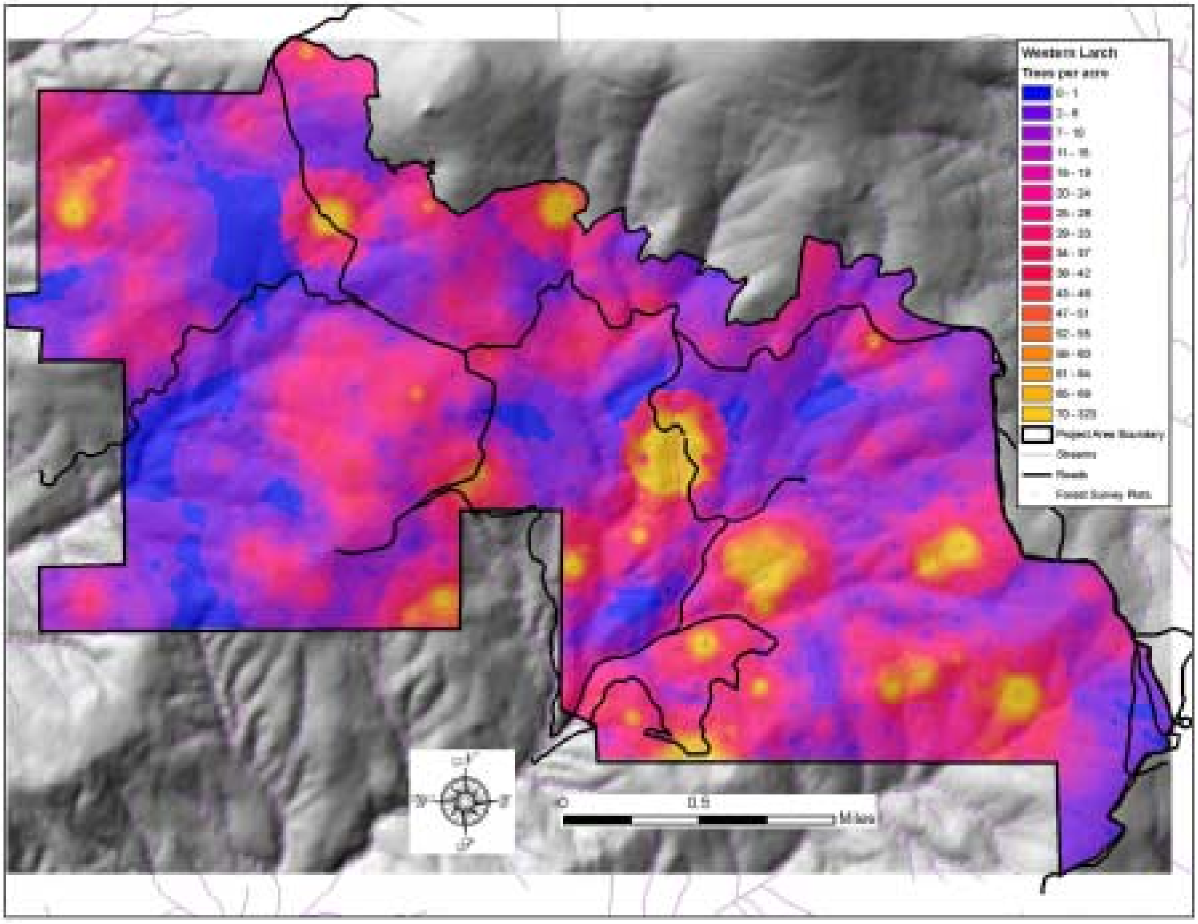

Figure 27. Western larch density (trees per acre) in the project area. (trees > 4 inches DBH)

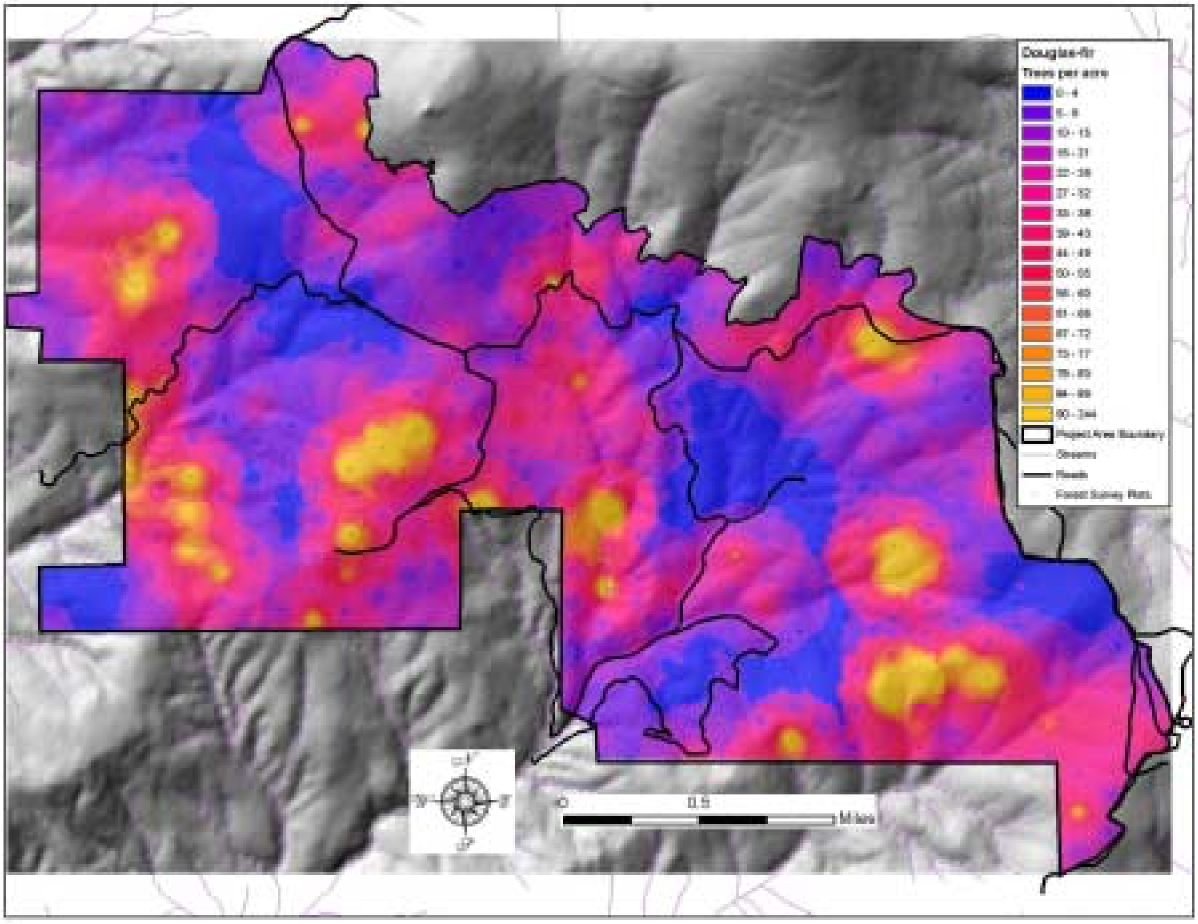

Figure 28. Douglas-fir density (trees per acre) in the project area. (trees > 4 inches DBH)

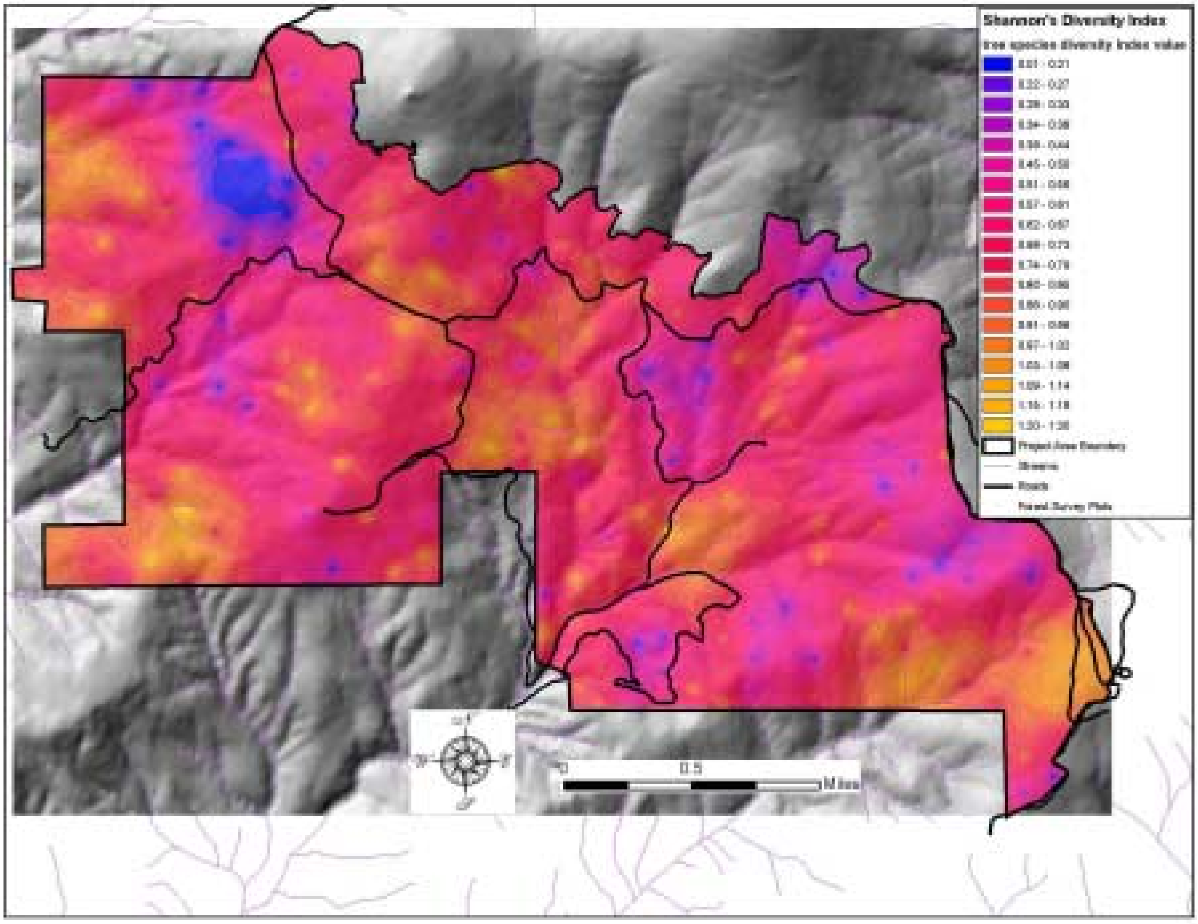

Figure 29. Shannon's Diversity Index in the project area. **(trees > 4 inches DBH)**

Distribution of Old-growth Forests

The distribution of old-growth forests at Mt. Spokane is an important factor in determining forest health conditions, especially with regard to wildlife habitat conditions. We explored a variety of ways of assessing the degree of old-growth forest development in the project area. We developed an indicator of old-growth forest development called "MaxDBH." The indicator is being based in part on prior methods of identifying and mapping old growth forests in the Pacific Northwest (Franklin and Spies 1984; Old-growth Definition Task Group 1986; Morrison 1988, 1990; Morrison et al 1990, 1991). These old-growth definitions and mapping methods uses a minimum density of stems per acre of a minimum diameter size as one of the parameters needed to classify stands as old growth or mature forests. In these prior studies, the value of eight trees per acre was used as the minimum density to classify a stand as old-growth. In our case, we are trying to determine the degree of development of old-growth or late-successional forest condition in a stand based on the same premise. However, since old-growth definitions are not well established for eastern Washington forests, we are not as concerned with a minimum diameter size threshold for identifying actual old-growth forests as we are about identifying the degree of development toward old-growth conditions.

From our adaptation of this indicator, we can see the general size of the presumed dominant or co-dominant cohort in a given area (the largest diameter class that has at least 8 trees per acre in the stand), as one indicator of stand age and development. For instance, if a forest stand has a MaxDBH value of 24 (inches), we can presume that there are at least 8 trees per acre in that stand that have a DBH of 24 inches or more. We also know that there are less than 8 trees per acre in any diameter class above 24, so we are presuming that at least 24-inch diameter trees are constantly occurring throughout the stand and that these trees would yield the best information as to the age of the oldest dominant cohort. A stand with a MaxDBH value of 24 might have seven trees per acre of 32 inches DBH, but not enough of the higher diameter classes to amount to eight trees per acre. Therefore it is just a rough indicator of the overall size distribution of the stand. Quadratic mean diameter (described above) is another indicator of the overall size distribution of a stand, but it accounts for the diameter of all the trees, not just the largest trees. Therefore, MaxDBH is a useful additional forest condition indicator and was used in subsequent wildlife habitat modeling (Figure 30). Graphs of the actual diameter distribution of all the plots are provided in Appendix M.

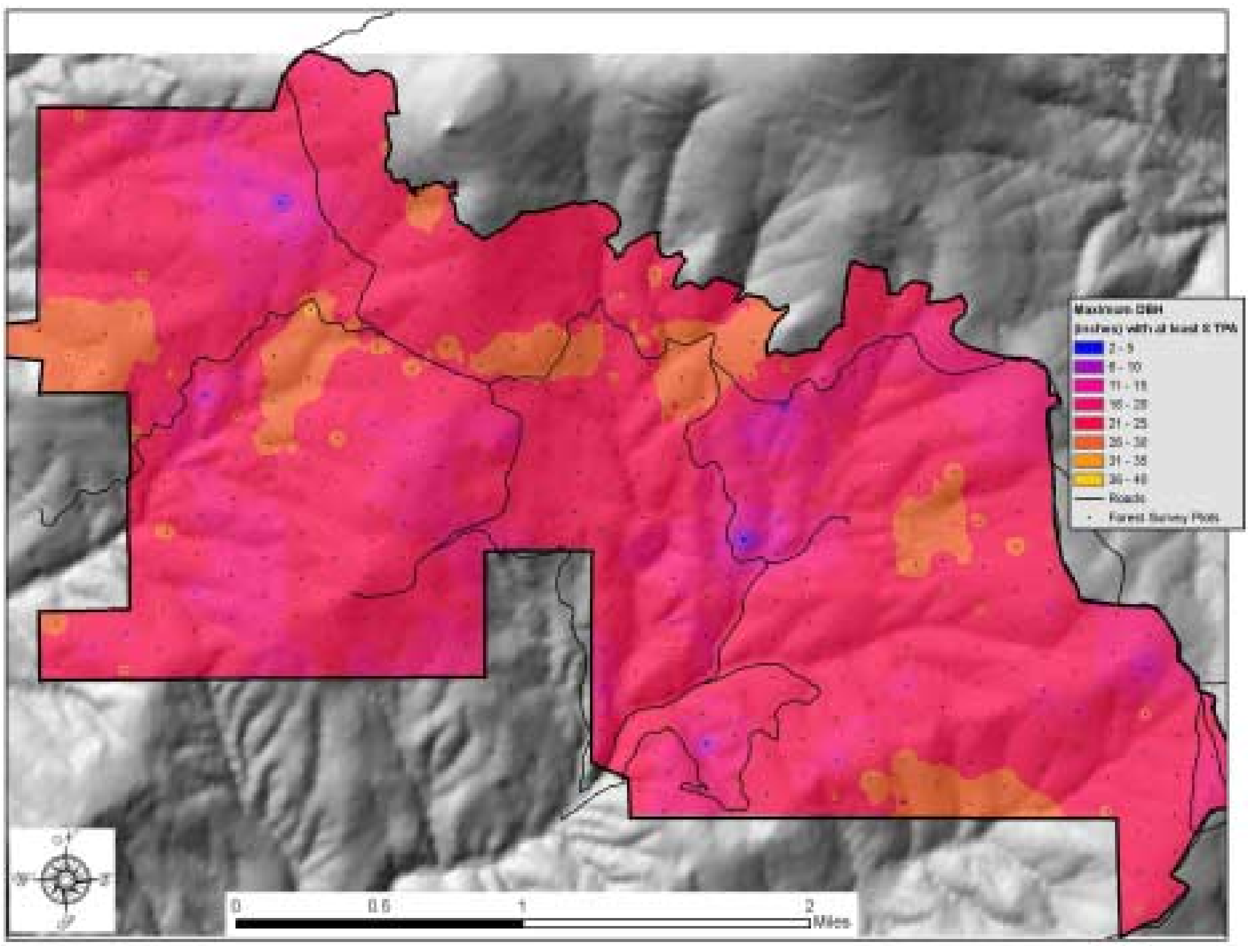

Figure 30. MaxDBH: the largest tree diameter classes possessing at least 8 trees per acre in the stands throughout the project area. (trees > 4 inches DBH)

Distribution of Snags

There is a wide variation in snag density, size, decay class and composition in project area. The illustration below (Figure 31) shows the number of snags in the project area. Other snag parameters (size, decay class and species) were also recorded and used in analyses. Snags are an important habitat component for many wildlife species.

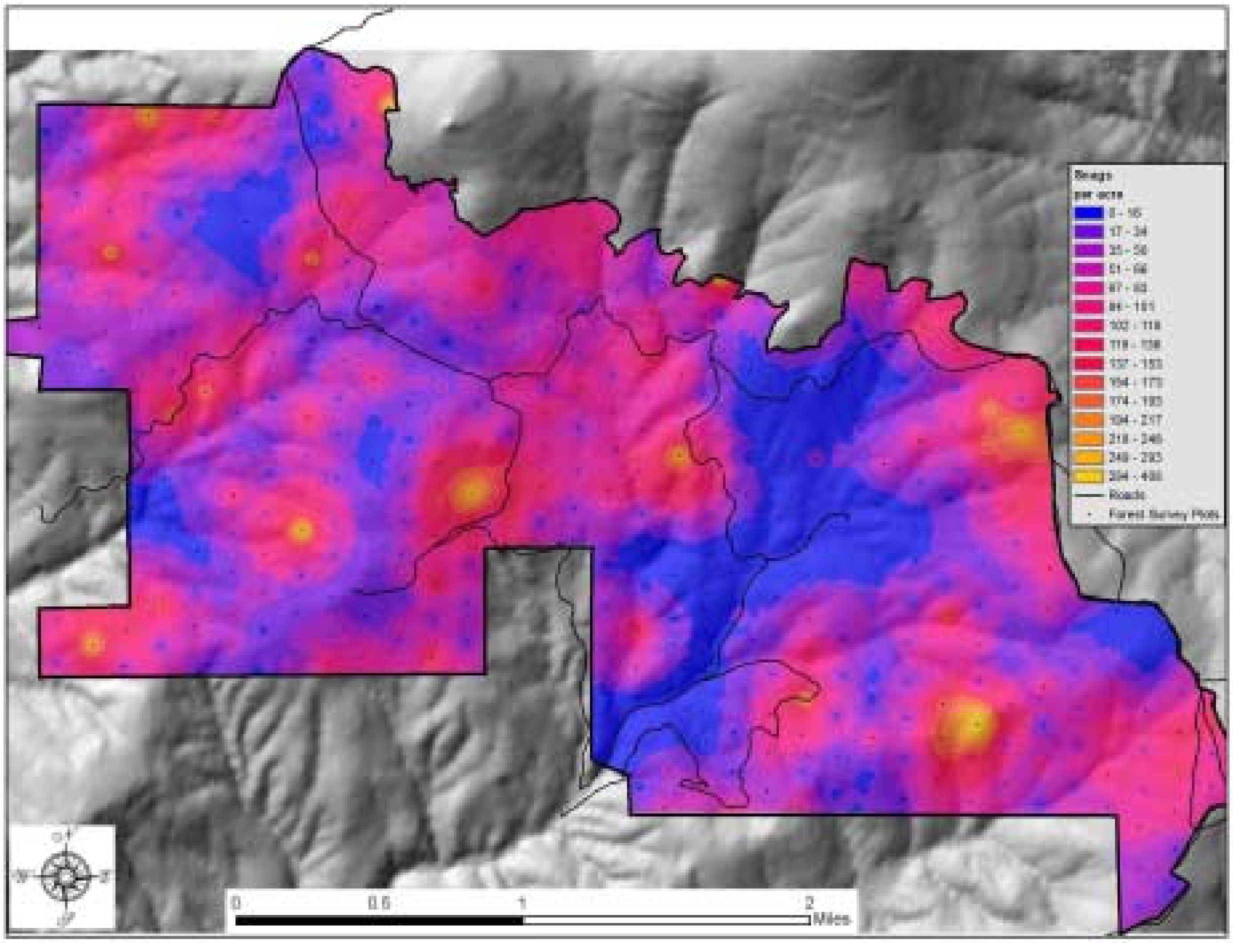

Figure 31. Snag density in the project area. (snags per acre for snags > 4 inches DBH)

Distribution of Coarse Woody Debris

Figure 32 illustrates the amount of ground surface area covered by coarse woody debris (CWD) in the project area. Most of the project area has CWD covering less than 10% of the ground surface. But some areas have CWD covering over 50% of the ground surface.

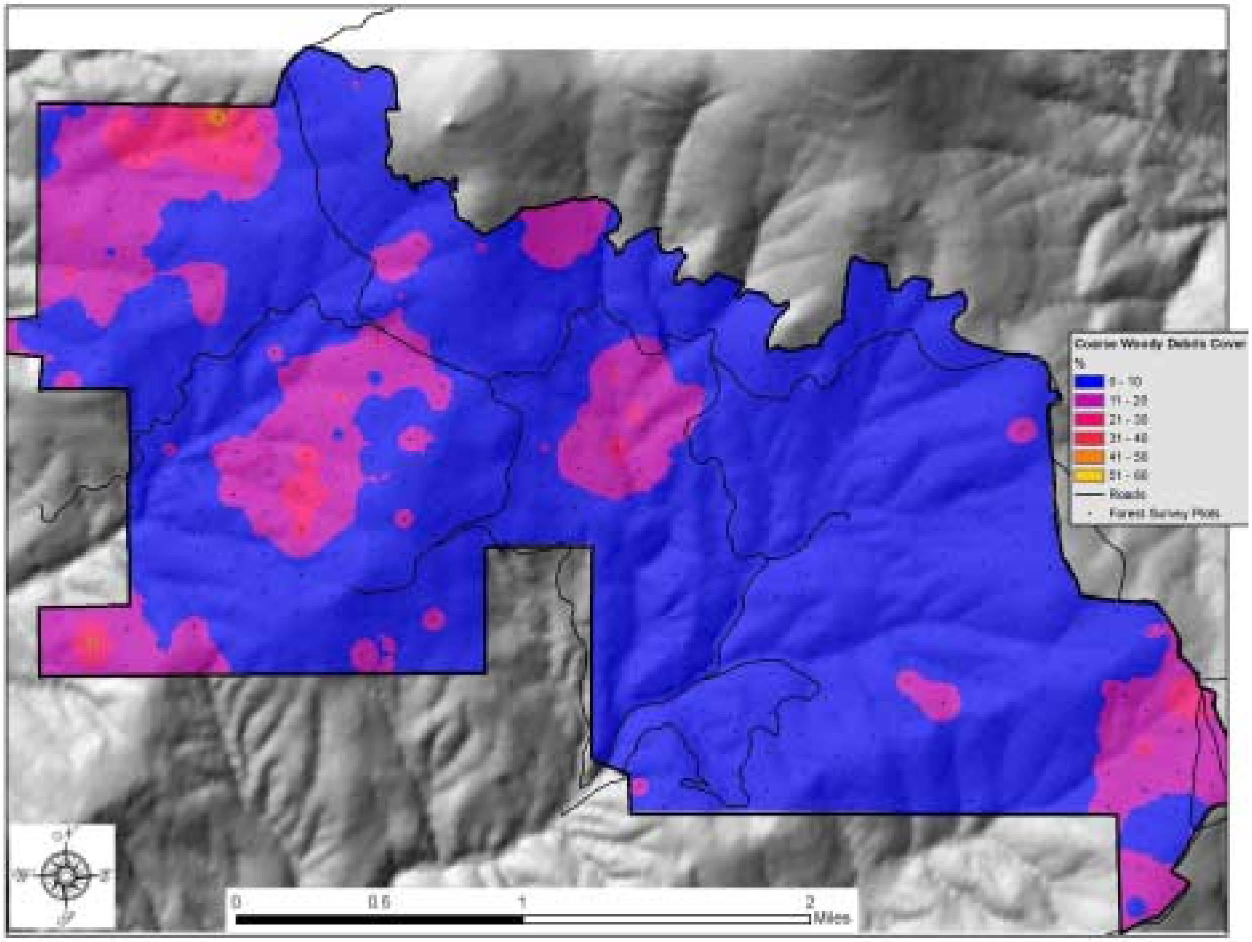

Figure 32. Coarse woody debris cover in the project area. (logs >6 inch diameter)

The number of pieces of coarse woody debris (CWD) in the project area is very variable (Figure 32). While much of the project area has less than 100 pieces of CWD (logs >6 inch diameter) per acre, some areas have densities of over 400 piece of CWD per acre. The presence of coarse woody debris is important habitat component for many wildlife species.

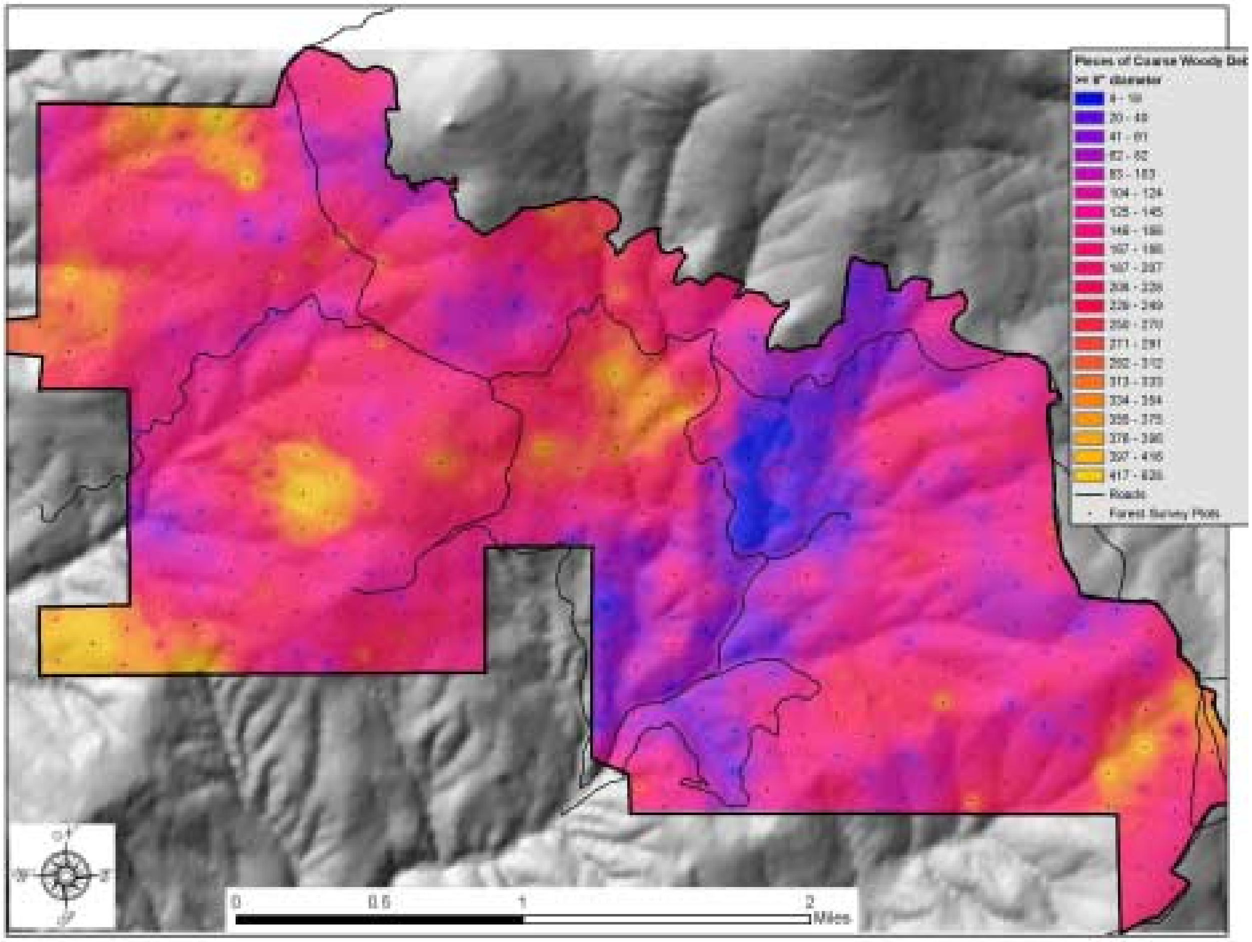

Figure 33. Coarse woody debris density in the project area. (logs >6 inch diameter per acre)

Distribution of Shrubs

There is a wide variation in shrub cover in the study area (Figure 34). Shrub cover influences wildlife habitat, fire behavior and forest successional dynamics.

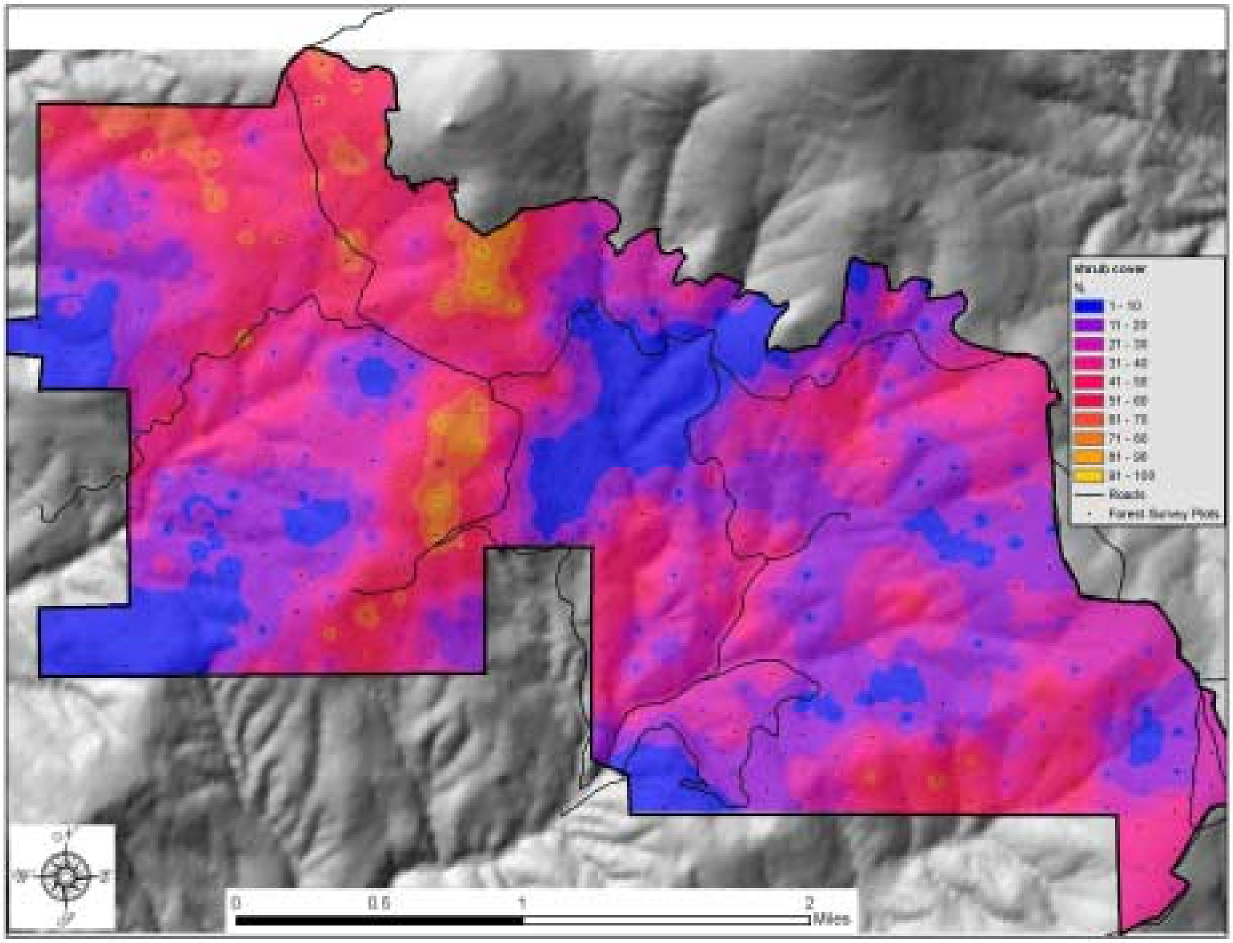

Figure 34. Shrub cover in the project area. (based on the three dominate understory species in each plot)

Wildlife Habitat Analysis

Introduction

Mount Spokane State Park provides important habitat for numerous species of wildlife in Spokane County. Many vegetation communities and habitat-types exist in the park, and most are in relatively good ecological condition. Factors contributing to these "good" conditions include: low to absent exotic species presence; natural succession processes occurring within the expected range of historic variation; high vegetation structural and species diversity; and artificial fragmentation of communities caused by roads and development is relatively low or absent (see Figures 12-34 above) . In the project area, many conifer forest types and forest succession stages are represented, as is demonstrated by our forest inventory results above. Also, small vegetation communities such as native shrublands, herbaceous meadows, and riparian wetlands add ecological complexity and diversity to the project area, enhancing wildlife habitat opportunities. Important structural habitat elements such as large snags and downed logs, while varying in size, density and distribution, occur throughout the project area. Finally, we encountered many species and signs of wildlife and wildlife guilds during our field work, and were impressed by the seemingly abundant presence of deer, elk, moose, and black bear in the park. Given these factors, ***we believe that the general habitat suitability of the project area, for a wide range of wildlife species, is currently good and not warranting major management interventions designed to improve/enhance habitat.*** The following discussion of the wildlife habitat analysis supports this statement.

The habitat quality for a select number of sensitive wildlife species was examined in detail. A wildlife habitat analysis was undertaken with three main components: 1) habitat suitability index (HSI) modeling for three target species; 2) a general literature and habitat needs review of nine additional sensitive wildlife species in the project area (chosen by WDFW and State Parks staff); and 3) a review of the potential impacts of forest prescriptions on the full twelve sensitive wildlife species looked at during this project. This latter point is addressed below in the Integrated Plan to Maintain Forest Health and Reduce Fire Risk section of this report. Lastly, we considered the overall condition of habitats for a wider range of wildlife species and the potential impacts of forest treatments on these conditions. A discussion on these considerations is provided below in the Evaluation of Forest Health Conditions in the Project Area section of this report.

Three Target Species

The three sensitive wildlife species analyzed via habitat suitability modeling were predetermined by Park staff and WDFW. They are listed in Table 5.

Table 5. Wildlife species focused on for habitat analysis in this project.

Common Name	Scientific Name	Class	Global Rank	State Rank	State Status	Federal Status
Canada Lynx	*Lynx canadensis*	Mammalia	G5	S1	T	LT
Northern Goshawk	*Accipiter gentilis*	Aves	G5	S3B, S3N	C	SC
American Marten	*Martes americana*	Mammalia	G5	S4	none	none

Global Rank Codes
G5 = Common; widespread, and abundant.

State Rank Codes
S1 = Critically imperiled (5 or fewer occurrences).
S2 = Imperiled (6 to 20 occurrences), very vulnerable to extirpation.
S3 = Rare or uncommon (21 to 100 occurrences).
S4 = Apparently secure, with many occurrences.
S5 = Demonstrably secure in state.

State Status Codes
T = Threatened. Likely to become Endangered in Washington.
C = Candidate Animal. Under review for listing.

Federal Status Codes
LT = Listed Threatened. Likely to become endangered.
SC = Species of Concern. An unofficial status, the species appears to be in jeopardy, but insufficient information to support listing.

For each of the target species we calculated Habitat Suitability Index (HSI) variables using habitat suitability modeling techniques described in Ecological Services Manual 103 (ESM 103) (USFWS 1981). HSI equations yield a value between 0 and 1 representing the ability of a given site to supply optimal habitat characteristics that could sustain the highest population density of the targeted species. If the result of an HSI calculation is 1, the site is considered to possess optimal habitat conditions for sustaining the highest population density of the targeted species. If the result is 0, the site is considered to provide no habitat value to the targeted species. Because use of wildlife habitats vary by season and by life stage, multiple HSI equations can be developed for a single species in a given area to account for differing preferences in habitat conditions based on a particular season or use. For our three target species, we developed multiple HSI equations as illustrated in Table 6. The decisions to model for these particular habitat uses and seasons were made by WDFW and WA State Parks staff.

Table 6. HSI models developed for three target wildlife species in Mt. Spokane State Park.

Species	Models Designed
Canada Lynx	Foraging - winter
	Foraging - summer
	Breeding
	Dispersal
Northern Goshawk	Breeding
	Foraging
American Marten	Foraging - winter
	Foraging - summer

Nine Additional Sensitive Wildlife Species

We performed a brief literature review of the habitat needs and current sensitivity ranks for nine additional wildlife species thought to occur in Mount Spokane State Park. The following table (7) provides a list of the nine wildlife species with information about their global, federal, and state sensitivity rankings.

Table 7. List of the nine additional sensitive wildlife species evaluated for in the project area.

COMMON NAME	SCIENTIFIC NAME	CLASS	GLOBAL RANK	STATE RANK	STATE STATUS	USESA
Wolverine	*Gulo gulo*	Mammalia	G4	S1	C	SC
Bald Eagle	*Haliaeetus leucocephalus*	Aves	G5	S4B, S4N	T	
Golden Eagle	*Aquila chrysaetos*	Aves	G5	S3	C	
Great Gray Owl	*Strix nebulosa*	Aves	G5	S2B	M	
Pileated Woodpecker	*Dryocopus pileatus*	Aves	G5	S4	C	
Black-backed Woodpecker	*Picoides arcticus*	Aves	G5	S3	C	
Townsend's Big-eared Bat	*Corynorhinus townsendii*	Mammalia	G4	S2S3	C	SC
Columbia Spotted Frog	*Rana luteiventris*	Amphibia	G4	S4	C	PS:C
Western Toad	*Bufo boreas*	Amphibia	G4	S3	C	

State Rank Codes
S1 = Critically imperiled (5 or fewer occurrences).
S2 = Imperiled (6 to 20 occurrences), very vulnerable to extirpation.
S3 = Rare or uncommon (21 to 100 occurrences).
S4 = Apparently secure, with many occurrences.
S5 = Demonstrably secure in state.
Global rankings follow a similar scaling, but on a global level

State Status Codes
T = Threatened. Likely to become Endangered in Washington.
C = Candidate Animal. Under review for listing.
M = Monitor. Taxa of potential concern.

Federal Status Codes (USESA)
LT = Listed Threatened. Likely to become endangered.
SC = Species of Concern. An unofficial status, the species appears to be in jeopardy, but insufficient information to support listing.
C = Candidate species
PS = Partial Status. Part of the taxon has the status following the colon and part has no status.

Habitat Suitability Modeling - Methods

Reference Materials

Habitat suitability models were developed according to specifications detailed in USFWS ESM 103. We also incorporated modeling techniques and information from previous habitat suitability modeling attempts conducted in other regions for the targeted species. WDFW provided us with a plethora of sample habitat suitability models developed for a variety of regions around North America. Because none of the models were directly suitable for the Mt. Spokane region, new unique models had to be developed for use in this project. The previous models provided important data on habitat requirements and modeling alternatives that we incorporated into our models. However, more locally relevant literature concerning habitat use and desirable conditions had to be incorporated to complete the HSI modeling.

Methods

We relied primarily on the data collected during this project to produce the input variables used in calculating habitat suitability for the target species. In some cases, input data were derived via remote sensing and GIS analysis. Field data collection and subsequent statistical processing methods are described below in the Forest Condition Survey section of this report. For the HSI modeling process, we relied on existing literature to identify the most logical limiting factors affecting habitat suitability for each species given a particular habitat use. Limiting factors had to be able to be either quantitatively expressed or spatially explicit to be useful in modeling. To translate limiting factors into empirical models we used a non-compensatory structure, meaning that the suitability equations were designed to decrease the overall suitability index value of a given habitat area by the amount that an individual limiting factor variable falls below its optimal range (1). Each suitability equation was developed either by borrowing similar equations from existing HSI models, or by producing a unique suitability equation that used information on parameters provided by existing literature. Figure 35 illustrates the sequence of building blocks used to produce the HSI models.

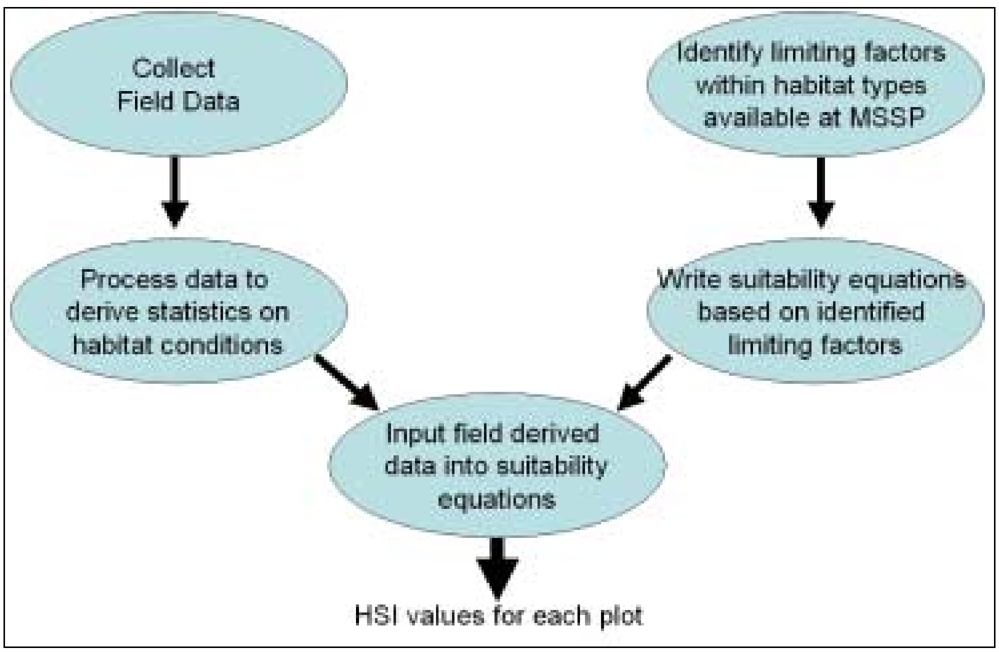

Figure 35. Sequence of steps used to produce HSI models.

Once the suitability index values were calculated for each plot, we input the results into the corresponding HSI equations for each habitat use for each species. The HSI equations are a simple multiplicative function whereby less than optimal ratings in more than one suitability index combine to decrease the overall suitability value. The HSI outputs were calculated on a plot-by-plot basis.

To extrapolate the HSI values from the plot scale to a greater landscape context, we used an inverse distance weighted interpolation (IDW) approach, similar to the methods used above to describe the vegetation attributes associated with the survey plots. IDW interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is an inverse function of distance. The surface being interpolated derives from a locationally dependent variable (in this case, our survey plots). The end result is a spatially continuous assignment of the interpolated variable whereby regions of similarity, based on the input variable, can be distinguished. For our use IDW was an effective way to objectively identify larger areas of connected high habitat suitability, or inversely identify larger areas of low habitat suitability.

All of our models were designed to fit the HSI rating criteria defined by Mahon et al. (2006) which produces HSI variable classes, as described in Table 8. This effectively condenses the continuum of output variables into four meaningful HSI classes.

Table 8. An example HSI rating interpretation using goshawk (from Mahon et al., 2006).

HSI Ratings	Class	Interpretation
0 - 0.249	Nil	Unsuitable. Condition fails to provide minimum requirements.
0.250 - 0.499	Low	Suitability Unknown. Condition of variable provides theoretical minimum requirements, but use by goshawks is unknown or rarely observed. Goshawks are not normally expected to use attributes in these conditions, but may do so if that is all that is available.
0.500 - 0.749	Moderate	Suitable. Suitability is lower than optimal conditions but exceeds minimum requirements. A small proportion of use by goshawks is expected to occur in areas with variables in this condition.
0.750 – 1.000	High	Suitable. Conditions at or near optimal (optimal = 1). Majority of use by goshawks is expected to occur in areas with variables in this condition.

It is important to note that these models are not derived from wildlife studies conducted in the park. These are theoretical models built under protocols defined in USFWS ESM 103 based on parameters gleaned from existing literature review and familiarity with the forest conditions in the project area. To predict actual wildlife occurrence and/or habitat use in the project area, additional studies would need to be conducted specifically for each species of concern in the project area.

Habitat Suitability Modeling – Results

Goshawk Habitat Suitability Model – Foraging

Notes on foraging habitat:

Goshawks feed on small mammals and birds occurring in a forest environment (Marshall 1992). While prey availability is the overall factor influencing goshawk use of a habitat and assuming adequate prey density equally distributed across a range of habitat conditions, a goshawk would prefer: a closed canopy (>50% canopy closure); mature to late-successional conifer forest with a large tree overstory (> 100 ft); and open mid and low canopies for flying through (Mahon et al. 2006). The presence of large trees with big branches suitable for landing on and supporting the weight of mature individuals improves habitat suitability (Mahon et al. 2006). As goshawks are known to be very sensitive to human activity, increasing distance away from any developed areas improves habitat quality (Mahon et al. 2006). While goshawks are known to prefer mature to late-successional conifer forests for foraging, other habitat types may be used while foraging, including non-forested habitats where prey occur (Mahon et al. 2006). Figure 36 contains photos of good goshawk foraging habitat in Mount Spokane State Park.

Figure 36. Photos of good goshawk foraging habitat in the project area at Mount Spokane State Park.

Goshawk Foraging Model:

The following equations were used to calculate the foraging habitat suitability ratings for goshawk in Mount Spokane State Park (see Appendix H for further information on the habitat elements used to calculate this HSI model):

Foraging Suitability (HSI) = Distance from Development Index * Stand Height Index * Stand Diameter Index * Canopy Closure Index * Shrub Index * VRP Small Tree Index * FRP Small Tree Index * Snag Density Index

All output HSI values greater than 0 and less than 0.3 were automatically converted to an HSI value of 0.3 because all non-developed areas in Mt. Spokane State Park hold a small level of potential use as goshawk foraging habitat.

IDW maps based on the Goshawk Foraging Model:

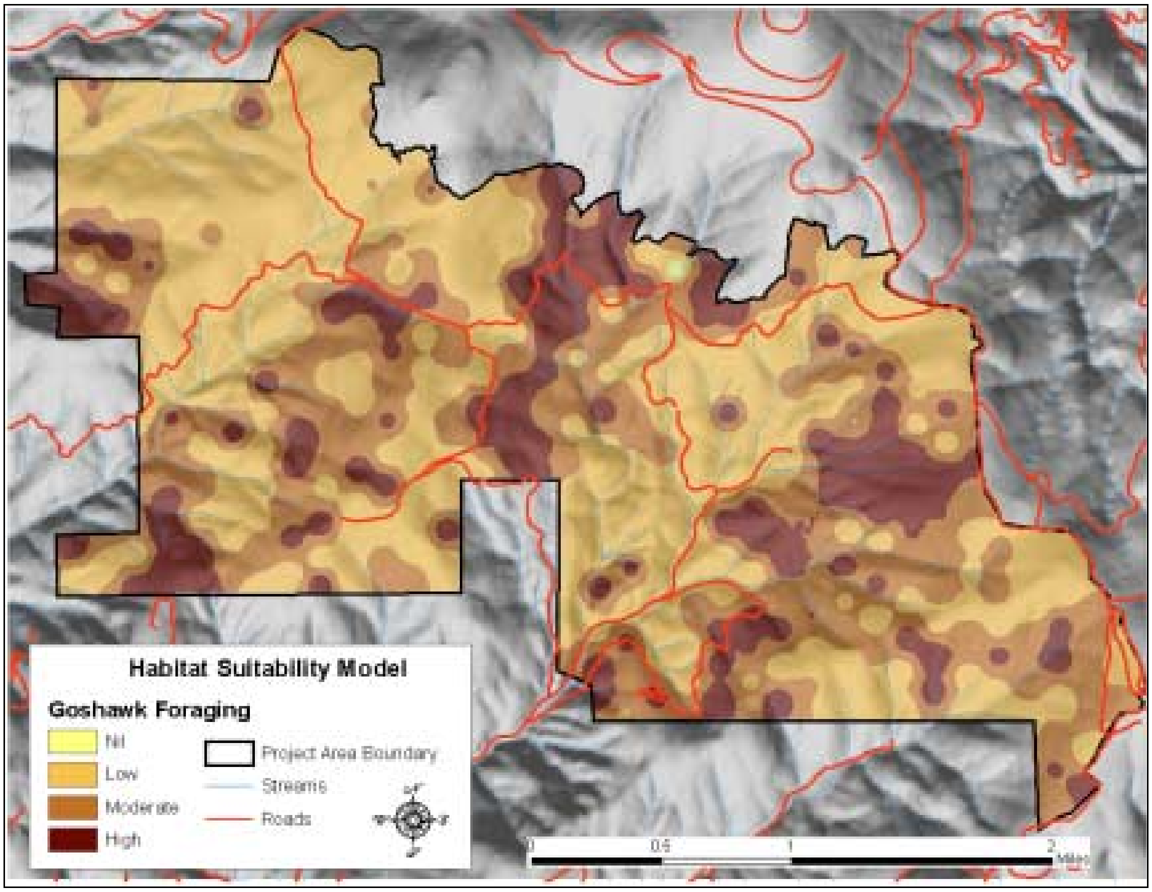

Figure 37. Map of the resulting IDW grid based on the HSI results for the goshawk foraging model (see Table 8 above for HSI ratings associated with habitat suitability classes).

The results of the goshawk foraging model are displayed in Figure 37. Approximately half of the survey area is modeled as having moderate to high foraging habitat suitability for goshawks, although some of these areas are small isolated patches. Based on this model it is probable that the project area would be used by foraging northern goshawks.

Goshawk Habitat Suitability Model – Nesting

Notes on Nesting Habitat:

Goshawks require large trees situated in closed canopy mature or old-growth forests for nesting (Mahon and Doyle 2003). Typically trees with large branches are selected for nesting, and many nests occur in the lower third of the tree canopy (Desimone and Hayes 2003). The presence of other large trees surrounding the nest tree seems to be important for goshawk nesting habitat (Desimone and Hayes 2003). Goshawks avoid nesting near forest edges caused by human or natural disturbances (Mahon et al. 2006). The availability and proximity of snags for use as plucking posts contributes to nesting habitat (Marshall 1992). Slopes with steepness greater than 40% seem to be avoided for nesting purposes (Mahon et al. 2006). Clear flight ways in the low and mid-canopy are required for good nesting habitat (Mahon et al. 2006). Figure 38 is provided by Mahon et al. (2006) as an example of good Goshawk nesting habitat. Figure 39 contains photos of good goshawk nesting habitat in Mount Spokane State Park.

Figure 38. Example of good Goshawk nesting habitat (from Mahon et al. 2006).

Figure 39. Photos of good goshawk nesting habitat in the project area at Mount Spokane State Park

Goshawk Nesting Model:

The following equation was used to calculate the nesting habitat suitability ratings for goshawk in Mount Spokane State Park (see Appendix H for further information on the habitat elements used to calculate this HSI model):

Nesting Suitability (HSI) = Stand Height Index * Stand Diameter Index * Canopy Closure Index * Shrub Index * VRP Small Tree Index * FRP Small Tree Index * Snag Density Index * Slope Index * Distance from Forest Edge Index

IDW maps based on the Goshawk Nesting Model:

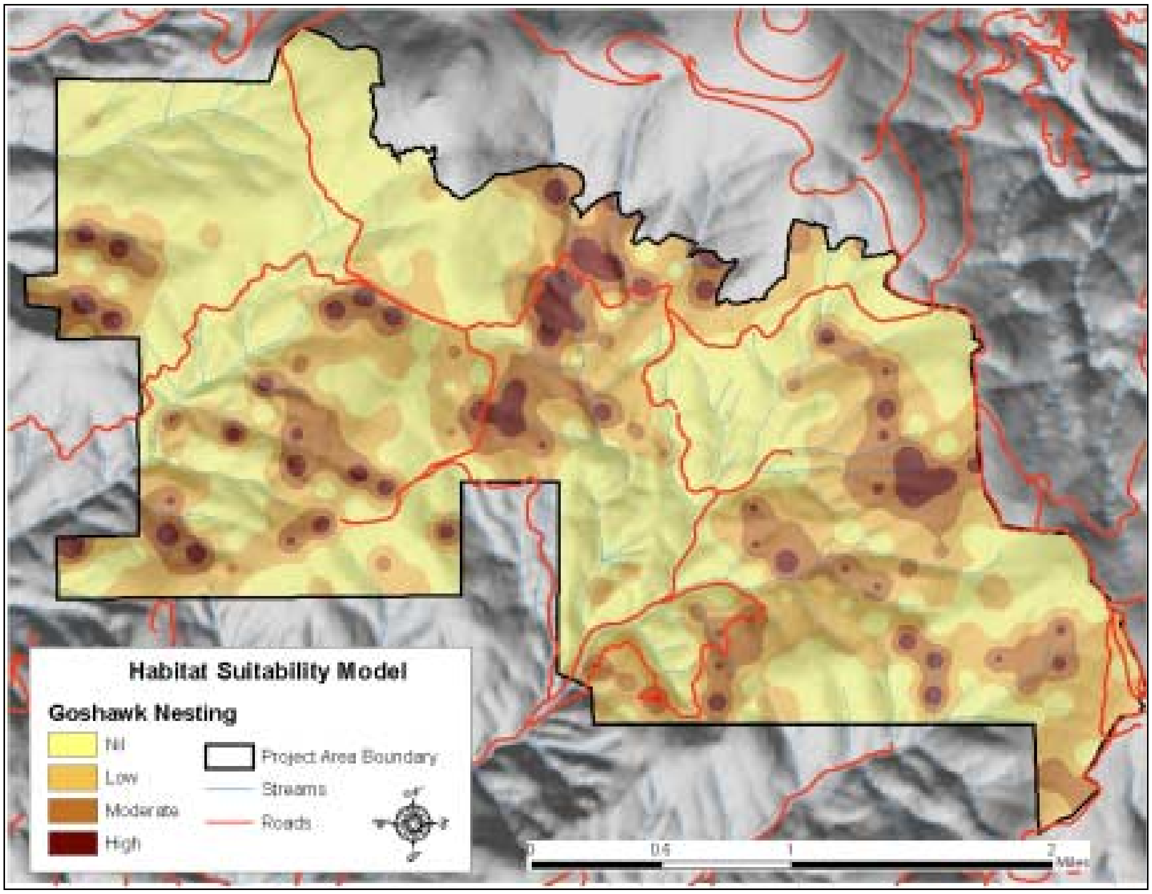

Figure 40. Map of the resulting IDW grid based on the HSI results for the goshawk nesting model.

The results of the goshawk nesting model are displayed in Figure 40. Approximately twenty percent of the survey area is modeled as having moderate to high nesting habitat suitability for goshawks, however, many of these areas are small patches that may not be large enough to suit goshawk nesting needs. Based on this model it is currently possible that very limited portions of the project area would be used for nesting by northern goshawks. Continued natural succession of some of the mid-aged conifer forest stands in the project area will probably increase the amount of moderate to high suitability nesting habitat over the next fifty years.

Lynx Habitat Suitability Models – Dispersal

Notes on Dispersal Habitat:

Lynx require areas with overhead and horizontal cover, and usually avoid moving through open areas larger than 100 meters (300 feet) in width (Stinson 2000). Lynx often use ridgelines, saddles and forested riparian areas when dispersing and traveling among foraging patches and dens (Stinson 2000). Pole and mature coniferous stands that may not provide optimal hunting or denning cover are important for providing cover for movements from one hunting area to another (Stinson 2000).

Lynx Dispersal Model:

The following equation was used to calculate the dispersal habitat suitability ratings for lynx in Mount Spokane State Park (see Appendix H for further information on the habitat elements used to calculate this HSI model):

Dispersal Suitability (HSI) = Large Openings Score * Topographic Features Score * Developed Areas Score

Maps based on the Lynx Dispersal Model:

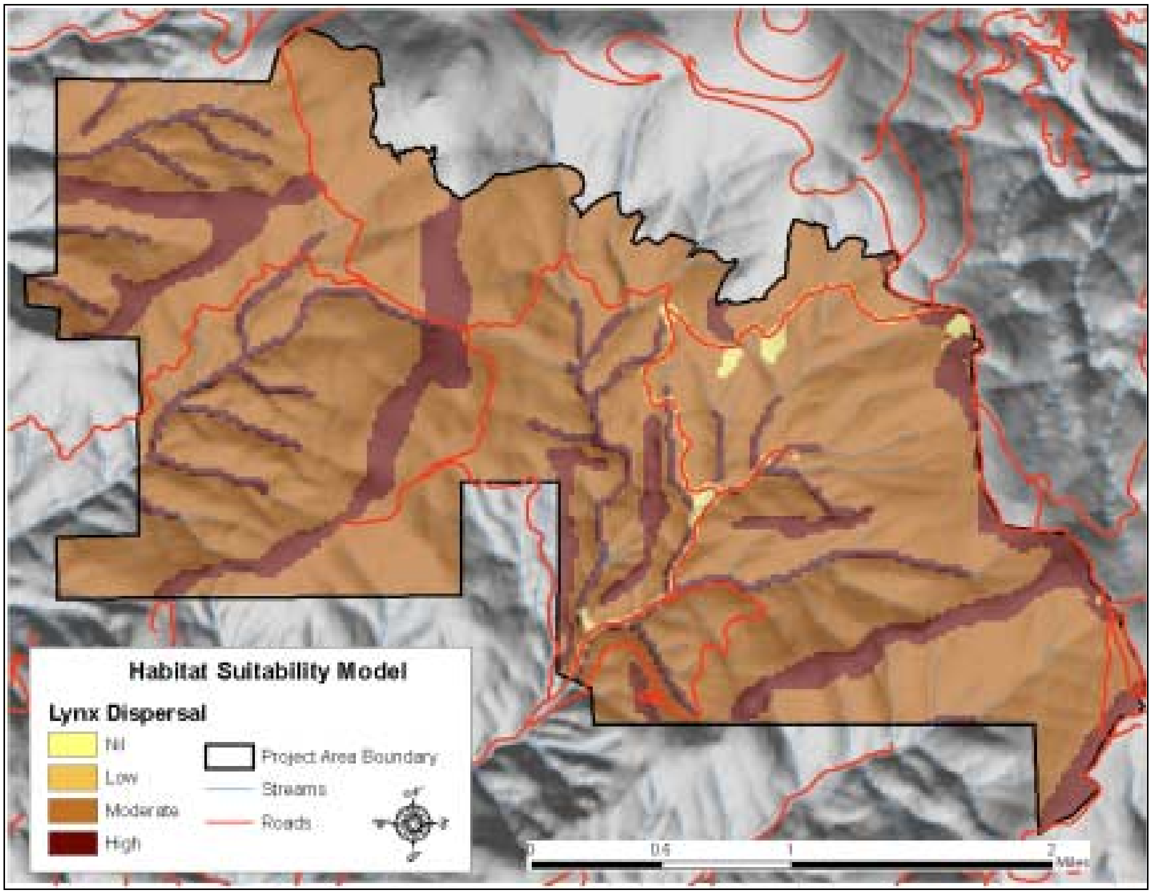

Figure 41. Map of the results of the HSI lynx dispersal model.

The results of the lynx dispersal model are displayed in Figure 41. Most of the project area is considered moderate or high suitability for lynx dispersal under this model. The main access road is the most significant barrier to lynx dispersal, although it is not known whether the road is an actual significant barrier or not. Mainly the road possesses the potential for increased non-natural mortality due to collision with fast moving vehicles.

Lynx Habitat Suitability Models – Breeding

Notes on Breeding Habitat:

Lynx natal den sites in Washington State are found in mature or old-growth conifer stands with high densities of large woody debris where wind-throw and burns build a dense network of fallen logs, creating spaces where kittens can hide (Stinson 2000). Almost all known den sites in Washington are in closed canopy stands with northern facing aspects (Stinson 2000). Figure 42 contains photos of good lynx breeding habitat in Mount Spokane State Park.

Figure 42. Photo of good lynx breeding habitat in the project area at Mount Spokane State Park.

Lynx Breeding Model:

The following equation was used to calculate the breeding habitat suitability ratings for lynx in Mount Spokane State Park (see Appendix H for further information on the habitat elements used to calculate this HSI model):

Breeding Suitability (HSI) = Stand Diameter Index * Coarse Woody Debris Index * Canopy Cover Index * Aspect Score

IDW maps based on the Lynx Breeding Model:

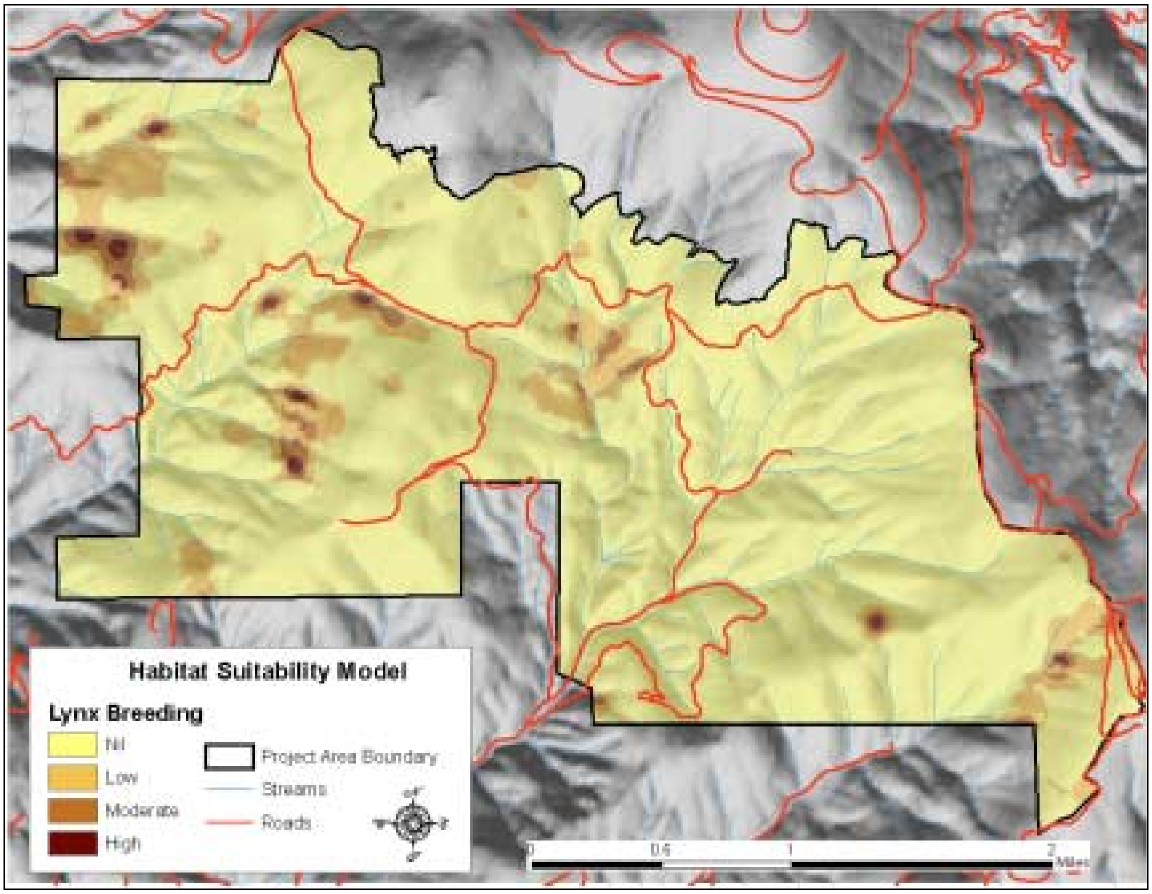

Figure 43. Map of the resulting IDW grid based on the HSI results for the lynx breeding model.

The results of the lynx breeding model are displayed in Figure 43. Most of the project area is not even considered low suitability for lynx breeding under this model. This is because of the lack of suitable coarse woody debris characteristics coupled with the abundance of non-north facing aspects throughout the project area. Continued natural succession of some of the mid-aged conifer forest stands in the project area may help to increase the overall suitability of breeding habitat due to the expected increase of large downed log recruitment associated with the succession cycle.

Lynx Habitat Suitability Models – Non-Winter Foraging

Notes on Non-Winter Foraging Habitat:

Lynx occurrence is strongly correlated with the presence and abundance of snowshoe hares, the lynx's principle prey species (Koehler and Aubry 1994). In the Selkirk Mountains, hare populations are considered relatively stable, albeit low, compared to northern boreal forests. In this region, lynx population density is also lower than in its northern range and lynx hunting and foraging strategies tend to mimic strategies used by northern lynx populations during times of low hare density (Koehler and Aubry 1994). Throughout the year, lynx will focus hunting on snowshoe hares, but in the non-winter months the habitat suitability requirements for hares becomes less restricted and the increased frequency of using alternative prey sources such as squirrels, carrion, mice, and voles expands the types of habitat suitable for lynx foraging (Koehler and Aubry 1994).

The presence of adequate browse drives the occurrence and abundance of lynx prey. High amounts of edible herbaceous and deciduous shrub material and moderate amounts of low to moderate height shrub cover provide the best food and cover to lynx prey in non-winter seasons (Koehler and Aubry 1994). Our model assumes that places that supply the best habitat for lynx prey will provide the best non-winter foraging habitat. Figure 44 contains photos of good lynx non-winter foraging habitat in Mount Spokane State Park.

Figure 44. Photos of good lynx non-winter foraging habitat in the project area at Mount Spokane State Park.

Lynx Non-Winter Foraging Model:

The following equation was used to calculate the non-winter foraging habitat suitability ratings for lynx in Mount Spokane State Park (see Appendix H for further information on the habitat elements used to calculate this HSI model):

Non-Winter Foraging Suitability (HSI) = Prey Browse Index * Prey Hiding Index

IDW maps based on the Lynx Non-Winter Foraging Model:

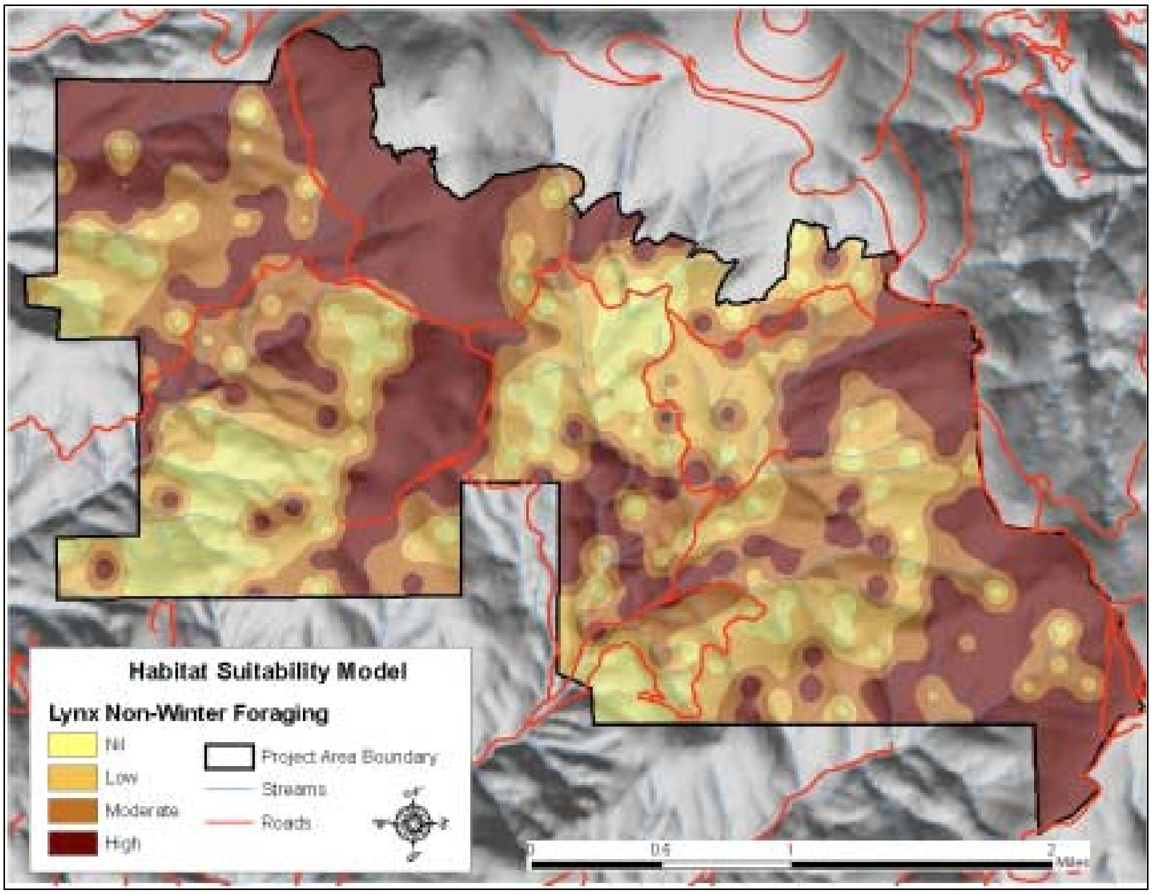

Figure 45. Map of the resulting IDW grid based on the HSI results for the lynx non-winter foraging model.

The results of the lynx non-winter foraging model are displayed in Figure 45. Sixty-five percent of the project area is considered moderate to high suitability for lynx non-winter foraging under this model, and 40% is considered high suitability. It is not known if lynx actually use the project area for non-winter foraging as lynx density in the Selkirk Mountains is known to be relatively low, and dispersal into the project area may be interrupted by habitat conditions on adjacent lands. It is likely that a lynx would use the project area for non-winter foraging should one or more occur in the park, given this model.

Lynx Habitat Suitability Models – Winter Foraging

Notes on Winter Foraging Habitat:

The availability of lynx winter foraging habitat is more restrictive than non-winter habitat because the suitability of habitat for lynx prey is more restrictive in winter. Lynx tend to focus more of their diet on snowshoe hair during the winter (Koehler and Aubry 1994); hence, snowshoe hare abundance and availability drives winter foraging habitat suitability for lynx.

During the winter, snowshoe hares supplement their diets by browsing on small twigs, buds, bark, and conifer needles (Stinson 2000). Conifer cover appears to be an important factor for winter habitat suitability because conifers provide greater concealment from predators, lighter snowpacks, and warmer understory temperatures (Koehler and Aubry 1994). Areas with high densities of small diameter tree and shrub stems (< 2.5 inches in diameter) have been shown to contain the highest abundance of snowshoe hares in winter. However, the small diameter stems must be above the height of the typical winter snow pack to provide habitat suitability to snowshoe hares (Koehler and Aubry 1994). Lynx tend to avoid activities on slopes greater than 40% in winter months (Stinson 2001). Figure 46 contains a photo of good lynx winter foraging habitat in Mount Spokane State Park.

Figure 46. Photo of good lynx winter foraging habitat in the project area at Mount Spokane State Park.

Lynx Winter Foraging Model:

The following equation was used to calculate the winter foraging habitat suitability ratings for lynx in Mount Spokane State Park (see Appendix H for further information on the habitat elements used to calculate this HSI model):

Winter Foraging Suitability (HSI) = Slope Index * Small Tree Index

IDW maps based on the Lynx Winter Foraging Model:

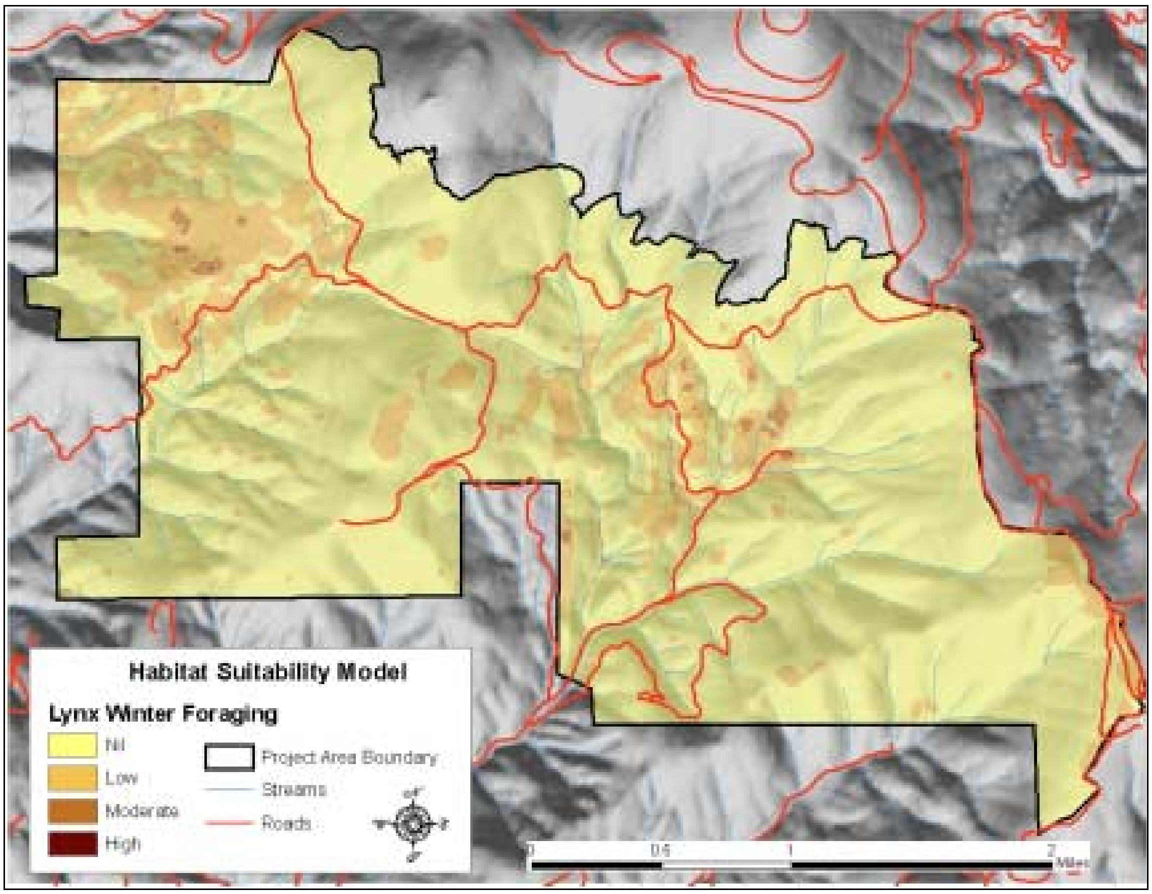

Figure 47. Map of the resulting IDW grid based on the HSI results for the lynx winter foraging model.

The results of the lynx winter foraging model are displayed in Figure 47. This model predicts that the vast majority of the project area is of nil habitat suitability for winter foraging, while a low percentage is of low suitability. One of the main factors reducing habitat suitability for winter foraging is the large amount of steep slopes in the project area. Although some small tree densities exist in certain areas that may support a viable snowshoe hare population, the slope steepness in these areas precludes good habitat suitability for lynx winter foraging. It seems unlikely that lynx would use the project area for winter foraging given this model.

Marten Habitat Suitability Models – Non-Winter Foraging

Notes on Non-Winter Foraging Habitat:

Martens are foraging generalists whose diets in the non-winter months consist of small mammals, carrion, birds, eggs, insects, fruit, nuts, and berries (Buskirk and Ruggiero 1994). Marten rely on conifer forests or mixed deciduous/conifer forests for use as cover while foraging (Allen 1982). Large openings such as large clear-cuts or intensively burned sites are typically avoided, although smaller openings are used as foraging habitat (Allen 1982). The presence of large coarse woody debris, large snags, and understory shrubs increase marten habitat suitability by providing increased habitat conditions for potential prey and browse species while also providing further cover options for an active marten (Allen 1982). Figure 48 contains photos of good marten non-winter foraging habitat in Mount Spokane State Park.


Figure 48. Photos of good marten non-winter foraging habitat in the project area at Mount Spokane State Park.

Marten Non-Winter Foraging Model:

The following equation was used to calculate the non-winter foraging habitat suitability ratings for marten in Mount Spokane State Park (see Appendix H for further information on the habitat elements used to calculate this HSI model):

Non-Winter Foraging Suitability (HSI) = Shrub Cover Index * Coarse Woody Debris Index * Snag Density Index

All output HSI values less than 0.5 were automatically converted to an HSI value of 0.5 because all areas in Mt. Spokane State Park hold at least a moderate level of suitability as marten non-winter foraging habitat. The model is not capable of accurately predicting HSI values lower than 0.5 based on the habitat elements used because the literature used to design the model does not describe any of the project area's existing habitat conditions as being less than moderate suitability.

IDW maps based on the Marten Non-Winter Foraging Model:

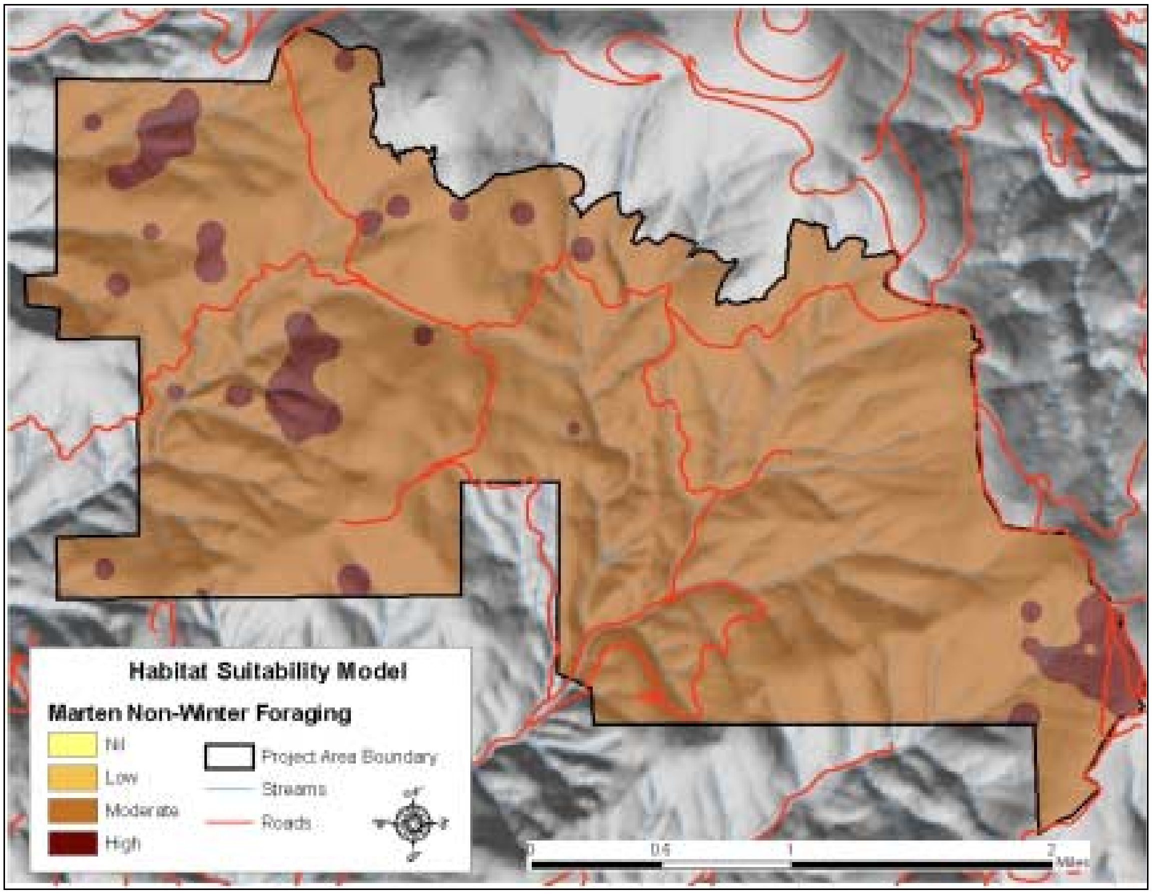

Figure 49. Map of the resulting IDW grid based on the HSI results for the marten non-winter foraging model.

The results of the marten non-winter foraging model are displayed in Figure 49. This model shows only a small percentage of the project area being of high non-winter foraging habitat, although based on our model's design the rest of the project area is of moderate habitat suitability. It is likely that if martens are present in the project area, they would not be limited from using any areas for non-winter foraging.

Marten Habitat Suitability Models – Winter Foraging

Notes on Winter Foraging Habitat:

Marten are active year-round and do not hibernate in the winter. While marten are foraging generalists during the non-winter seasons, food availability and diversity decreases substantially in the winter months forcing marten to become mostly dependent on hunting small mammals (Bull 2000). The presence of coarse woody debris becomes substantially more important to marten foraging success in the winter because it offers opportunities to access subnivean spaces where prey species may occur (Buskirk and Ruggiero 1994). Snags also offer increased opportunity for hunting success as they provide critical wintertime habitat for prey species (Buskirk and Ruggiero 1994). Marten tend to show a stronger avoidance of non-forested areas in the winter (although areas with ample shrub cover may be used) and are more reliant on mature to over-mature forests during the winter months, as these stands provide better thermal cover and habitat conditions for prey species (Allen 1982). Figure 50 contains a photo of good marten winter foraging habitat in Mount Spokane State Park.

Figure 50. Photo of good marten winter foraging habitat in the project area at Mount Spokane State Park.

Marten Winter Foraging Model:

The following equation was used to calculate the winter foraging habitat suitability ratings for marten in Mount Spokane State Park (see Appendix H for further information on the habitat elements used to calculate this HSI model):

Winter Foraging Suitability (HSI) = Big Tree Index * Coarse Woody Debris Index * Snag Density Index

IDW maps based on the Marten Winter Foraging Model:

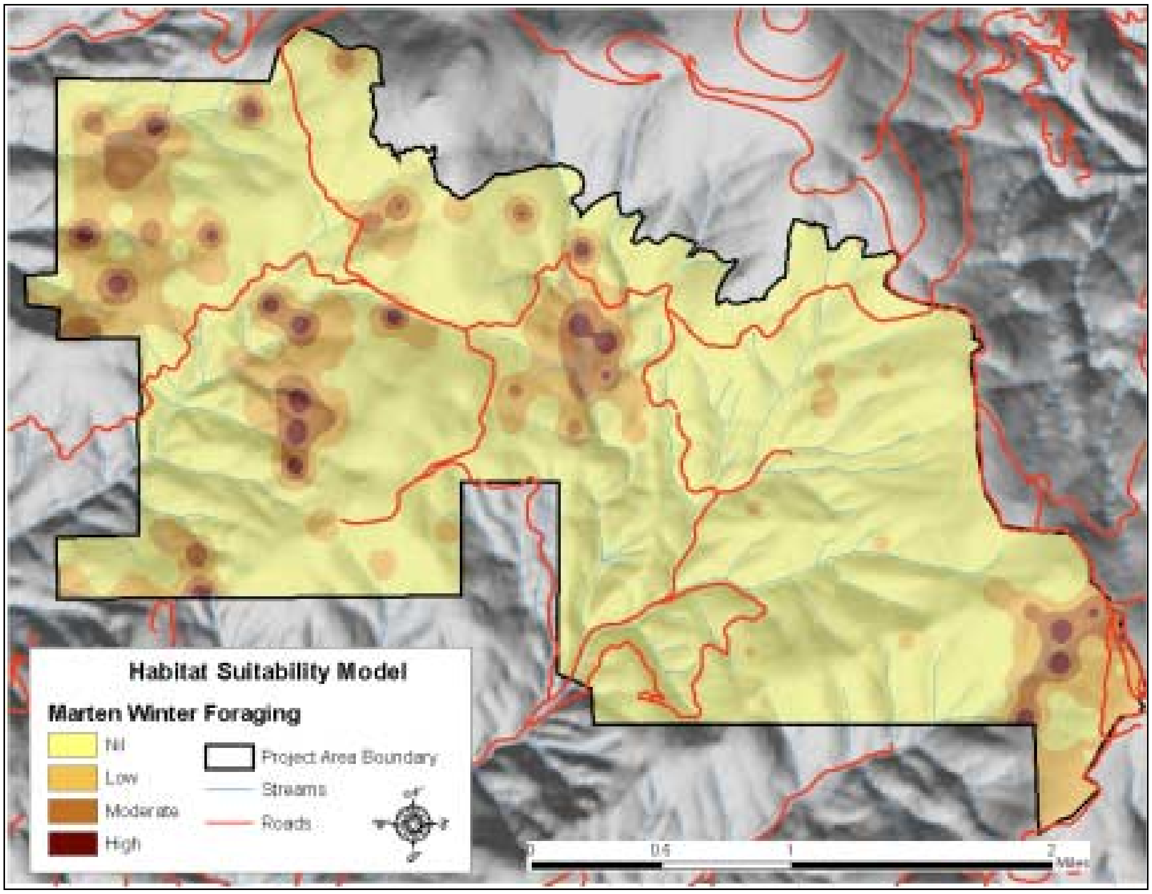

Figure 51. Map of the resulting IDW grid based on the HSI results for the marten winter foraging model.

The results of the marten winter foraging model are displayed in Figure 51. Most of the project area is shown as not suitable for winter foraging based on this model. Some small patches of moderate to high suitability foraging habitat exist, but they are quite small in size and discontinuous from each other, so it is not known if martens would actually use these areas with any regular frequency. Continued natural succession of some of the mid-aged conifer forest stands in the project area may help to increase the overall suitability of foraging habitat over the next fifty years, due to the expected increase of large snag and large downed log recruitment associated with the succession cycle.

Habitat Suitability Modeling – Discussion

As evidenced by the maps provided in the Habitat Suitability Modeling Results section, the landscape in the project area of Mount Spokane State Park contains a wide variation in habitat suitability ranks based on the species being looked at and the particular type of habitat or seasonal use. The park provides large patches of habitat to each of the three species for some uses, but other uses appear to lack any sizable patches of suitable habitat. From a management perspective, the models that depict large patches of suitable habitat indicate that stewardship and forest management activities should look to preserve and enhance the underlying forest characteristics that are providing large areas of quality habitat opportunities. Areas not depicted as having highly suitable habitat for a particular species given a particular habitat use should not be considered poor or bad habitat. It is likely that such areas provide high quality habitat to other species not modeled for, possibly even for critical prey species that the targeted wildlife relies on. The models showing that the majority of the landscape is not highly suitable for a particular species' habitat use are probably a good indication that the particular species is not using the habitat for the modeled use, although because these models are theoretical there is no way to determine actual habitat use trends in the project area without further research and field surveys.

With the results of the HSI models converted into continuous spatial datasets it is possible to begin to see where areas of high suitability coincide between the three species studied. This information can give us a perspective on what regions of the park currently provide habitat that simultaneously supports these three sensitive species. Figure 52 illustrates the relative overlap of habitat suitability ratings between all three species in the park for all modeled habitat uses and seasons (eight models total). Figure 53 illustrates the relative overlap of habitat suitability ratings for the activities each species is most likely to use the project area for (one model for each species – so three models total). Figure 53 is based on the coincidence of goshawk foraging, marten non-winter foraging, and lynx dispersal. These habitat uses were selected as the most likely types based on the higher amount of area predicted as moderate and good habitat suitability according to our models.

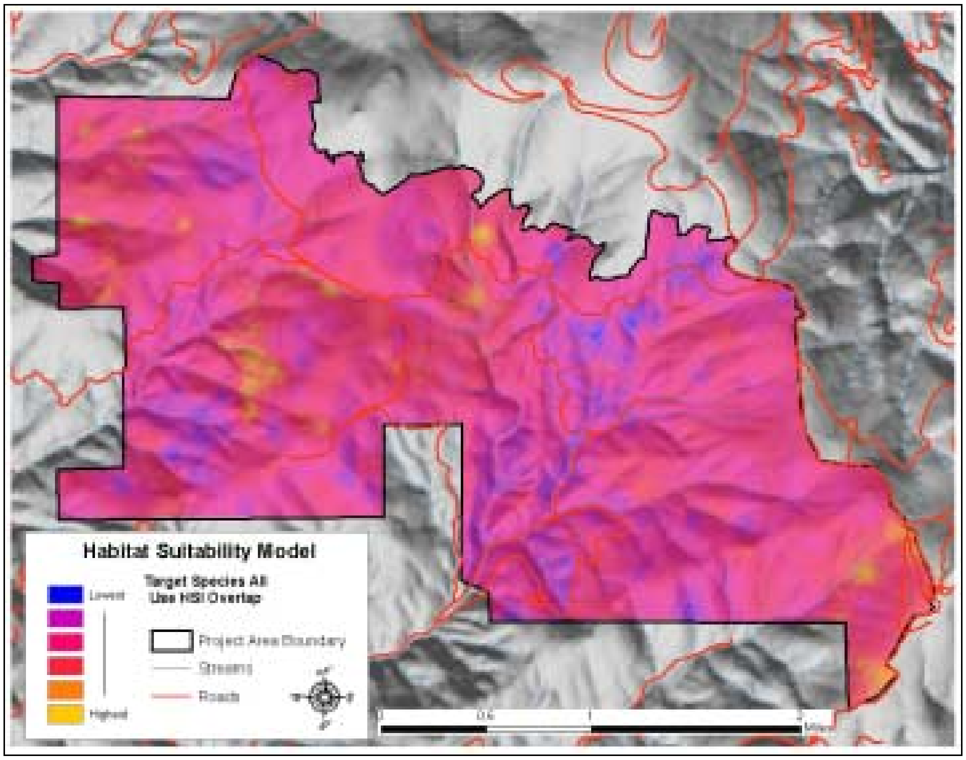

Figure 52. Map illustrating the relative overlap of habitat suitability ratings between all three species and modeled habitat uses and seasons (eight models total).

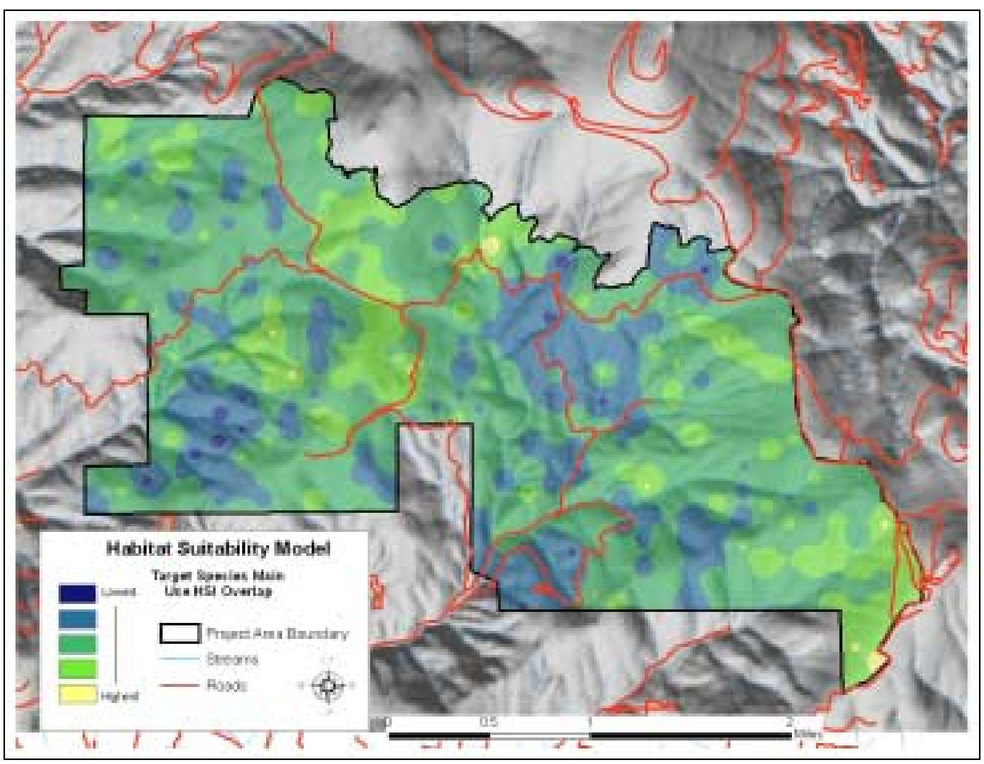

Figure 53. Map illustrating the relative overlap of habitat suitability ratings for the three targeted species based upon the HSI model that represents the most likely type of habitat use each species engages in inside the project area (three models total).

The most important take home message from this analysis is that ***good wildlife habitat for sensitive species does currently exist in Mount Spokane State Park***. Given the protected status of the park versus the surrounding landscape matrix of heavily managed timber lands the significance of Mount Spokane State Park greatly increases in terms of providing habitat for sensitive species. One of the key habitat elements provided for in the project area that coincides to provide good habitat to these three target species is mature to old-growth mixed conifer forests. While historic logging and fires have created a rich mosaic of diverse forest conditions throughout the landscape, there still exists a considerable amount of large patches of mature to late-successional forest. It is unlikely that similar forest conditions exist in the surrounding non-State Park lands; hence from a wildlife conservation perspective, the park should consider these forests as high conservation priorities.

General Review of the Nine Additional Sensitive Wildlife Species

In addition to the more intensive habitat suitability modeling done for lynx, goshawk, and marten, we performed a brief literature search and compiled notes on the habitat needs of nine other sensitive wildlife species known to be present in the greater region. For review, Table 9 lists the names and sensitivity ranks of the nine additional wildlife species evaluated during this project.

Table 9. List of the 9 additional sensitive wildlife species evaluated for in the project area.

COMMON NAME	SCIENTIFIC NAME	CLASS	GLOBAL RANK	STATE RANK	STATE STATUS	USESA
Wolverine	*Gulo gulo*	Mammalia	G4	S1	C	SC
Bald Eagle	*Haliaeetus leucocephalus*	Aves	G5	S4B, S4N		
Golden Eagle	*Aquila chrysaetos*	Aves	G5	S3	C	
Great Gray Owl	*Strix nebulosa*	Aves	G5	S2B	M	
Pileated Woodpecker	*Dryocopus pileatus*	Aves	G5	S4	C	
Black-backed Woodpecker	*Picoides arcticus*	Aves	G5	S3	C	
Townsend's Big-eared Bat	*Corynorhinus townsendii*	Mammalia	G4	S2S3	C	SC
Columbia Spotted Frog	*Rana luteiventris*	Amphibia	G4	S4	C	PS:C
Western Toad	*Bufo boreas*	Amphibia	G4	S3	C	

State Rank Codes
S1 = Critically imperiled (5 or fewer occurrences).
S2 = Imperiled (6 to 20 occurrences), very vulnerable to extirpation.
S3 = Rare or uncommon (21 to 100 occurrences).
S4 = Apparently secure, with many occurrences.
S5 = Demonstrably secure in state.

State Status Codes
T = Threatened. Likely to become Endangered in Washington.
C = Candidate animal. Under review for listing.
"B" and "N" qualifiers are used to indicate breeding and nonbreeding status, respectively, of migrant species whose nonbreeding status (rank) may be quite different from their breeding status in the state

Federal Status Codes
LT = Listed Threatened. Likely to become endangered.
SC = Species of Concern. An unofficial status, the species appears to be in jeopardy, but insufficient information to support listing.

Wolverine

Wolverines prefer alpine grasslands and shrublands, subalpine forests, montane mixed-conifer forests and montane conifer wetland habitats (O'Neil et al. 2001). They are very sensitive to human disturbance and do not tend to co-exist well in areas with sustained human activities (Banci 1994). Large herbivore carrion is an important food source throughout the year (Banci 1994). Denning tends to occur in areas possessing boulder-sized talus (O'Neil et al. 2001).

While the project area provides good over-all habitat conditions for most types of wolverine use, it is unlikely that a resident population occurs in much of the project area due to year-round human activities including hiking, biking, skiing, snowmobiling, wood-cutting, driving, and road maintenance. Wolverines might occasionally use parts of the project area for dispersal and/or feeding activities. Providing habitat for wolverine food sources is a good way to manage for this species in the project area. Currently elk, moose, and deer use the park throughout the year and probably provide scavenging opportunities for wolverine.

Bald Eagle - Roosting

According to the WDFW Fact Sheet on bald eagles in Washington (WDFW, 2001), "habitat needs of bald eagles include timber with large trees near water. In Washington, 97% of nests are within 3,000 ft of a marine, lake or river shore. Large trees along shorelines are important perch sites for foraging. Roost sites are selected that provide a favorable microclimate, such as protection from prevailing winds. Many roosts located near winter food sources are used year after year." (WDFW 2001)

While an assortment of lakes and rivers occur around the base of Mt. Spokane, none of these water features occur within 3,000 ft of the project area. Although good structural habitat conditions for roosting occur in the project area, it is unlikely that bald eagles are perennially using the forests in the project area as a roost site due to the long distance and the probable abundance of quality roosting sites nearer to the water features. The retention of large snags and dead topped trees in the forests of the park should provide good temporary roosting habitat for bald eagles should they choose to travel up to the project area.

Golden Eagle – Roosting and Foraging

Golden eagles are commonly associated with open, arid plateaus deeply cut by streams and canyons, western shrub-steppe and grassland communities and transition zones between shrub, grassland and forested habitat (Watson and Whalen 2003). Nests generally are located on cliffs and are occasionally located in large trees in open areas (Watson and Whalen 2003). During hunting they are often found in alpine parkland, mid- elevation clear-cuts, shrub-steppe areas and open forests.

The project area provides very limited hunting opportunities for golden eagles due to the lack of large open areas. Other parts of Mt. Spokane State Park outside of the project area offer better hunting potential, such as the open meadow summit area of the mountain. Structural elements for golden eagle roosting are provided for in the project area but it is unknown how frequently potential roosting sites are used. Apparently WDFW staff have observed perennial territory use in the Mount Kit Carson area by golden eagles. The retention of the largest trees in older forests, large snags and large dead topped trees should provide good roosting habitat for golden eagles.

Great Gray Owl – Breeding, Foraging, Roosting

Great gray owls prefer areas where mature stands, used for nesting and roosting, exist near open grassy areas, used for foraging (Quintana-Coyer et al. 2004). Great gray owls tend to select nest sites in mature or remnant old-growth mixed-conifer forests near openings (within 600 – 700 feet of openings) that have sufficient prey numbers (Quintana-Coyer et al. 2004). Great gray owls rely on old hawk and raven stick nests or natural depressions on broken-topped snags or stumps for nest sites, or they also nest on natural platforms formed by dwarf-mistletoe (Quintana-Coyer et al. 2004).

Great gray owls typically roost in trees near the trunk. They roost in trees with fairly dense canopies during hot weather and close to the trunk in inclement weather. Foraging habitat throughout the great gray owl's range is relatively open grassy habitats including bogs, natural meadows, open forests and selective/regeneration harvest areas (Quintana-Coyer et al. 2004).

Preferable foraging habitat in the project area seems to be limited, though it may not be limited throughout the park. At the highest elevations in the project area, mature mixed conifer forests occur near open grassy meadows where prey availability is highest. The majority of the project area may provide decent roosting or nesting habitat structure, but these areas are less likely to be used due to the increased distance away from adequate foraging habitat. Conservation of mature and old-growth mixed conifer forests in the higher elevation portions of the project area should help provide nesting, foraging, and roosting opportunities for great gray owls.

Pileated Woodpecker – Breeding, Foraging

The critical components of pileated woodpecker habitat are large snags, large trees, diseased trees, dense forest stands, and high snag densities (Schroeder 1982). Optimum nesting and foraging habitats in Oregon contain sound snags greater than 20 inches dbh at a density of 0.14 snags/acre (Schroeder 1982). Distance from water sources may be a limiting factor in breeding habitat. Pileated woodpeckers depend heavily on carpenter ants (*Camponotus* spp.) and other wood-boring insects for food (Schroeder 1982).

The lack of large snags in some portions of the project area may be a limiting factor to breeding and foraging use. While many portions of the project area do possess an abundance of large snags, historic logging and burning of some portions of the project area has all but eliminated snag availability. Specifically with regards to breeding, large snag availability near adequate water sources should be considered. Creation of snags through intentional tree killing may be warranted in some areas to produce more habitat for pileated woodpeckers.

Black-backed Woodpecker – Breeding, Foraging

The availability of burned areas that are not subjected to salvage logging, and of insect-damaged forests with numerous snags, limits the distribution of the black-backed woodpecker (Lewis and Azzerad 2003). The black-backed woodpecker requires small diameter yet tall trees less than 5 years dead for foraging and breeding (Lewis and Azzerad 2003). Pine beetles *(Dendroctonus* spp.) constitute most of this species diet. Areas with high abundance of larch and lodgepole pine snags less than 5 years dead offer the best breeding and foraging habitats (Lewis and Azzerad 2003).

There are limited patches in the project area offering an abundance of suitable sized lodgepole pine and western larch snags for black-backed woodpecker breeding and foraging, although tree death ages are probably over five years for a majority of the snags currently available. The absence of patches of fire killed trees in the suitable diameter class severely limits adequate habitat availability in the project area. Prescribed burning may in some cases improve habitat availability for black-backed woodpeckers, if enough trees in the desirable diameter classes become snags due to the burn.

Townsend's big-eared bat

Townsend's big-eared bats prefer roosting sites that have little disturbance and have been known to abandon sites permanently when disturbed (Barbour and Davis 1969, Nagorsen and Brigham 1993). They tend to favor riparian vegetation, particularly in areas where the surrounding habitat includes open grasslands (Fellers and Pierson 2002). When foraging, Townsend's big-eared bats tend to avoid open areas however, instead traveling along riparian corridors, hedgerows, and edges of forests (Smith 2000; Fellers and Pierson 2002). Townsend's big-eared bats are primarily cavity-dwellers, with most roost sites located in caves or abandoned mines (Lacki et al. 1994, Sherwin et al. 2000).

No known caves or abandoned mines exist in the project area, so roosting and hibernation most likely don't occur. Preferable foraging habitat is limited due to the lack of riparian habitat near open spaces, although some small patches of foraging habitat might occur.

Columbia Spotted Frog

Columbia spotted frogs are highly aquatic and live in or near permanent bodies of water, including lakes, ponds, slow streams and marshes. They prefer areas with thick algae and vegetation for cover, but may also hide under decaying vegetation. They are most often found in non-woody wetland plant communities (Green et al. 1996).

The lack of availability of the necessary wetland plant communities in the project area is a severe barrier to the occurrence of the Columbia spotted frog.

Western Toad

Western toads appear to seek habitats that include areas with open forest canopies or non-treed openings, with south-facing slopes, that are close to water, and that have a high density of burrows, rocks, or logs that can be used for cover (Bull 2006). The eggs and larvae need shallow areas of ponds, lakes, or reservoirs, or pools of slow-moving streams for development (NatureServe 2006).

Western toad habitat is potentially available in the project area where slow moving streams exist. The use of any habitat available in the project area is undocumented but their occurrence should be considered probable. Upland areas that meet the descriptions provided above should be considered possible toad habitat. Small wetlands and riparian areas that could provide important reproductive habitat for Western toad should be further inventoried for.

Additional Wildlife Considerations

Mapping Important Habitat Elements

Considering the sensitive wildlife species we looked at during this project, and considering our interpretations of forest conditions and habitat elements encountered during our surveys and analysis for this project, we identified CWD and snags to be habitat elements of critical importance for wildlife in the project area (large snags and coarse woody debris are known to be important habitat elements for hundreds of wildlife species occurring in Washington and Oregon [Johnson and O'neil 2001]). Much of the CWD and snags tallied during our plot surveys were of small diameter classes, and we have become concerned about the lack of sufficient large diameter (≥ 12 inches DBH) dead wood in portions of the park landscape. To understand the distribution of large diameter snags and CWD in the project area better we performed a spatial analysis using grids containing our plot data derived via the IDW process (described in the forest condition survey methods section of this report).

We used an Arc/INFO AML (see Appendix J) to analyze IDW grids containing information on snag and log characteristics to locate areas of varying priority for the creation of snags and logs through forest treatments to alleviate deficiencies in these habitat elements. The result of this approach is displayed in Figure 54. The areas that we prioritized for possible creation of additional snags and logs can be linked to intensive historic logging and large stand replacing fires which eliminated the large trees for CWD and snag recruitment, and consumed many of the existing CWD and large snags.

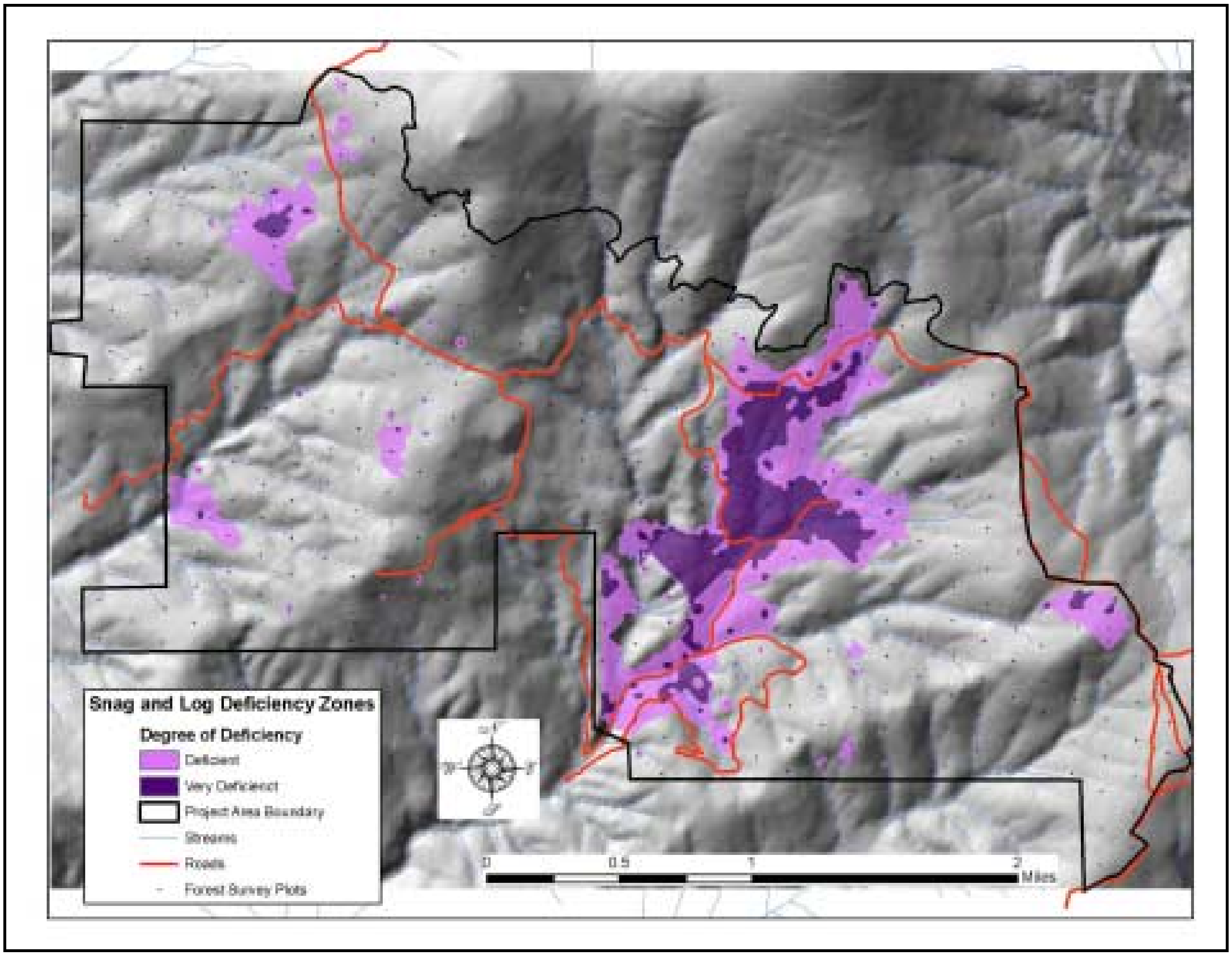

Figure 54. Priority areas for creation of additional snags and logs (CWD) for wildlife habitat structural elements.

Other Habitats of Importance

Some regions of the project area also possess unique habitats that are less common in the project area than the upland mixed conifer forests. The following maps and photos provide a brief review of some of these unique habitats that provide additional habitat features for park wildlife. When considered with the vegetation and wildlife habitat analyses described above, we believe that the project area (with the possible exception of some younger-aged stands near the roadways [areas represented in Figures 52 and 54]) contains a rich mosaic of habitat elements capable of supporting most forest wildlife typical of mid-elevation mountain sites like those found on Mount Spokane.

Non-forested ridgeline meadows

On Linder Ridge, along the east boundary of the project area, small patches of herbaceous meadowlands occur. These meadows are significant features for area wildlife, offering unique hunting and browse opportunities that are rare in the project area, although more extensive meadowlands occur at higher elevations on Mt. Kit-Carson and Mt. Spokane proper. Extensive use of the meadows by elk and deer was noted during our field surveys. Figures 55 and 56 provide graphical examples of the non-forested ridgeline meadows.

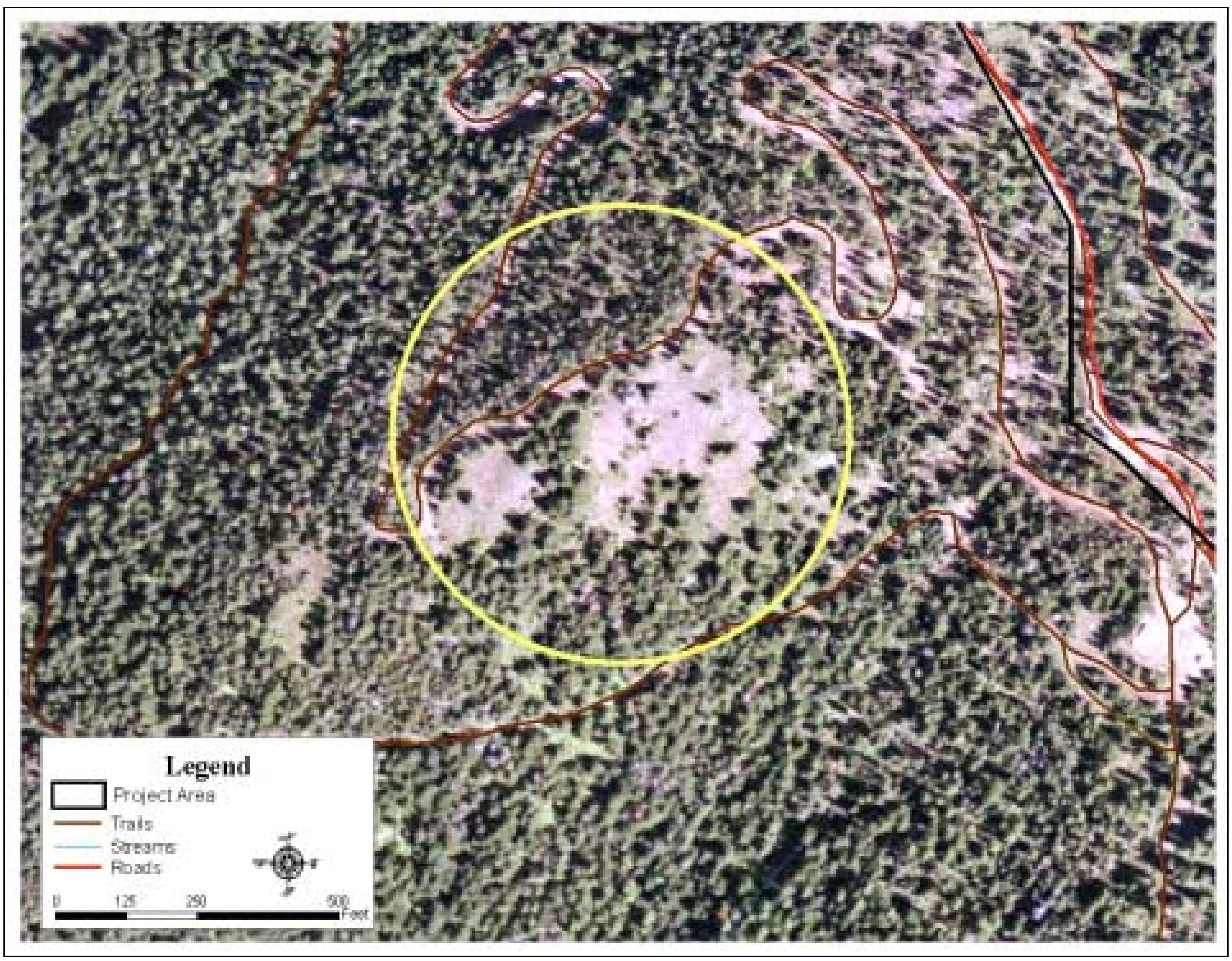

Figure 55. Map showing the location of one of the open meadows occurring along Linder Ridge, south of the Selkirk Lodge.

Figure 56. Photo of an open meadow in the Linder Ridge area.

Deciduous Shrublands

Large patches of deciduous shrub cover that lack significant conifer overstory or regeneration occur in limited locations in the project area. Figures 57 – 60 provide examples of two large deciduous shrublands found in the project area. Two other obvious patches of deciduous shrubland occur along the park's main access road. Extensive use of these shrublands by area wildlife was noted during field surveys. These areas provide unique foraging and cover opportunities to predators and prey alike.

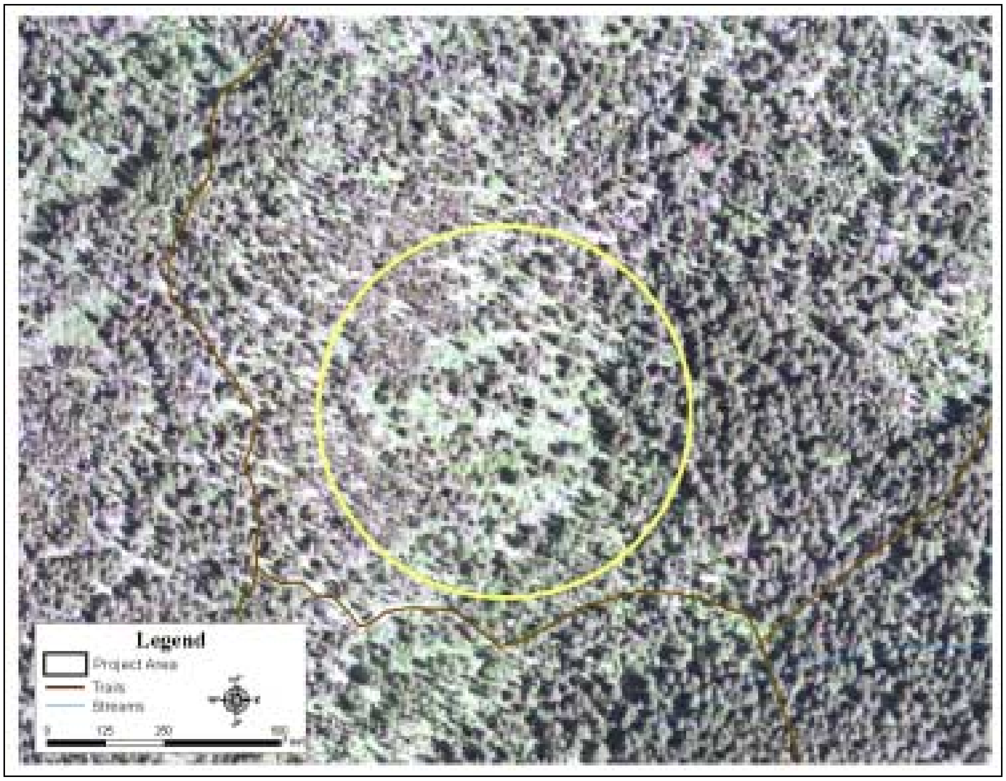

Figure 57. Map of one of the deciduous shrublands occurring in the project area. This particular area showed lots of signs of elk bedding and use.

Figure 58. Photo of the deciduous shrubland depicted in Figure 57.

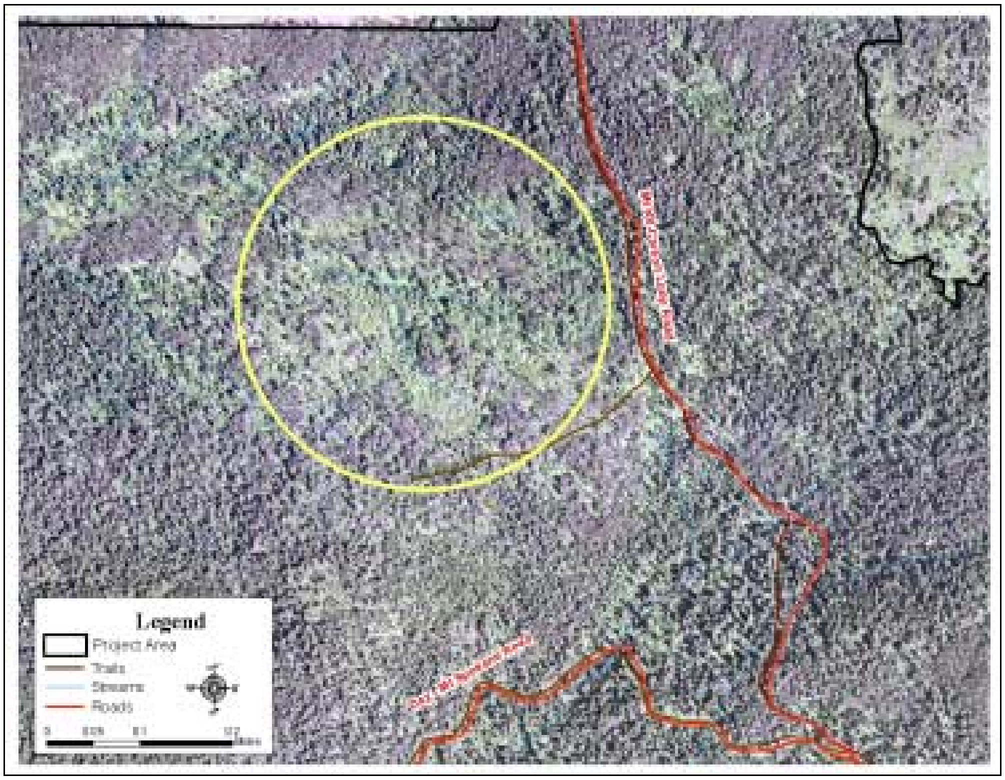

Figure 59. Map showing the location of the extensive shrubland in the northwest section of the project area.

Figure 60. Photo of the extensive shrubland occurring in the northwest section of the project area.

Forested Low-Gradient Headwater Streams

Throughout the lower elevations of the project area, in the matrix of mixed conifer forests that dominant the landscape, forested low-gradient headwater streams can be found that offer unique wildlife habitat for forest dwelling species including possible sensitive amphibians such as the western toad. These areas are typically very wet and have a higher cover of deciduous herbs and ferns than are found in the upland forest environment. Figure 61 provides an example of this type of unique habitat from the project area.

Figure 61. Example of the forested low-gradient headwater streams occurring in the lower elevational areas of the mixed conifer forests of the project area.

Fire Hazard Analysis and Wildfire Modeling

Methods

Overview

To protect and enhance healthy forest habitats in Mt. Spokane State Park while reducing the risk of catastrophic fires, it was necessary to predict fire behavior across the landscape, given the type of fuels and climate found in the assessment area. This section summarizes the methods used to develop refined fire behavior fuel models and predict expected fire behavior for Mt. Spokane State Park. Software used to characterize fire behavior was chosen based on the recommendations of project advisors and on considerations given in Peterson et al. (2007) and Stratton (2006).

To assess fire hazards and fire behavior in the project area it was necessary to engage in a fairly complex analysis of many factors and to use a variety of methods and software products designed to lend insight into various aspects of fire behavior. Each method and software product that we used has its own strengths and weaknesses. We often compared and contrasted results produced by various methods and used our best professional judgment to draw final conclusions. The combined suite of methods provided a sound basis for assessment of fire hazards and the development of prescriptions that incorporate the use of prescribed fire.

To predict how fire will behave under varying conditions, fire behavior modeling requires multiple inputs for the simulated landscape, as well as weather and fuel moisture data that dynamically affect the burning characteristics of fuels. The fuel parameters are contained in a "fuel model" (also called "fire behavior fuel model" or FBFM) that characterizes forest fuels based on their type, size, distribution, surface area, flammability and response to moisture. Each fuel model contains a set of fuel values that can be accessed by fire modeling software.

Originally, there were 13 "standard" fuel models (Anderson 1982). For this project we used a more comprehensive set of 40 fuel models developed by Scott and Burgan (2005), which are referred to here as "Scott and Burgan fuel models" or "dynamic fuel models". The rationale for using the dynamic fuel model set is that: (1) there are more models available; (2) the new models include different climatic characteristics of vegetation and fuels; (3) the new models allow dynamic fire behavior modeling that incorporates changing fuel moisture conditions; and (4) the models are published and integrated in new versions of fire behavior modeling software, thereby avoiding the difficulties of creating custom models from scratch. The only drawback to the Scott and Burgan fuel models is that they haven't had as long a period of use by fire managers to allow understanding of the inherent assumptions in their use.

Our methods for modeling fire behavior for Mt. Spokane State Park required analysis with a number of different software programs. The sequence of fire behavior modeling began by grouping sets of field plots into data sets with expected similar fuel characteristics. These data sets were used to characterize fuels by averaging the values for the amount and distribution of live and dead fuels contained in the different strata of trees, understory, shrubs and herbs.

While our survey crew assigned the forest survey plots to a fuel model in the field, we refined and standardized these classifications based on further data analysis and fieldwork. Fuelbed information was input into the Fuel Characteristic Classification System (FCCS) developed by the Fire and Environmental Research Applications Team of the US Forest Service to develop a "fuelbed", which characterizes the fuel parameters and gives a relative prediction of fire behavior (FCCS version 1.1, Ottmar and Wright 2002). This refined fuel information was used to compare plot fire behavior with that expected for the dynamic fuel models developed by Scott and Burgan. These initial fuel parameters were input into NEXUS version 2.0 fire behavior modeling software (Scott 1999) as a custom fuel model. NEXUS fire behavior predictions for the custom fuel model were compared with other Scott and Burgan fuel models to help classify the custom model into the most similar Scott and Burgan fuel model, based on having similar flame lengths, rates of spread and similar vegetation.

The fire behavior computer software BehavePlus version 3 (Andrews 2003) was used sparingly to confirm the predictions of NEXUS and other programs.

Weather predictions were made using FireFamily Plus version 3.05 (Fire and Aviation Management System Help Desk 2004) to access and summarize online data from remote automated weather stations (RAWS). Extreme weather scenarios were developed based on either reconstructing the weather during extreme fire events or by calculating the highest percentile scores for summer weather at the RAWS. FireFamily Plus was also used to predict the moisture of fine fuels, based on the percentile weather for the most similar RAWS in the area.

Fire mortality predictions were made using the program First Order Fire Effects Model, version 4 (FOFEM, Reinhardt et al. 1997), based on the characteristics of trees in the data sets and other parameters.

The fire behavior predictions were extended across the Mt. Spokane landscape using the programs FARSITE ("Fire Area Simulator") version 4.01 (Finney 1998) and FlamMap version 3 (Finney et al. 2004).

Details of procedures

The following outline summarizes the sequence of procedures described in more detail below.

1. Assess fire history and occurrence in the project area and surrounding landscape
2. Review fire ecology literature and information on forest types
3. Organize plots into sets with similar fuel characteristics
4. Characterize plot sets using FCCS to develop fuelbeds
5. Characterize wind using RAWS online data
6. Characterize 96th percentile temperature and humidity using FireFamily Plus
7. Characterize 98th percentile fuel moistures using FireFamily Plus
8. Characterize weather suitable for controlled burning using FireFamily Plus
9. Characterize fire behavior of plot sets using NEXUS
10. Verify fire behavior predictions using BehavePlus
11. Characterize fire effects using FOFEM
12. Use FlamMap to predict fire behavior characteristics for the entire landscape
13. Use FARSITE to characterize fuel characteristics and predict dynamic fire behavior

1. Assess fire history and occurrence in the project area and surrounding landscape

We obtained fire history and occurrence data from all readily available sources. These sources included data compiled as part of a national effort to compile spatial data for wildland fire and fuel management (Schmidt et al. 2002). We obtained fire history geospatial data from the Washington State Department of Natural Resources GIS website and directly from the DNR fire manager for the northeastern region. We also obtained fire history spatial data from the Colville National Forest and the Idaho Panhandle National Forest. We reviewed this data and made a variety of maps with the data to explore the fire history and occurrence both in the Mt. Spokane project area and in the larger landscape.

We also collected information on fire history and occurrence during our fieldwork at Mt. Spokane. We photographed and recorded information from fire-scarred trees, from stumps with fire scars and from recorded tree origin data (tree age data) from dominant trees in many stands.

We combined all this information to gain a sense of the probable long-term fire history of the project area and used this knowledge to guide our assessment of forest condition and forest health in the project area.

2. Review fire ecology literature and information on forest types

We reviewed literature on the fire ecology of the forest types in the project area. Three documents produced by Forest Service scientists provided substantial insight into the fire ecology of the forest types found at Mt. Spokane (Smith and Fisher 1997, Williams et al. 1995, and Cooper et al. 1991). We also reviewed information contained in Jim Agee's (1993) seminal volume on fire ecology of Pacific Northwest forests.

3. Organize plots into sets with similar fuel characteristics

Data from the forest condition assessment plots was used to determine the values of fuel load variables for sets of plot data.

Plots were grouped into similar sets to aid classification into the most similar Scott and Burgan fuel model. Fuel loads were assessed for each of the strata and fuel types used as input into NEXUS to build a fire behavior model (see Appendix E for details).

In some cases, the initial fuel model classification of plots was changed following analysis of fire behavior. Although all field plots were keyed to a fuel model while in the field, the key in Scott and Burgan (2005) is not quantitative, and it was necessary to successively refine the classification by comparing expected fire behavior and fuel characteristics between the plot sets and the fuel models. For each set of plots, this process involved consideration of over a dozen fuel characteristics, all of which influence fire behavior, and all of which vary their influence with changes in wind, slope and fuel moisture. The fire behavior software helped by reducing many fuel input variables to a few important output characteristics, particularly flame length, fireline intensity, and rate-of spread. Because fire behavior modeling was crucial for classifying plots into fuel models, it was important that fuel characteristics were thoroughly analyzed for accuracy.

All of the fire behavior modeling software used in this project except FCCS is based on the Rothermel (1972) fire spread model. The algorithms used in fire behavior models are too complex for discussion here, except to note that the use of desktop computer software allowed processing large amounts of fuel data that would otherwise have to be evaluated qualitatively. However, there is no computer program that can replace the human experience factor. Therefore, as a check on the reasonableness of our fuel and fire behavior models, we also consulted with fire management specialist, Tom Leuschen, who has both many years of experience and familiarity with fire behavior software.

4. Characterize plot sets using FCCS to develop fuelbeds

Plot sets were characterized using the Fuel Characteristic Classification System (FCCS) (Ottmar et al. 2006) to develop a "fuelbed" (see Appendix E for more details on the use of FCCS). A fuelbed is a detailed type of fuel model and it is defined in the FCCS as "the inherent physical characteristics of fuels that contribute to fire behavior and effects. The Fuel Characteristic Classification System describes fuelbeds in 6 horizontal layers including canopy, shrub, nonwoody vegetation, woody fuels, litter - lichen - moss, and ground fuels. Each layer, or stratum, is further divided into one or more categories to represent the complexity of wildland and managed fuels. A fuelbed can represent any scale that the user considers to be mostly uniform." The fuelbeds developed for Mt. Spokane stands were saved for possible future use in the FCCS program suite.

FCCS was used as the initial tool for characterizing fuelbed characteristics, prior to using other fire behavior modeling programs. FCCS uses a unique, but largely undocumented algorithm for calculating fire behavior characteristics, whereas most of the other programs (Behave Plus, NEXUS, FOFEM, FARSITE and FlamMap) predict fire behavior based on the Rothermel (1972) fire behavior model.

FCCS creates reports of fire behavior and fuel characteristics that were helpful for developing input characteristics for herb and shrub loading for the other fire behavior programs. FCCS reports the fire potential of the fuelbed relative to the Rothermel (1972) fire spread model, using a default slope of 0% and a wind speed of 4 mph, which could not be varied. FCCS was used in this project only for characterizing fuelbeds and successional pathways expected to occur after disturbances or fire suppression.

Plot data sheets were used to develop FCCS fuelbeds. The most important fuel characteristics that affect FCCS calculations include the cover, canopy base height, stem diameter, and number of stems per acre of overstory, midstory and understory trees; cover, height and fuel loads of live herbaceous and woody species; loading of dead woody fuels; presence of ladder fuels, and fuelbed depth. Unlike the Rothermel (1972) model, FCCS fuelbed depth only includes dead woody fuels, and thus conversion between fuelbeds and fuel models required separate, sometimes extensive, calculations.

5. Characterize wind speed and direction for Mt. Spokane using RAWS online data

Weather data are required for input into FARSITE and FlamMap (Stratton 2006). Wind and humidity are important controlling variables affecting fire growth and intensity, the latter largely through its effect on humidity and fuel moistures.

Weather parameters representative of conditions occurring at Mt. Spokane State Park were developed from online data from RAWS. Several approaches were used to model wind and weather. One approach was to model wind based on actual weather during a wildfire, while another approach was to model 96th to 98th percentile summer weather profiles. The 96th percentile was initially chosen as the interval for modeling extreme fire weather because the values were calculated manually from the four extreme weather points in two sets of 50 observations, because it was often difficult to find a weather station with more than fifty consecutive observations. Later on, the extreme weather was changed to the 98th percentile because this was the closest default value provided by FireFamily Plus software.

For modeling weather based on actual fire weather, the extreme fires of Firestorm '91 (October 16 1991) were used. The RAWS used for this were Midnight Mine and Gold Mountain, both of which are close to Mt. Spokane State Park. The wind data from these sites was averaged and used to generate an average hourly circadian wind pattern for use as input into FARSITE. More details on the weather modeling procedures and results are given in Appendix F.

6. Characterize 96th percentile temperature and humidity using FireFamily Plus

Weather modeling was also developed using FireFamily Plus software to characterize climatic data imported from nearby RAWS. There are a number of differences in data availability between the RAWS public internet site and the FireFamily Plus RAWS site. The latter is updated yearly, but does not include the current year's data. The RAWS used with FireFamily Plus are shown in the table in the following section.

Weather variables determined by FireFamily Plus include high and low temperatures, high and low humidity, precipitation, and cloud cover. FireFamily Plus was used to determine 96th percentile weather for six months of summer for the stations listed in Table 10.

The method used to determine the 96th percentile weather began by determining the 4th percentile lowest humidity as the two lowest relative humidity (RH) values in a 50-day sequence of summer weather days. This was determined for five different RAWS. The 4th percentile RH was matched with the high RH of the same day, along with the daily highs and lows of the same days. The 96th percentile summer wind speed was also determined by FireFamily Plus as 14 mph.

FARSITE weather input data requires the time of the daily high and the daily low, as a composite of temperature and humidity. To determine these times, an example circadian weather pattern report was generated from the July 29 and 30, 2003 weather chart for Flowery Trail (see Appendix F).

7. Characterize 98th percentile fuel moistures using FireFamily Plus

Percentile weather was determined for input into FARSITE and FlamMap, using the RERAP procedure (Rare Event Risk Assessment Program) of FireFamily Plus (see Appendix F for default values). The default 98th percentile was used as the closest quantile value to extreme weather values already determined (96th percentile).

8. Characterize weather suitable for controlled burning using FireFamily Plus

FireFamily Plus was used to characterize mild weather and fuel moistures suitable for controlled burning at Mt. Spokane State Park, using the Weather – Climatology command. The same default run parameters were used as before. The evaluation period was chosen as May 1 through June 30 as an example of one option that could be changed if desired. The mean 25th percentile and 75th percentile scores were recorded for the calculated values of mean temperature, RH, Mean RH, Wind Speed, and fuel moisture of 1-hr, 10-hr, 100-hr, herbaceous, and woody fuels. See Appendix F for more details on the results of modeling weather suitable for controlled burning conditions.

9. Characterize fire behavior of plot sets using NEXUS

NEXUS was used in this project primarily as a tool to categorize sets of plots into the most similar Scott and Burgan fuel models based on having similar fire behavior outputs and matching the key to the fuel models. NEXUS was used to predict flame lengths and rates-of-spread of plot data for comparison with the fire behavior of the Scott and Burgan fuel models. See Appendix E for more details on fire behavior modeling with NEXUS.

NEXUS is an Excel spreadsheet application used to predict fire behavior and crown fire potential for different fuel models. NEXUS creates output reports that graphically display the predicted fire behavior for each input fuel model. NEXUS allows input of both standard fuel models and custom fuel models.

Plot data was input into NEXUS as a custom fuel model containing values of fuel parameters averaged from the sets of plots. These values were developed from the Mt. Spokane plot data, based on the fuels characteristics cited in Brown (1974).

Plot data was input into NEXUS using custom fuel model files. Up to four different fuel models could then be specified for comparison of the output charts. Each model used the same set of input parameters for consistency (see Appendix E). The default fuel moisture contents were chosen to be consistent with the "low" moisture fire scenario used by Scott and Burgan (2005). The wind reduction factor (Figure 60) was taken from published values cited in NEXUS for the effect of canopy on wind speed (Albini 1976). The 0.1 wind reduction factor is appropriate for closed canopy stands. When multiplied by a 20 mph wind speed, this factor results in a 4 mph wind speed. For purposes of comparison, we maintained this wind speed for all of the NEXUS runs; however, it is understood that stands in more open areas will experience higher wind speeds.

Canopy Cover	Wind Adjustment Factor
0-5	use table below
5-10	0.30
10-15	0.25
15-30	0.20
30-50	0.15
50-100	0.10

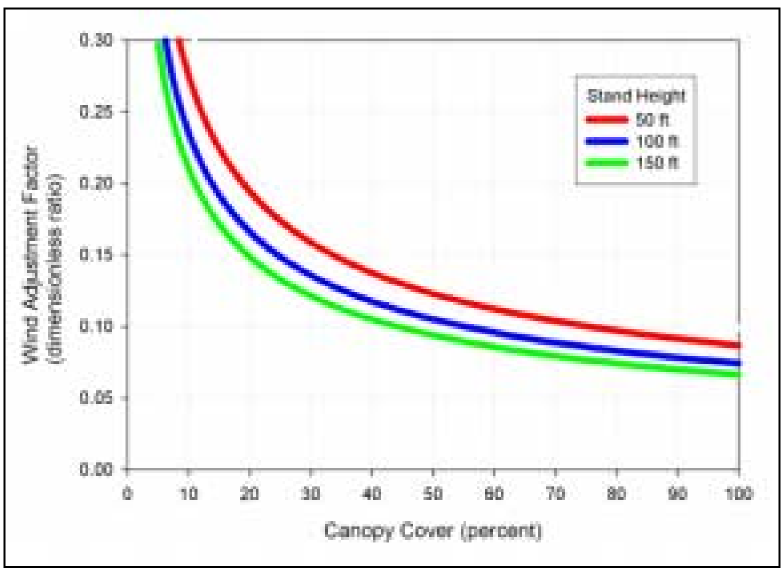

Figure 62. Wind adjustment factors based on canopy cover.

For most NEXUS runs, only the surface fire simulation was used. Once the fire models were determined with NEXUS, other fire behavior parameters and crown fire characteristics were modeled with FOFEM, FARSITE and FlamMap.

Flame length and rate-of-spread were the two main fire behavior characteristics used to classify plots into fuel model sets. See Appendix E for detailed descriptions of the development of fuel models using NEXUS.

NEXUS was also used in developing controlled burning plans, using families of curves created to show the effects of varying fuel moistures (Albini 1976). Controlled burns were modeled based on FireFamily Plus averages for May and June weather, although other seasons could be evaluated relatively easily by changing the simulated weather and fuel conditions. Conditions used for modeling controlled burns were based on average slopes, and desirable wind speeds as follows (see the Methods section for FireFamily Plus for a description of how fuel moistures were determined):

1-hr Fuel Moisture = 9%
10-hr Fuel Moisture = 11%
100-hr Fuel Moisture = 15%
Herb Fuel Moisture = 115%
Woody Fuel Moisture = 125%
Wind Speed = 6 mph
Slope = 10%

The results of modeling controlled burns were further developed using FOFEM (see Appendix E and Appendix I for detailed descriptions of the calculated fire behavior of controlled burning).

10. Verify fire behavior using BehavePlus

BehavePlus is a fire modeling system that describes fire behavior, fire effects, and the fire environment, based on the Rothermel (1972) fire spread model. BehavePlus input was based on the 40 Scott and Burgan fuel models. Output reports were created that graphically display the predicted fire behavior under hypothetical conditions and fuel loads.

The BehavePlus software program has been around for the longest time of any of the programs used in this project, and consequently its usage and limitations are well understood by fire analysts. BehavePlus was used to verify the fire behavior modeling outputs from the other software programs based on the Rothermel (1972) fire spread model. This was done primarily to reduce the likelihood of errors that might arise from transferring data between software programs, each of which has different default values, memory limitations, and output values.

11. Characterize fire effects using FOFEM

FOFEM is a computer program for predicting tree mortality, fuel consumption, smoke production, and soil heating caused by prescribed fire or wildfire. FOFEM was used for predicting tree mortality using flame lengths and fuel models developed from NEXUS for average mild May and June weather and moderate fuel moistures. Mortality predictions were made based on characteristics of tree species of representative plots within the sets of burn units, using flame lengths determined by NEXUS in conjunction with the standardized Mt. Spokane fuel model parameters and mild weather scenarios. Appendix I contains more detailed descriptions of the use of NEXUS.

12. Use FlamMap to predict fire behavior characteristics for the entire landscape

FlamMap was used to determine fire behavior across an entire simulated landscape. Whereas both FlamMap and FARSITE use the same raster input files and can analyze fire behavior across an entire landscape, FlamMap calculates the fire behavior for each input pixel independently, i.e., it is not a dynamic model. The advantage of FlamMap over FARSITE is that it is much faster to run.

The use of FARSITE and FlamMap requires rigorous attention to data quality, along with an understanding of the underlying assumptions used to drive the fire behavior models (Stratton 2006, Keane et al.1998).

Landscape files were created for the greater Mt. Spokane State Park landscape by combining fuel data from the national LANDFIRE program (Rollins and Frame 2006) with the much more rigorously collected and assembled data from our forest surveys in the project area. FARSITE was used to develop a "landscape file" containing a set of 8 co-registered and collinear raster input files based on a combination of LANDFIRE data for the greater Mt. Spokane area and data extracted from our Mt. Spokane forest survey data (Appendix G). Our forest survey data was used in the project area and the LANDFIRE data was used outside the project area. We used the LANDFIRE data to be able model fires that might start outside the project area and spread into the project area, which is a likely scenario. The same set of raster data inputs were used for both FlamMap and FARSITE. A landscape file is a set of pointers to the input files used by FARSITE and FlamMap. Both programs were also run with the same fire weather, fuel moisture, and wind files, when the option for fuel moisture pre-conditioning was enabled.

FlamMap was used to create landscape-level maps of fire-spread rates, flame lengths and crown fire potential for various weather, wind and moisture scenarios. We also analyzed the effects of fuel treatments on these fire behavior parameters and used FlamMap to help predict behavior of prescribed fire in our treatment units.

Two basic weather scenarios were modeled with FlamMap. Summer ("August") weather was modeled to predict wildfire behavior during extreme (96^{th} to 98^{th} percentile) fire weather conditions. Weather conditions referred to as "May-June" predict fire behavior during mild weather suitable for controlled burning. Controlled burning conditions can be thought of as a burn "window" where fuel moistures are neither too wet nor too dry, and wind speeds are enough to help fire burn, but not out of control. Summer 20-foot wind speeds were set at 20 mph. Controlled burning wind speeds were set at 10 mph based on an expected 50% to 90% reduction of wind speed by FlamMap to correct for the effect of forest canopies (Figure 62).

Fire behavior is strongly affected by changes in wind and weather. FlamMap and FARSITE allow fuel moistures to be fixed or to vary hourly during the course of the day, depending on wind and weather. As implemented by FlamMap and FARSITE, variable fuel moistures require at least three days to "precondition" the fuels under a given set of wind and weather conditions to establish initial fuel moistures at the beginning of a run.

Since it was not possible to obtain detailed weather profiles for Mt. Spokane, the fuel moistures developed using FireFamily Plus were used with fixed fuel moistures and these runs were compared with FlamMap runs with variable fuel moistures enabled. See Appendix G for more details on the methods and input data used in our modeling of the project area with FlamMap.

13. Use FARSITE to characterize fuel characteristics and predict dynamic fire behavior

FARSITE was used primarily to develop landscape files for FlamMap, and to validate the output of FlamMap. FARSITE was also used to model of dynamic fire spread across a simulated Mt. Spokane landscape under given environmental conditions. More details of FARSITE input files and methods are contained in Appendix G.

Results

Assessment of fire history and occurrence

From our assessment of fire occurrence and history in and around the project area at Mt. Spokane, we determined that relatively few fires have started in the project area in recent times (Figure 63). The fires that occurred in Mount Spokane State Park did not get very large. The largest fire in the park was a 15.4-acre fire started by a camper in 1999. All other fires in the park remained less than 3 acres in size. Only three fires started in our project area during this time period and the largest was only 0.4 acres in size.

In contrast with this, numerous fires have started outside the park since 1970 to the present time period. Many of these fires exceeded one acre, and one fire burned 720 acres of land. The largest fire recorded close to the project area occurred about 14 miles to the northeast on the Idaho Panhandle National Forest in 1926. The size of this fire was over 16,000 acres.

Other than the information presented above and in the figures below, we were not able to locate any fire history study done at Mt. Spokane or the adjacent area. The closest recorded fire history study was conducted on the Fernan Ranger District of the Idaho Panhandle National Forest about 32 miles to the south east of the project area at latitude 47.42, longitude –116.3. This study was done in a lodgepole pine forest type and recorded 20 fires during the period between 1908 and 1930 (ICBEMP fire study data). A second site, about 36 miles southeast of the project area (lat 47.4, lon –116.25), in western larch, western while pine and western redcedar forests at Deep Creek on the Idaho Panhandle National Forest recorded 3 fires between 1889 and 1919. A third fire history study is recorded on the Sandpoint Ranger District of the Idaho Panhandle National Forest about 38 miles to the northeast of the study area. This study recorded 10 fires between 1910 and 1929. It also occurred in a lodgepole pine forest type. The spatial extent and methods used in these fire history studies is not know, but we assume that they do not reflect fires at one given site. All that we can determine from this data is that fires were frequent during the late 1800's and early 1900's in the region. This is true throughout the west and is due in part to frequent burning during the Euro-American settlement period. The frequency of fires during this period tells us little about the pre-settlement fire history.

We collected limited tree age data and examined fire scars that we found while conducting the forest surveys. This data indicated that fire was very infrequent during the last century, but occurred every 20 to 150 years in presettlement times. Past logging of much of the project area effectively erased much of the tree record of past fires.

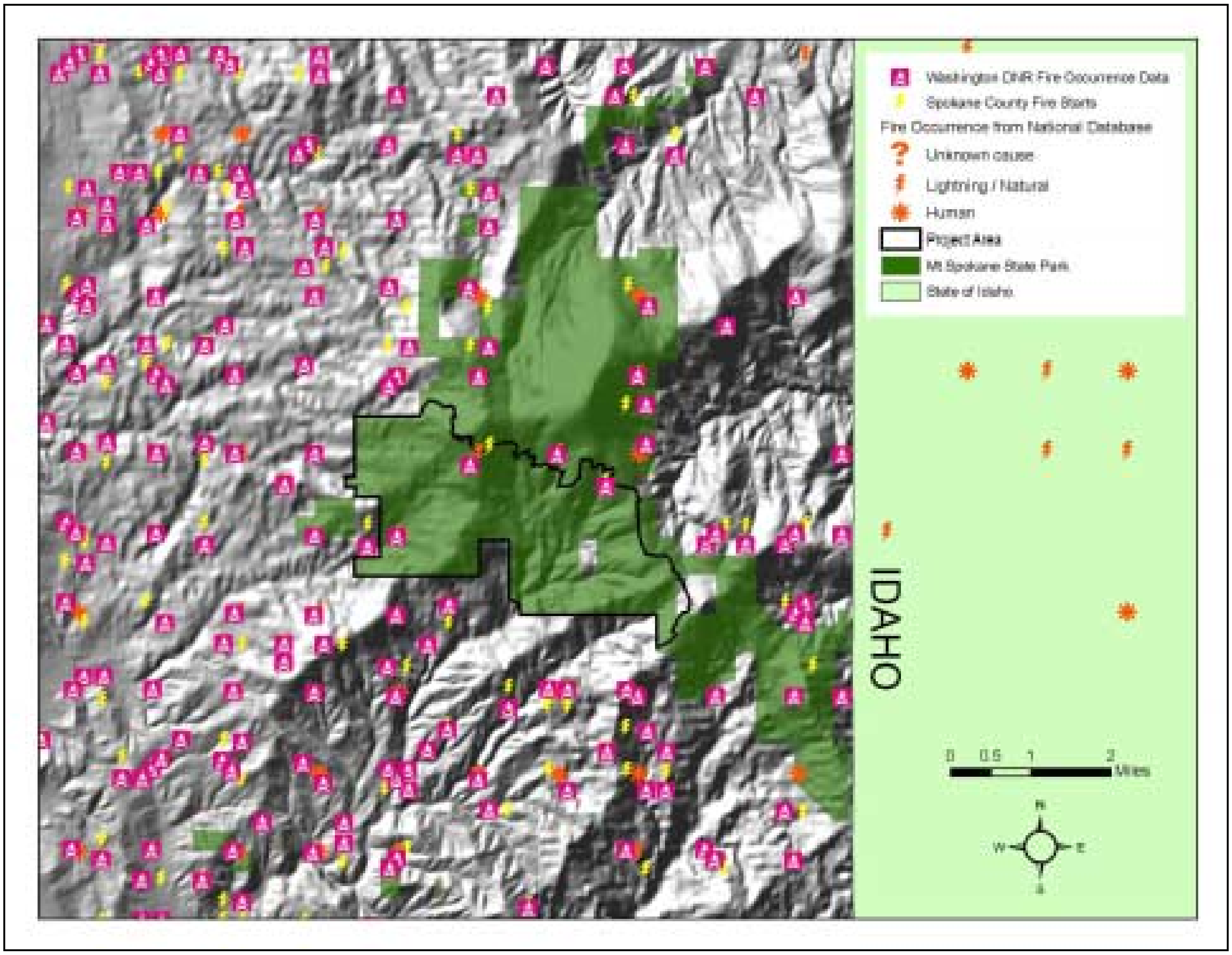

Figure 63. Fire occurrences in the Mt. Spokane vicinity since 1970 from various state and federal databases.

Information gained from review of fire ecology literature

An excellent treatment of the fire ecology of the forest types found at Mt. Spokane is provided by Smith and Fisher (1997). They divided the forest habitat types of northern Idaho into nine “fire groups.” The plant communities we found in the Mt. Spokane project area are fairly similar to some of the habitat types that have been described in northern Idaho (Cooper et al 1991).

The dominant plant communities in our project area are several grand fir associations that Smith and Fisher (1997) group into their Fire Group Seven, which characterizes the fire ecology of moderate and moist grand fir habitat types. In Idaho, this fire group has a highly variable fire regime with fire intervals ranging from 18 year to over 800 years. Most sites where fire history studies were conducted had mean fire return intervals of at least 50 years, with nearly half the sites having mean fire return intervals of over 100 year. Sites in the grand fir mosaic habitat type often recorded no fires and the mean fire return interval is estimated to exceed the life of the seral trees. Fire-related forest succession is usually dominated by Douglas-fir, western larch, ponderosa pine, lodgepole pine, western white pine and grand fir. As succession proceeds grand fir becomes more and more dominant. If fire is excluded from these stands for two to three centuries, the early seral species decline, leaving an old-growth stand of grand-fir and scattered other species (Smith and Fisher 1997).

Also, nearly as common in our project area are several western hemlock plant associations that Smith and Fisher (1997) group into their Fire Group Eight, which characterizes the fire ecology of moderate and moist western hemlock and western redcedar habitat types. This fire group has a mixed-severity fire regime with fire intervals ranging from 4 to 452 years at the study sites that Smith and Fisher review. Most sites have a mean fire return interval over 100 years. Typically, these stands burned erratically, leaving unburned patches and significant surviving trees. Even stand-replacing fires regularly left some large surviving trees, which moderated the microclimate and influenced the composition of the subsequent stand (Smith and Fisher 1997).

The Douglas-fir/ninebark and grand fir/ninebark plant associations that we found in our project area are characterized by Smith and Fisher (1997) in Fire Group Two. This fire group is characterized by more frequent fire, and often, low severity understory burns were common. The mean fire return interval in the study sites that Smith and Fisher examined ranged from 12 to 138 years, with most of the sites having a mean fire return interval less than 40 years. The longer fire return interval sites favored grand fir successional patterns, while the shorter fire return interval sites favored Douglas-fir successional patterns.

Several subalpine forest plant associations that we found in our project area are characterized by Fire Groups Four and Five (Smith and Fisher 1997). Sites in these fire groups have longer return interval fires, with mean fire return intervals often exceeding 100 years. Subalpine fir, lodgepole pine and Douglas-fir dominate forest succession after fire on these sites.

Smith and Fisher (1997) rate the degree of fire resistance of the tree species that we found in the project area. Western larch has the highest level of fire resistance. Both ponderosa pine and Douglas-fir are rated very high. Western white pine, lodgepole pine, grand fir and western redcedar are rated medium. Western hemlock and subalpine fir are both rated as having low and very low fire resistance. They comment that western larch is often able to survive severe crown fires that kill nearly all other tree species.

Williams et al (1995) also provide much useful information about the effects of fire in forested plant associations of the Colville National Forest. This information is applicable to the Mt. Spokane project area and often mirrors the fire ecology interpretations of Smith and Fisher (1997). Between these two publications, there is a wealth of information about the fire ecology of the forest types at Mt. Spokane and fire management implications.

Characterization of Mt. Spokane fuelbeds using FCCS

As described in the methods section of this report, we used FCCS to better characterize fuelbeds associated with individual forest survey plots. Figures 64-69 are screen captures made to illustrate the data input process of fuelbed characterization using FCCS with our Plot 73 as an example.

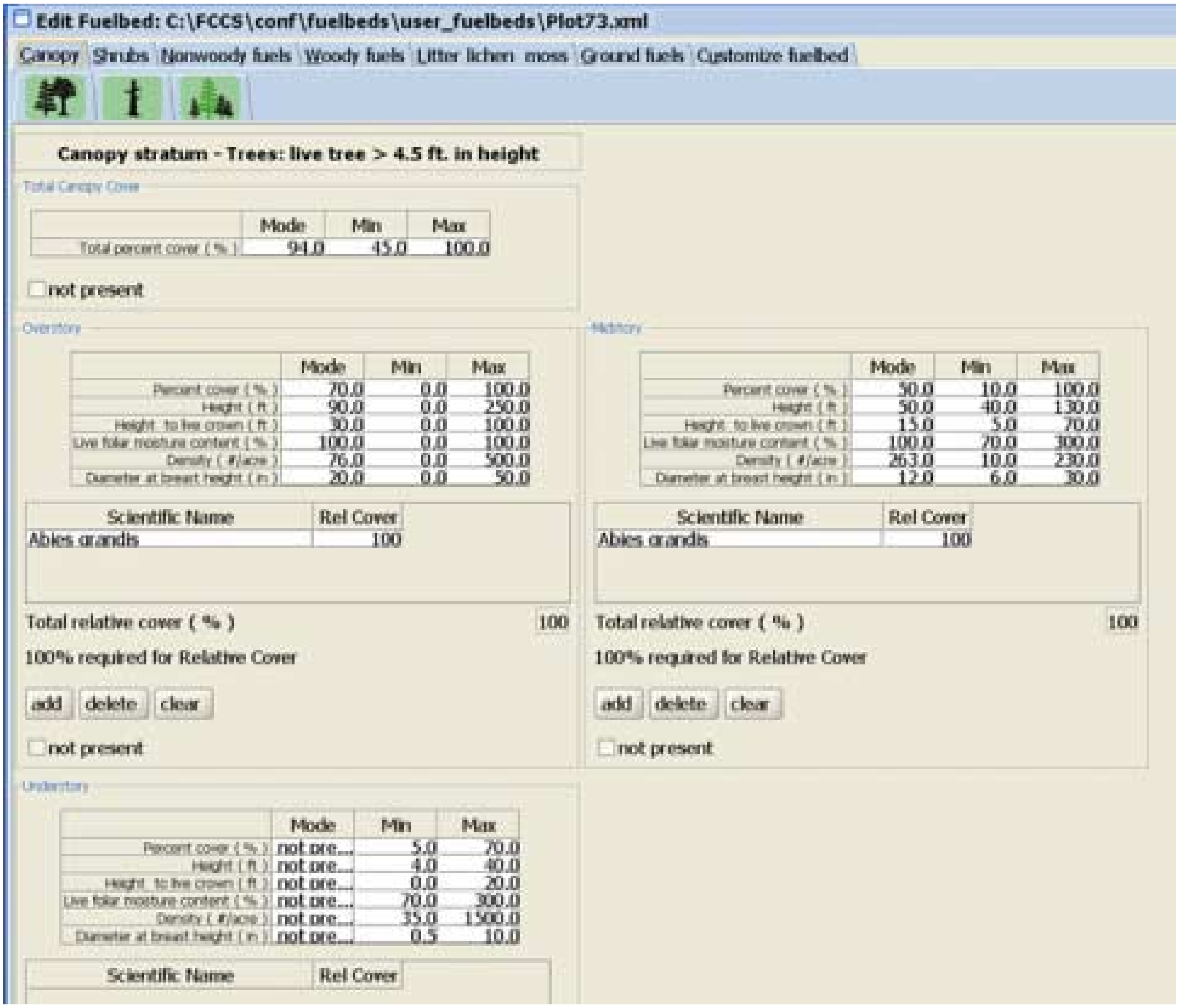

Figure 64. FCCS data input: tree canopy layer for Plot 73.

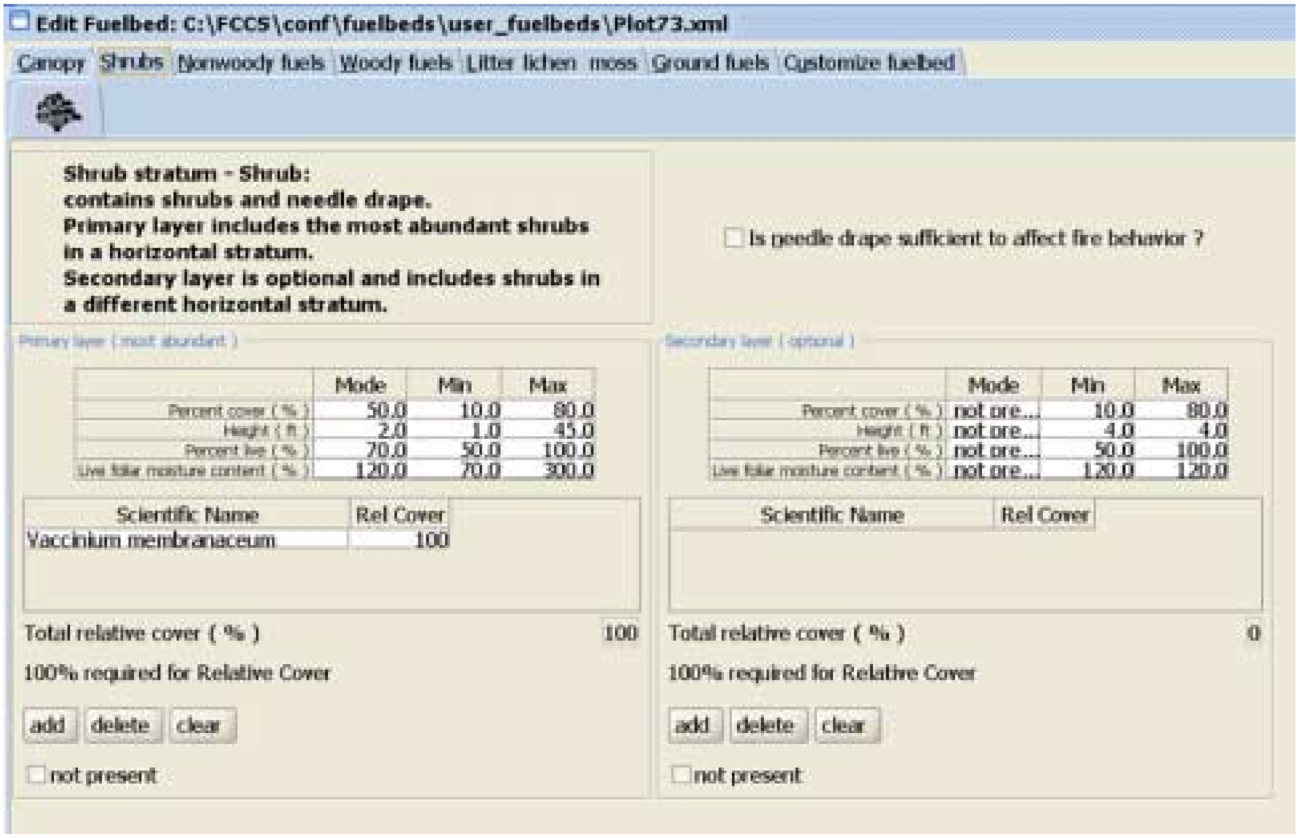

Figure 65. FCCS data input: shrub layer for Plot 73.

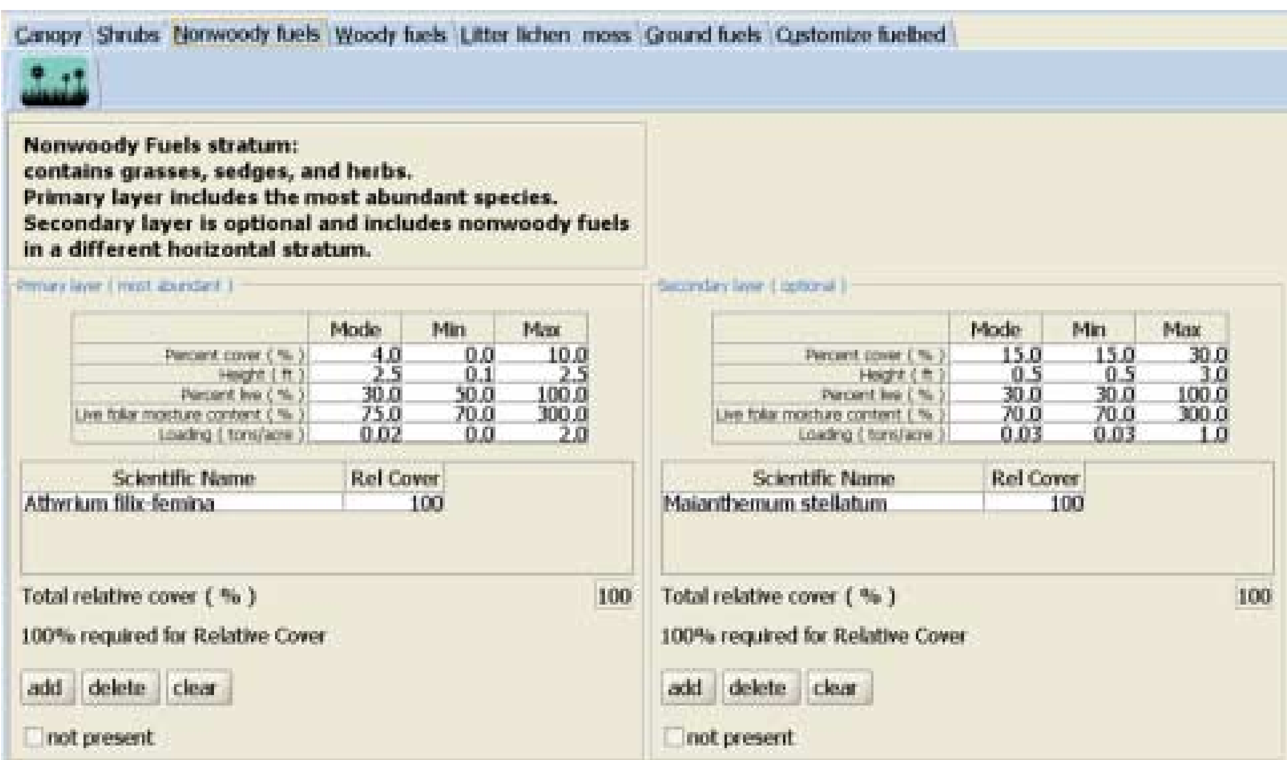

Figure 66. FCCS data input: non-woody fuel layer for Plot 73.

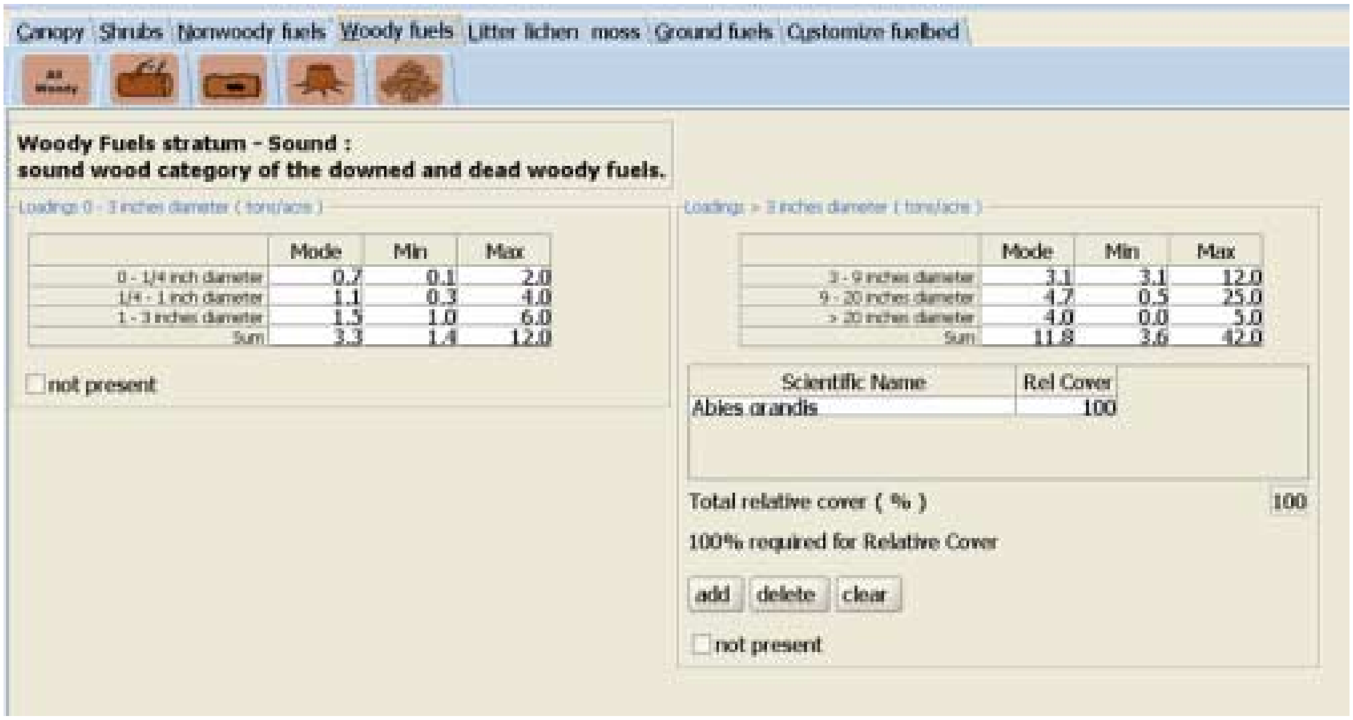

Figure 67. FCCS data input: woody fuel layers for Plot 73 (not shown are input screens for depth, % cover, rotten wood, stumps, piles, jackpots, windrows).

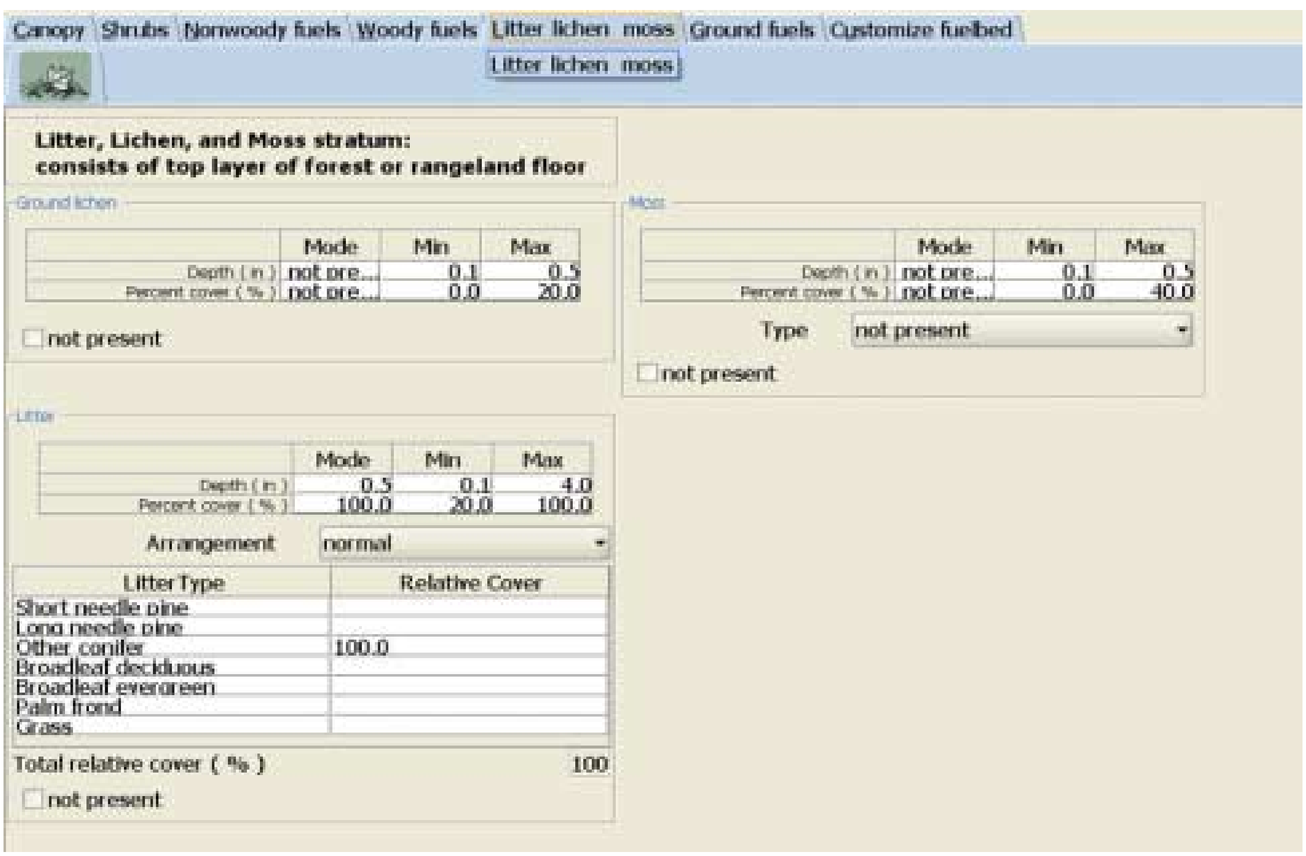

Figure 68. FCCS data input: litter, lichens and moss layer for Plot 73.

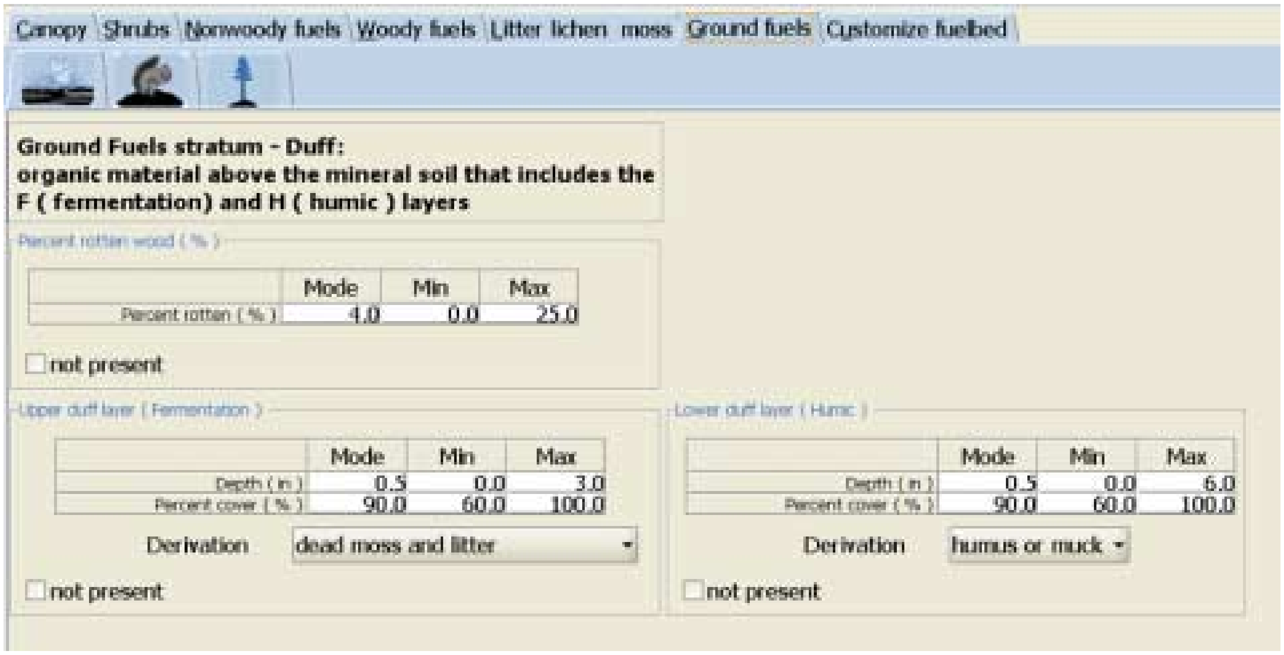

Figure 69. FCCS data input: ground fuels layer for Plot 73 (not shown are squirrel middens and basal accumulation input screens).

Despite the comprehensive approach to characterizing fuels, not all the FCCS output was used in this project. The fire behavior predictions produced by FCCS are a very new feature of the software and have not been verified by experts or empirical data yet. We found that they did not correlate well with output from the other software programs used. Nevertheless, the primary outputs from FCCS on basic fuel loading as a result of a complex fuelbed are useful and can be helpful in developing customized fire behavior fuel models. These outputs are described below.

FCCS fuelbeds were characterized intensively for plots 73 and 82 (and to a lesser extent for other plots) as a means of developing a thorough understanding of the effects of fuels and weather on fire behavior effects on Mt. Spokane. These two plots represent conditions commonly found in forested stands on Mt. Spokane. Plot 73 is a multi-canopy forest of grand fir/thinleaf huckleberry with a cover of 50% thinleaf huckleberry and 19% herbs (common lady fern and starry false lily of the valley), but without many small trees or Douglas maple. Plot 82 is a young grand fir forest dominated by small trees. It has 35% cover of Douglas maple and about 13% cover of mallow ninebark and thin-leaf huckleberry. Both plots represent plant associations and fuel models that are very common in the project area. The results of the FCCS fuelbed characterization of plot 73 are presented in Figures 70 and 71 below.

Fuelbed Number: C:\FCCS\conf\fuelbeds\user_fuelbeds\Plot73.xml					
FCCS GENERAL OUTPUT REPORT					
		Percent cover (%)	Fuel loading (tons/acre)	Fuel area index* (FAI)	Optimum Packing ratio** (Bopt)
Canopy	All	94.0	25.6	63.452	0
	Trees	100.0	17.3	63.403	0.0
	Snags	0.0	8.4	0.049	0.0
	Ladder fuels	0	0	0	0.0
Shrubs	All	50.0	0.7	3.439	3.4387392E-6
Nonwoody vegetation	All	19.0	0	0.165	4.251265E-7
Woody fuel	All	55.0	18.1	1.198	0.13367799
	Sound	0	15.1	0	0
	Rotten	0	3	0	0
Litter/ Lichen/ Moss	All	100.0	1.5	5.51	0.006211155
	Litter	100.0	1.5	5.51	0.0
Ground fuel	All	0.0	11.7	20.661	0.0
	Upper Duff	90.0	3.6	13.223	0.0
	Lower Duff	90.0	8.1	7.438	0.0

* Fuel area index (FAI) is the fuel surface area per unit groud area (dimensionless). FAI represents a fuel combustion environment and provides a starting point for determininng the optimum fuel packing ratio.

** Optimum Packing ratio is the fuel packing ratio in which the fire intensity of fuel has maximum value.

Figure 70. FCCS General Output Report for Plot 73

FCCS Output by Fuelbed - Strata and Categories

Stratum	Category / Subcategory	Percent Cover (%)	Depth - Canopy (ft), others (in)	Height to Live Crown (ft)	Live Foliar Moisture (%)	Density (#/acre)	DBH (in)	Loading Total (tons/acre)	Loading Live (tons/acre)	Loading Dead (tons/acre)	FAI	Packing Ratio	Optimum Packing Ratio
Canopy		94	90.0	0	0	0	0	25.63	17.26	8.37	63.452	0.0026927958	0
	Trees	100	90.0	0	0	0	0	17.26	17.26	0	63.403	6.393574E-4	0.0
	Overstory	70	60.0	30.0	100.0	76	20	12.18	12.18	0	44.755	3.729585E-4	0
	Midstory	50	35.0	15.0	100.0	263	12	5.08	5.08	0	18.648	2.663989E-4	0
	Understory	0	0	0	0	0	0	0	0	0	0	0.0	0
	Snags	0	10.0	0	0	0	0	8.37	0	8.37	0.049	0.0020534385	0.0
	Class 2	0	0	0	0	41	0	8.37	0	8.37	0.049	0.0020534385	0
	Ladder fuels	0	0	0.0	0	0	0	0	0	0	0	0.0	0.0
Shrubs		50	24	0	0	0	0	0.75	0.52	0.22	3.439	6.8774744E-4	3.4387392E-6
	Primary	50	24	0	120.0	0	0	0.75	0.52	0.22	3.439	6.8774744E-4	0
	Secondary	0	0	0	0	0	0	0	0	0	0	0	0
Nonwoody		19	30	0	0	0	0	0.05	0.02	0.03	0.165	1.2488471E-4	4.251265E-7

Strata & Categories Report — Page 1

Figure 71. FCCS Strata and Categories Report (page 1 of 3)

FCCS was also used to examine successional pathways of stands. Successional pathways represent the successional stage of vegetative fuels since the last disturbance in a stand. Successional pathways were used to guide selection of an appropriate fuelbed and they are also useful in predicting the effects of treatments over time. Figure 72 shows an example of successional pathway 023 that we used to develop the fuelbed for forest survey plot 73. Plot 73 is best represented by successional stage 026 or 028 in the diagram below. The successional pathway allows one to visualize and analyze how disturbance and successional processes could affect the forests at this site. See Appendix E for more details on FCCS successional pathways.

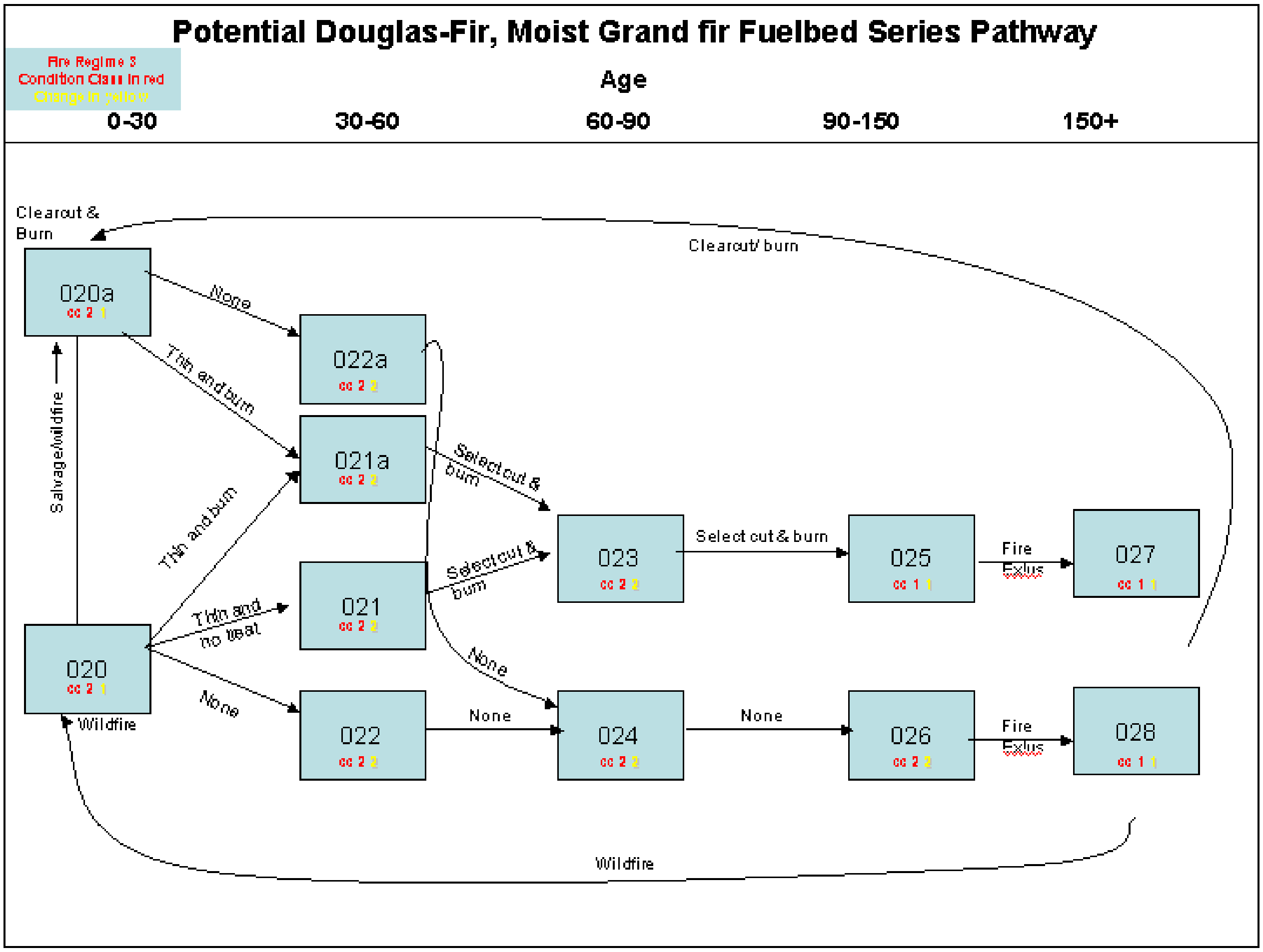

Figure 72. Diagram of FCCS pathway 023

Fuelbed pathways were used to aid the process of determining which fuelbeds to use when characterizing our forest survey plot data. After a pre-developed fuelbed was chosen, we further modified / refined the fuelbed based on the specific data collected at each plot. Plots 73 and 82 were analyzed intensively; while other plots representing the conditions in the project area were assessed more quickly using the FCCS approach.

Characterization of wind speed and direction for Mt. Spokane using RAWS online data

The fire behavior model under extreme weather conditions used wind scenarios modeled after Firestorm '91. The wind speeds of Firestorm '91 (27 mph for several hours) are higher in magnitude than the 96th percentile summer wind speed reported by FireFamily Plus for Flowery

Trail RAWS (14 mph). Firestorm '91 wind speeds are also higher than the FireFamily Plus determination of 98th percentile wind speeds calculated for the Tacoma Creek RAWS (11 mph). This may be due to Tacoma Creek RAWS being located in a more sheltered site.

For fire modeling programs that use a single, uniform wind direction, rather than hourly azimuth data (e.g. FlamMap), the wind was determined to come primarily from 240 degrees azimuth, based on the average wind direction for Firestorm '91 and also considering that the most frequent directions at the other RAWS during the summer were also primarily from the southwest.

Characterization of 96th percentile summer temperature and humidity using FireFamily Plus

The 96th percentile summer weather values determined by FireFamily Plus are listed in Table 10 for the weather stations described.

Table 10. List of FireFamily Plus reports of 96th percentile climate records.

Station	96th percentile wind	4th percentile minimum RH	96th percentile mean RH
Hayden Lake, ID	18	12	40
Hoodoo, ID	12	16	44
Pal Moore Orchard	8	10	32
Tacoma Creek	11	12	32
Midnight Mine	14	11	22

For modeling the hourly circadian weather, the 96th percentile weather values were determined manually as the most extreme 2 out of 50 observations for 5 RAWS (totaling 250 sequential days of summer weather observations). The 96th percentile weather determined this way was 12% for the low RH, 34% for the high RH, 60 degrees for the corresponding low temperature and 99 degrees for the corresponding high temperature. Cloud cover and precipitation were specified as zero.

Characterization of fuel moistures using FireFamily Plus

The FireFamily Plus RERAP procedure (Rare Event Risk Assessment Program) was used to determine the 98th percentile summer fuel moistures by averaging the weather between May and October. The calculations were based on weather from Tacoma Creek RAWS, modified by setting precipitation to match the mean annual precipitation in the project area (40 inches per year) and by specifying the fuel model as a closed canopy forest with normal fuel loads). Results are shown in Table 11 below.

The determination of mild weather conditions suitable for controlled burning was made using FireFamily Plus to analyze 1125 observations taken from the months of May and June only, from Tacoma Creek RAWS, between 1981 and 2006. These values are given in Table 11.

Table 11. FireFamily Plus fuel moistures modeled for Mt. Spokane for 98th percentile summer weather and for weather suitable for controlled burning, extrapolated from 25th to 50th percentile historical May and June weather at Tacoma Creek RAWS.

Fuel type	98th percentile summer weather	Controlled burning weather
1-hr Fuel Moisture	6	9
10-hr Fuel Moisture	12	11
100-hr Fuel Moisture	11	15
1000-hr Fuel Moisture	13	20
Herb Fuel Moisture	27	115
Woody Fuel Moisture	77	125

The 98th percentile fuel moistures calculated for Mt. Spokane correspond to a low to moderate level of fuel moisture using the scenarios given in Scott and Burgan (2005; p. 8).

The average low spring temperature was 41 degrees F; the average high temperature was 67 degrees F; the average low mean RH was 39 percent; the average high mean RH was 88 percent.

Characterization of Mt. Spokane plot sets using NEXUS

NEXUS was used to help classify from the Mt. Spokane project area plots into the appropriate Scott and Burgan (2005) fuel models. This was done by comparing the fire behavior outputs from the plot data with that of the fuel models. The NEXUS output charts of these sets of data were used to compare the fire behavior of different fuel models. This comparison was used to help classify plots into the most similar Scott and Burgan (2005) fuel model and then to develop a map layer for use as input into the spatial fire modeling programs FlamMap and FARSITE. The custom fuel model data developed from Mt. Spokane plot data is presented in Appendix E.

For initial comparisons of plot data with other fuel models, NEXUS was run as a surface fire with the “low” moisture fire scenario of Scott and Burgan (2005), with slope typically set equal to the plot slope, wind speed of 20 mph and a 0.1 wind reduction factor. For analysis of extreme event fire behavior, NEXUS was used with input conditions based on summer 96th percentile weather, summer 98th percentile fuels, and extreme fire weather matching Firestorm ’91.

NEXUS was also used to predict flame lengths for controlled burning conditions for input into FOFEM, FARSITE and FlamMap. Flame lengths were calculated by NEXUS for all of the timber fuel models on Mt. Spokane St. Park, using May-June fuel moistures and weather determined by FireFamily Plus. The results of these calculations are shown in Table 12, and details are given in Appendix E.

Table 12. Results of the NEXUS calculations for controlled burning conditions using 6 mph winds and a 0.1 wind reduction factor. Flame lengths were calculated for 1 mph wind speeds, which is the result of reducing 6 mph wind speeds by a 0.1 wind reduction factor.

Original Fuel Model	Flame lengths (feet)
TL1: low load timber-compact litter (1-2 in deep) or burned forest	0.2
TL2: low load broadleaf timber-litter (1-2 in deep)	0.3
TL3: moderate load timber-litter (w/o coarse fuels)	0.4
TL4: moderate load timber-litter (w/small logs)	0.5
TL5: high load timber-litter (w/o coarse fuels)	0.7
TL7: high load timber-litter (w/large logs)	0.7
TU1: dry, low load timber-understory	0.2
TU2: humid, moderate load timber-shrub	0.9
TU4: dwarf conifer-grass	2.0
TU5: dry, very high load (conifer litter) timber-shrub	1.8

Fire behavior modeling should correspond to actual, typical winds found on Mt. Spokane. Since these were not available during this project, wind and weather conditions were modeled using nearby RAWS. Ideally, burning outcomes should be designed with a target wind speed of slightly more than 5 mph, however higher wind speeds could involve more stringent permit regulations.

Fuel model development relied heavily on NEXUS to characterize expected fire behavior of plots. The initial development of fuel models for Mt. Spokane used Plot 73 as a test example of commonly encountered fuel conditions. To match conditions found on plot 73, the slope was set to 33% and the wind reduction factor was set to 0.1. Wind speed was set to 20 mph. Fuel moisture scenario was set to “low” using the Scott and Burgan (2005) fuel moisture scenarios.

NEXUS determined the surface fire behavior of Plot 73 to be intermediate between that of the two closest fuel models, TU1 (low-load dry climate timber-grass-shrub) and TL3 (moderate load timber-litter without coarse fuels). See Figures 73, 74, 75.

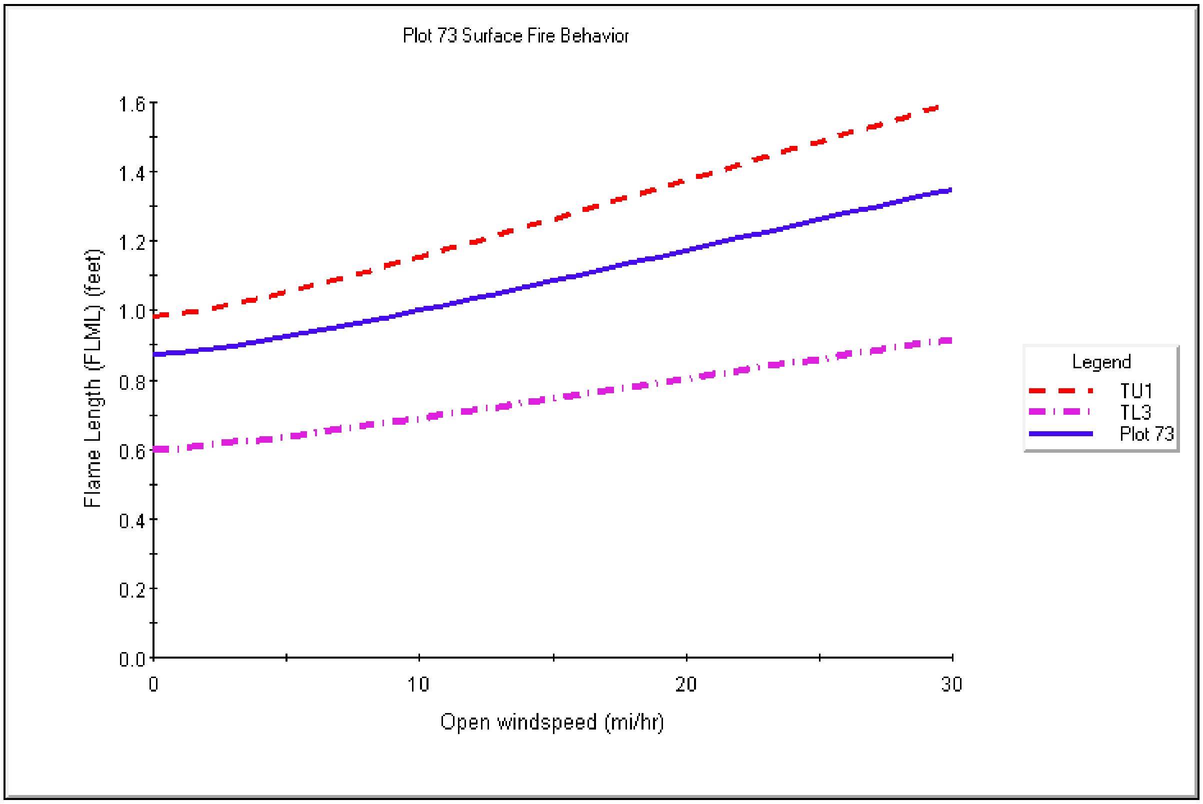

Figure 73. Surface fire flame lengths of plot 73 and other fuel models varied by wind speed (slope = 33%; wind speed reduction factor = 0.1; fuel moisture = low).

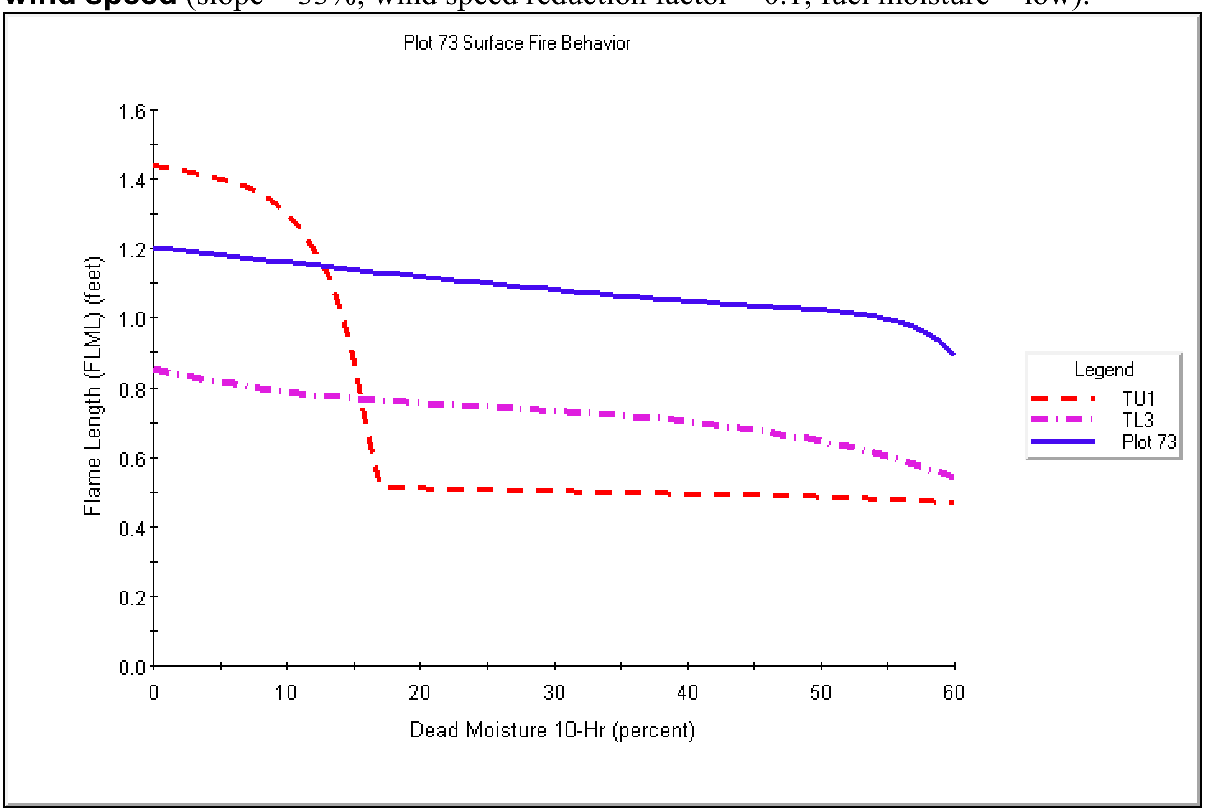

Figure 74. Surface fire flame lengths of plot 73 and other fuel models varied by 10-hr fuel moisture. (slope = 33%; wind speed reduction factor = 0.1; fuel moisture = low).

In addition to flame length, rate of fire spread was the other most commonly used determinant of fire behavior in classifying plots into fuel models. Rate-of-spread results need to be interpreted carefully though, since rate-of-spread is very sensitive to wind speed, and this in turn is dependent on the canopy cover. Using a wind speed reduction factor of 0.1 and a slope of 33%, NEXUS predicted fire-spreading rates for Plot 73 to be almost identical to that of fuel model TL3 (Figure 75).

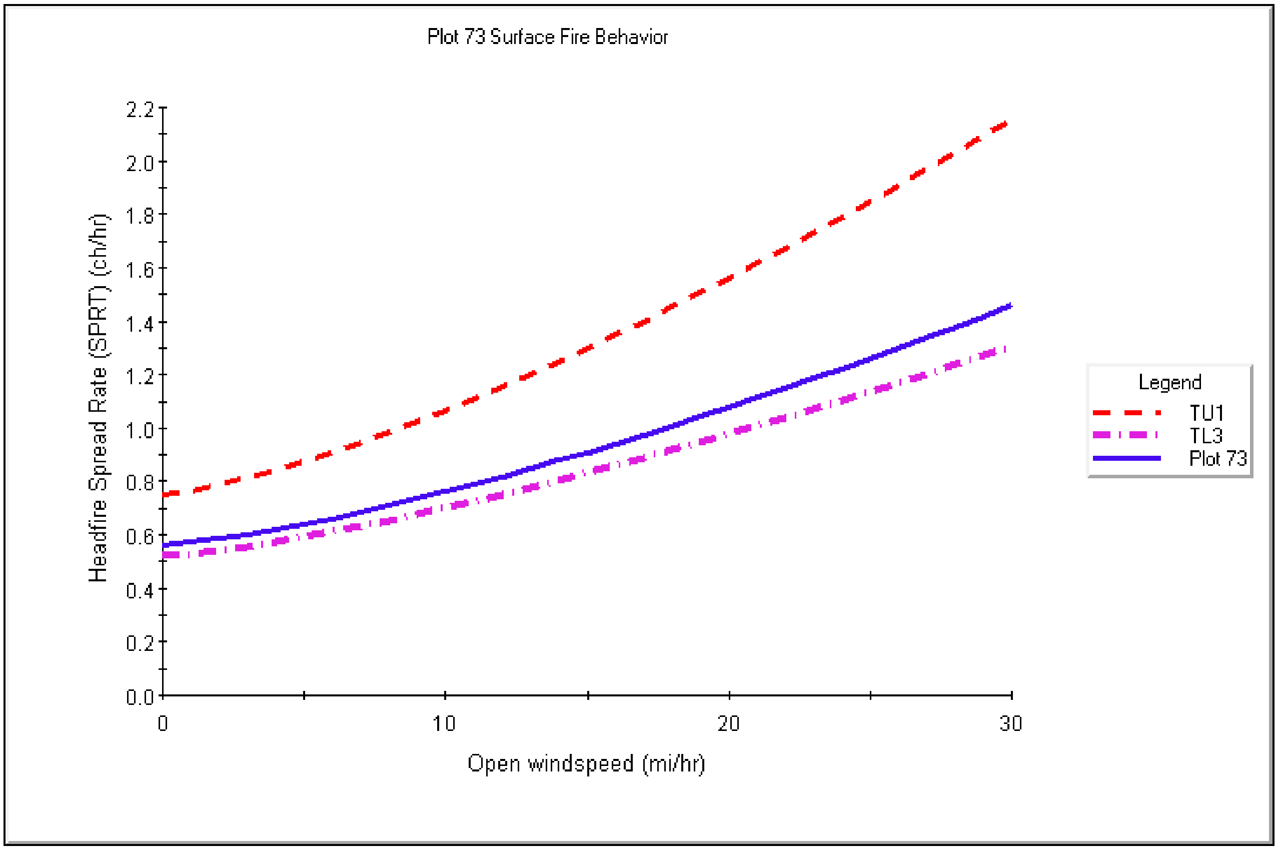

Figure 75. Comparison of fire spreading rates varied by wind speed for plot 73 and other fuel models. (slope = 33%; wind speed reduction factor = 0.1; fuel moisture = low).

Based on the NEXUS calculations, Plot 73 was classified as fuel model TL3 for the purpose of spatial fire modeling (discussed later in this section). Like many of the other plots at Mt. Spokane, Plot 73 was not an ideal match with the available fuel models provided by Scott and Burgan (2005). Possible reasons for these discrepancies are briefly addressed in the Discussion section of this section.

Following the initial classification of fuel models, NEXUS was used to predict flame lengths and fire-spreading rates at different fuel moistures and wind speeds that could occur on Mt. Spokane (see Figures 76 and 77 for these results displayed for Plot 73). See Appendix E for the results of NEXUS calculations for the other fuel models.

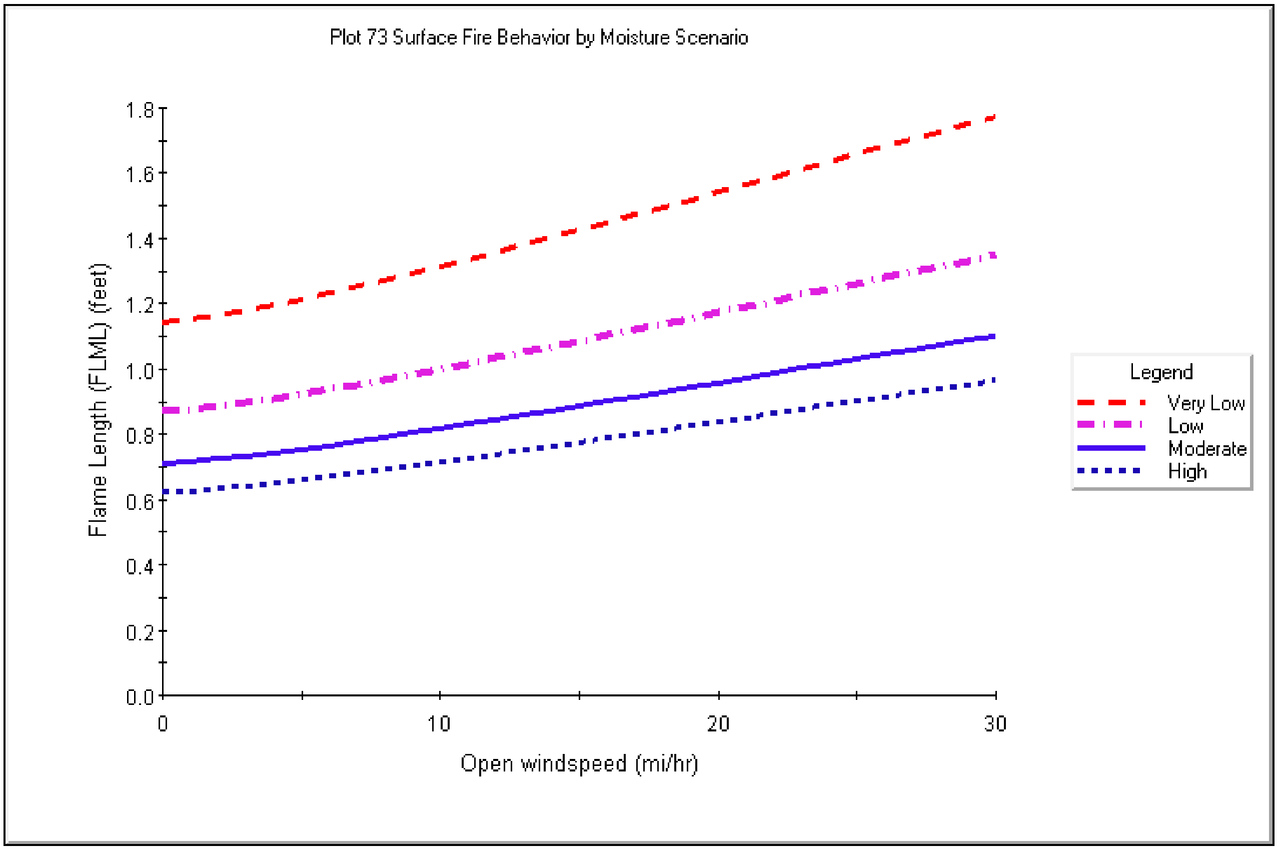

Figure 76. Flame lengths of plot 73 varied by wind speed and fuel moisture.

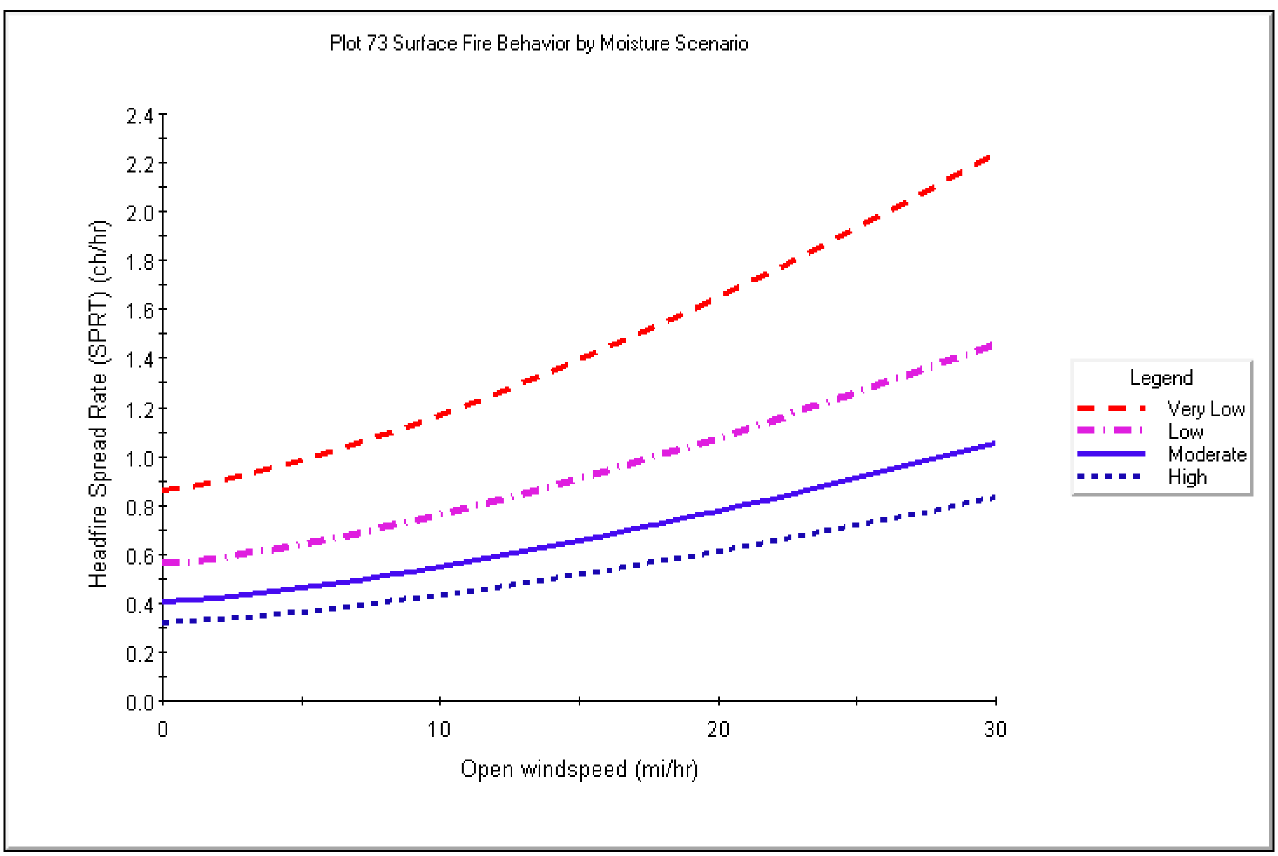

Figure 77. Spread rates of plot 73 varied by wind speed and fuel moisture.

Characterization of fire effects using FOFEM

FOFEM was used for predicting controlled burn outcomes using flame lengths and fuel models developed from NEXUS for average May and June weather and fuel moistures. Details of the fire behavior effects determined using FOFEM are presented in Appendix I.

FOFEM is capable of determining mortality based on species characteristics and tree diameter. For example, using the species characteristics in Table 13, the mortality of 16-inch DBH Douglas fir can be compared with 14-inch and 2-inch DBH grand fir, at varying flame lengths (Figure 78).

Table 13. Input parameters for plot 146 mortality calculations.

Species (colors are from graph below)	**Density (trees/ac)**	**DBH (in)**	**Height (ft)**	**Crown ratio (1-10)**
ABIGRA (Abies grandis)	25	14	60	7.0
PSEMEN (Pseudotsuga menziesii)	10	16	70	7.0
ABIGRA (Abies grandis)	1000	2	15	9.9

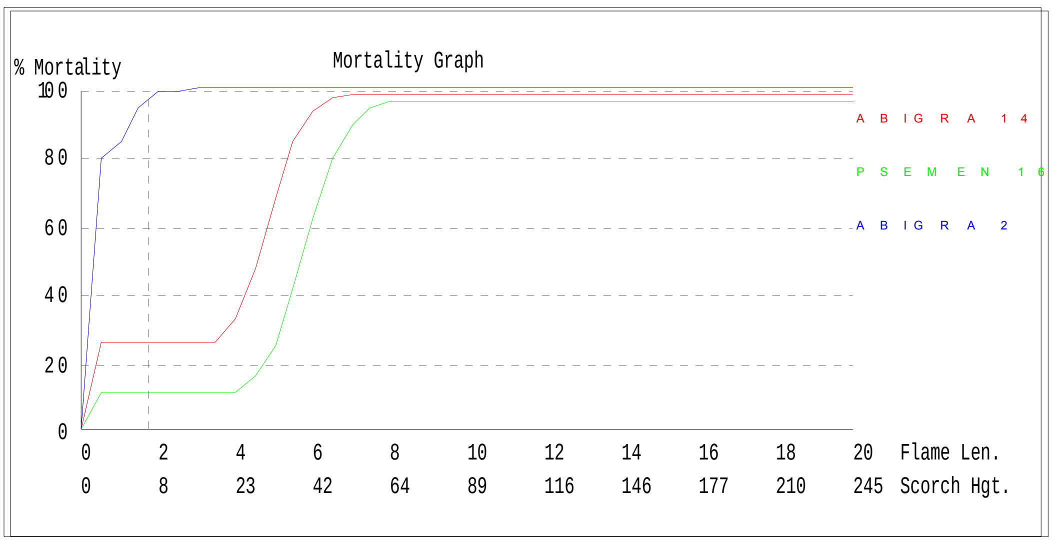

Figure 78. Results of mortality calculations for plot 146.

Mortality predictions were made for plots 3, 31, 141, 146, and 309, which are representative of planned burning units (see subsequent section: An Integrated Plan to Maintain Forest Health, Rehabilitate Habitat, and Reduce Fire Risk). Mortality was calculated by FOFEM based on characteristics of tree species within the sets of burn units, using flame lengths determined by NEXUS in conjunction with the standardized Mt. Spokane fuel model parameters and FireFamily Plus weather scenarios suitable for controlled burning. The results of the mortality predictions are given in Table 14.

Table 14. Results of FOFEM mortality calculations for selected plots. Species cohorts with desired high mortality are highlighted in red. Species cohorts with desired low mortality are highlighted in blue.

Plot	Fuel Model	Flame length (ft)	Species	DBH (inch)	Trees/ac	Height (ft)	Crown ratio (1-10)	Mortality (%)
146	TU5	1.8	ABGR	14	25	60	7	**25**
146	TU5	1.8	PSME	16	10	70	7	**10**
146	TU5	1.8	ABGR	2	1000	15	10	**100**
141	TU5	1.8	ABGR	14	65	50	9	**28**
141	TU5	1.8	ABGR	10	40	35	9	**45**
141	TU5	1.8	ABGR	2	1000	15	10	**100**
31	TU1	0.2	ABGR	18	21	80	6	**18**
31	TU1	0.2	ABGR	10	120	70	9	**40**
31	TU1	0.2	ABGR	2	40	15	10	**85**
31	TU1	0.2	PICO	14	48	70	4	**50**
3	TU1	0.2	PSME	20		70	7	**6**
3	TU1	0.2	PIMO	16	10	70	6	**34**
3	TU1	0.2	ABLA	8	18	30	10	**55**
3	TU1	0.2	PICO	10	48	60	5	**60**
3	TU1	0.2	PSME	14	40	50	9	**15**
3	TU1	0.2	ABLA	2	680	15	10	**85**
309	TU4	2.0	LAOC	20	28	130	2	**5**
309	TU4	2.0	PSME	30	8	90	6	**3**
309	TU4	2.0	LAOC	18	28	100	5	**5**
309	TU4	2.0	ABGR	12	110	50	9	**5**
309	TU4	2.0	ABGR	6	150	20	9	**90**
309	TU4	2.0	ABGR	2	1100	15	10	**100**

The calculated mortality from controlled burning with the given flame lengths indicated that controlled burning could be effective at reducing excess fuels without excessive mortality of larger trees. The percent mortality of species needing reduction (less than 6 inches DBH) was in all cases > 85%; the mortality of species targeted for retention (>16 inches DBH) ranged from 3-34%. The high figure was for PIMO (*Pinus monticola*). It may be necessary to use additional protection measures, like duff raking, to protect some of these trees from fire mortality. Intermediate diameter trees had intermediate levels of mortality, which could exceed retention objectives.

Spatial characterization of fire behavior across the landscape using FlamMap

We created landscape-level maps of fire-spread rates, flame lengths and crown fire potential for various weather, wind and moisture scenarios.

Figure 79 shows flame lengths predicted for the Mt. Spokane project area (black outline) during a 20-mph wind with very low fuel moistures scenarios given in Scott and Burgan (2005; p. 8). This simulation assumes no treatments or pre-treatment conditions. Figure 80 shows rate-of-spread and

Figure 81 shows crown fire potential, under the same conditions. We also ran scenarios using 20-mph wind and both low and moderate fuel moistures. And we ran a scenario using 20-mph wind and fuel moistures derived from 98%-percentile fire weather data combined with moisture preconditioning. The results of these scenarios are presented in Appendix H.

In these and all other figures in this section, note that in the project area (bold outline), the results are based on the detailed forest survey data we collected. The fire behavior displayed outside the bold outline are based on data provided by the LANDFIRE project and is derived from satellite imagery and landscape modeling and has an unspecified level of accuracy. The differences in fire behavior that can be seen inside and outside the project area boundary are in part the result of differences between the input values for the two datasets for canopy height, canopy base, canopy bulk density, canopy cover, and fuel model, as discussed below. Some of the differences are also due to differences in forest composition, structure and topography.

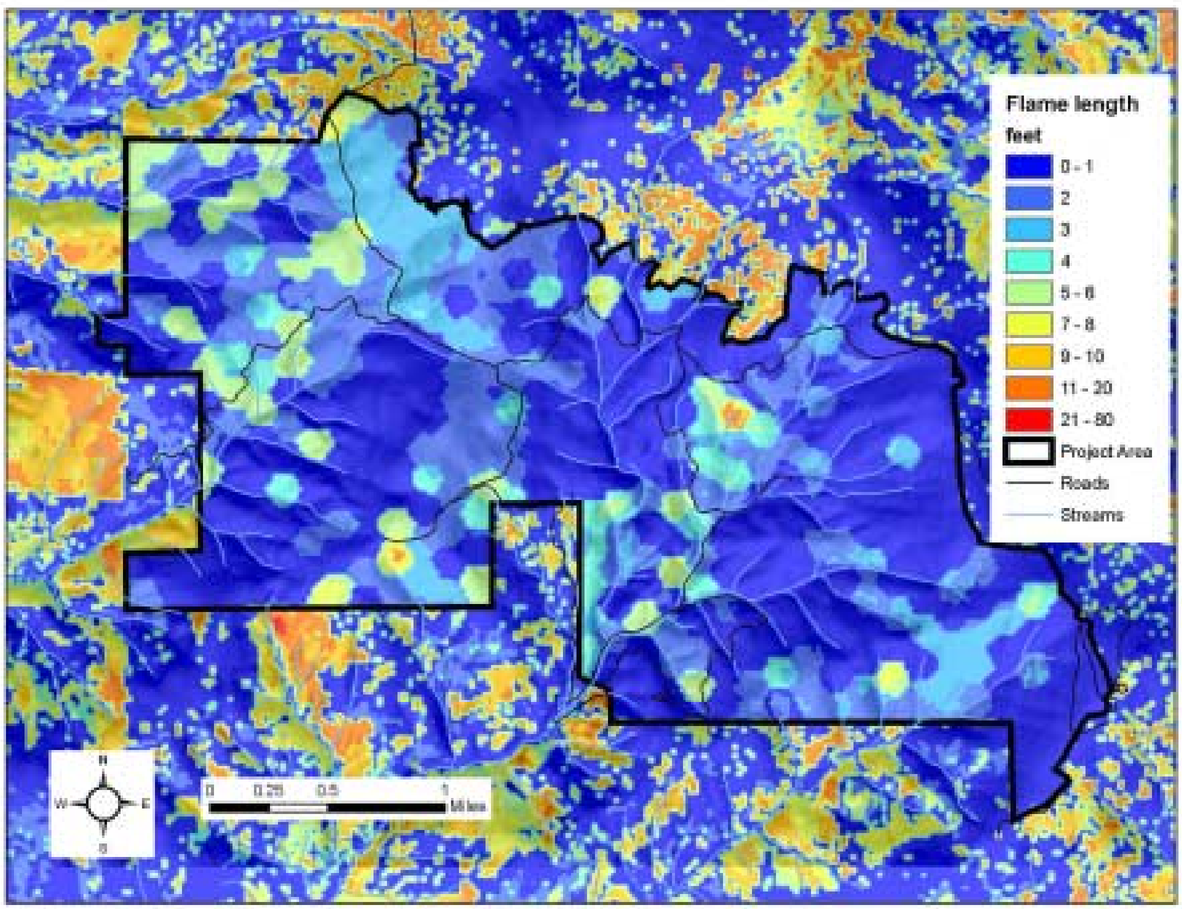

Figure 79. Pre-treatment flame lengths in the Mt. Spokane project area, modeled for summer weather using an unconditioned very low fuel moisture scenario.

One obvious feature of Figure 79 is that flame lengths in the project area are mostly less than 4 feet. The areas in the project area where flame lengths exceed 7 feet are typically forest stands that we classified as fuel model TU5 (high-load conifer litter, dry climate timber-shrub) or fuel model TU4 (dwarf conifer with understory). Fuel model TU4 was only used in our project area; the LANDFIRE project replaced fuel model TU4 with either fuel model TU1 (low-load, dry climate timber-grass-shrub), TU5, or TL4 (small down logs).

The most common fuel models in areas with flame lengths less than four feet were TU2 (moderate load humid climate timber-shrub) and TL3 (moderate load conifer litter). The areas where flame lengths differed the most from the LANDFIRE project predictions were classified in the LANDFIRE data as fuel model TU5. Although we classified some areas as TU5 (e.g., the northernmost point of the project area), this fuel model was generally uncommon in the project area. We found that the conifer litter loads in most of the project area were insufficient to classify stands to the TU5 fuel model. It appears that the LANDFIRE project misclassifies the fuel models for much of the project area. This is not surprising considering the fact that the LANDFIRE project created data with a national extent from rather coarse scale data and complex modeling.

Another obvious feature of Figure 79 is the result of the strong influence of the fuel model on fire behavior output. The fuel models can be identified where their common boundaries have sharp contrasts, which is actually just an artifact related to data resolution. The point here is that a given fuel model can produce radically different fire behavior between adjacent areas. Areas with flame lengths greater than 8 feet are less common. In the project area, these areas are often classified as fuel model TU4 (dwarf conifer with understory) or TU5 (very high load dry climate timber-shrub).

Figure 80 shows that the rate-of-spread of a frontal fire in the Mt. Spokane project area during extreme summer fire weather conditions is relatively low, and predominantly less than 2 meters (6 ft) per minute. Slower fire-spreading rates are expected under closed-canopy forests, in part due to reduction of wind speeds by as much as 90% due to forest canopies (Figure 52).

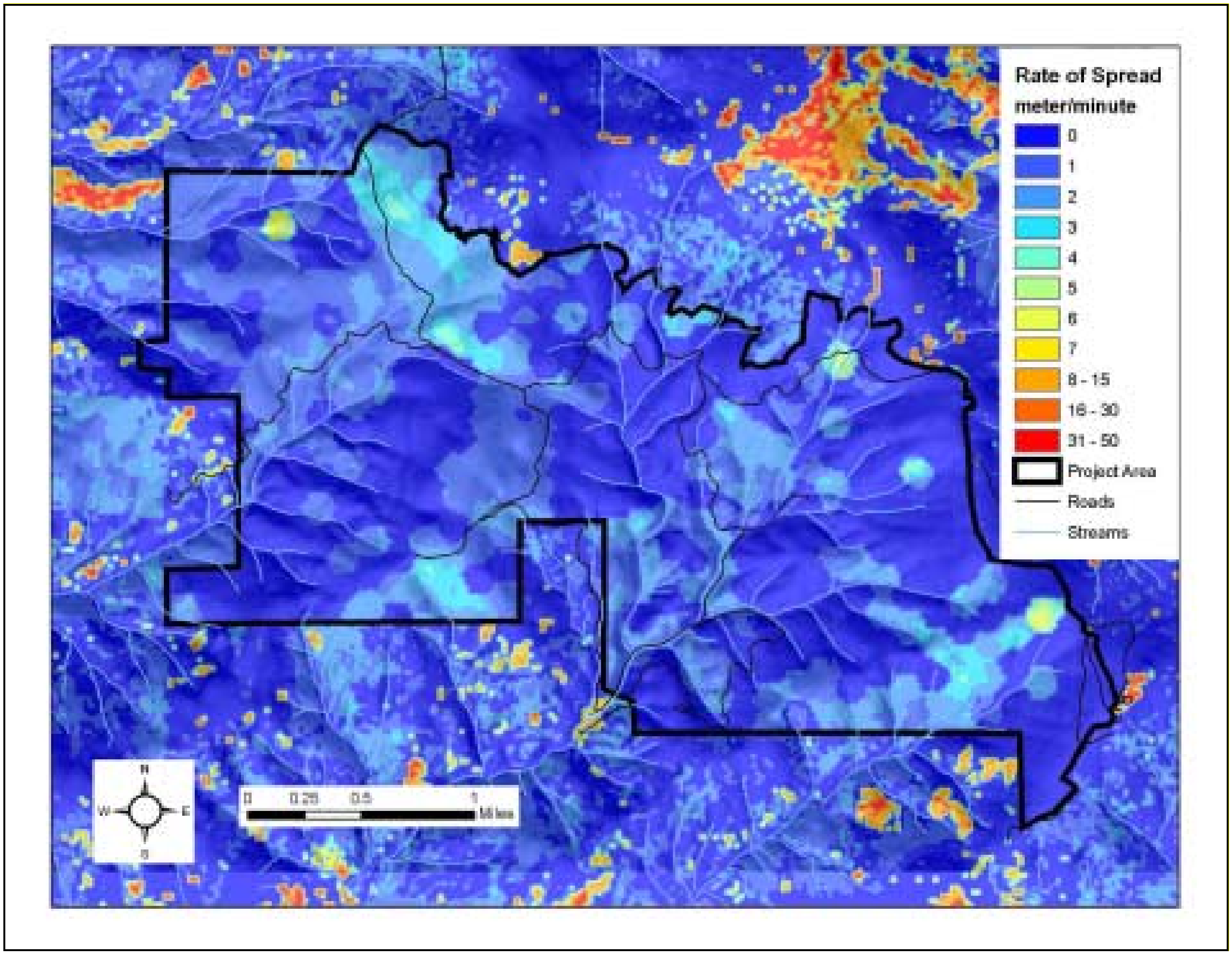

Figure 80. Pre-treatment rate of spread in the Mt. Spokane project area, modeled for summer weather using an unconditioned very low fuel moisture scenario. 1m = approximately 3 ft.

The combination of low flame lengths such as those of Figure 79 with the relatively high crown base heights (Figure 20) at Mt. Spokane results in a landscape with a very low potential for active or passive crown fire (Figure 81). These two factors point to ***a low likelihood of catastrophic wildfire in the project area under most circumstances.***

This suggests that limited funds may be more effectively spent by addressing forest health issues related to fire suppression than by attempting to reduce crown fire potential over large areas. To be cost-effective, treatments for reduction of crown fire potential need not necessarily treat an entire landscape. Fuel treatments can provide reasonable insurance against extreme fire events through the limited use of shaded fuel breaks. Fuel treatments should be strategically located in areas where they can be the most effective and easily maintained (e.g., along roads).

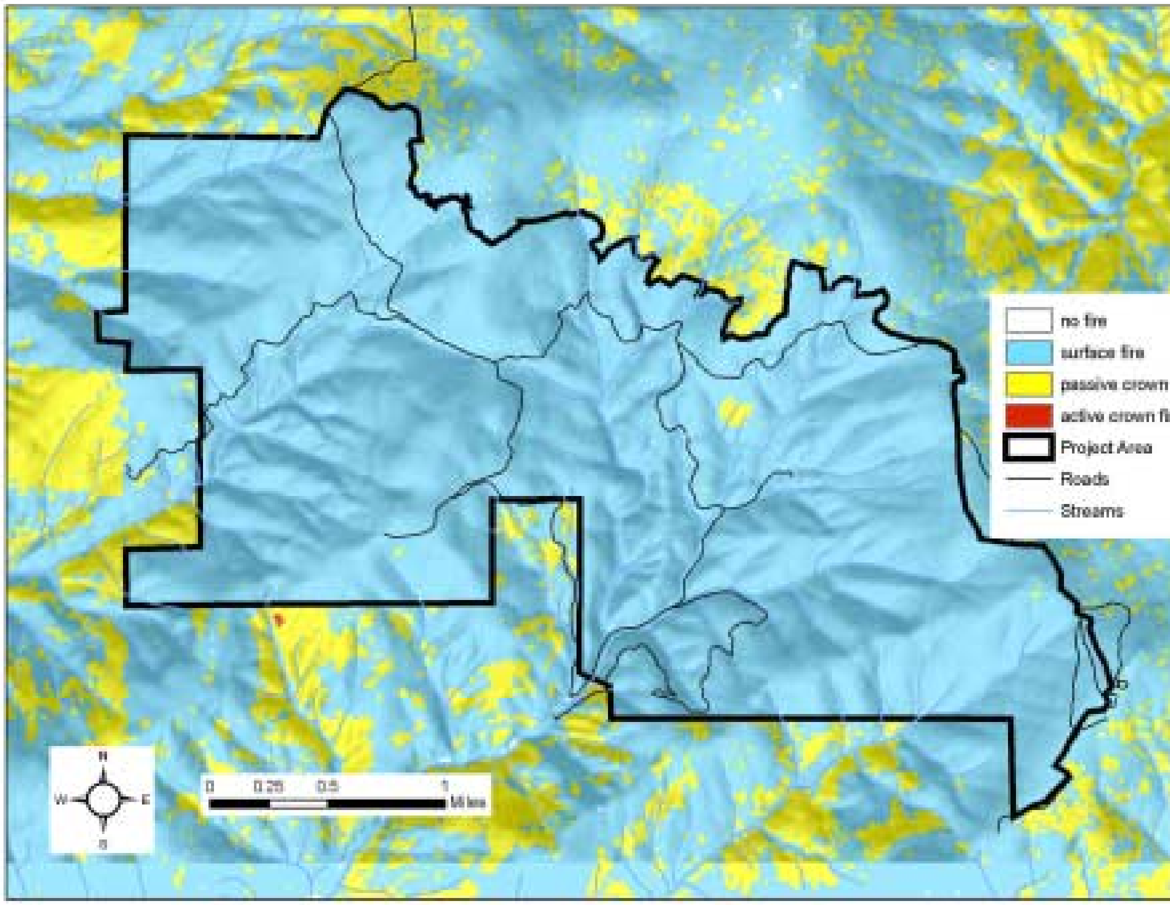

Figure 81. Pre-treatment crown fire potential in the Mt. Spokane project area, modeled for summer weather using an unconditioned very low fuel moisture scenario.

FlamMap fire behavior predictions under mild weather conditions suitable for controlled burning are shown in Figure 82 (flame lengths), Figure 83 (rate of spread) and Figure 84 (controlled fire).

Under the mild weather conditions suitable for controlled burning, the FlamMap fire behavior model predicted flame lengths predominantly less than 1-foot long, rate-of-spread predominantly less than 1 m (3 ft)/min and only surface fire behavior. These conditions were used to help design the fuel reduction plans described in the Forest Health section of this document.

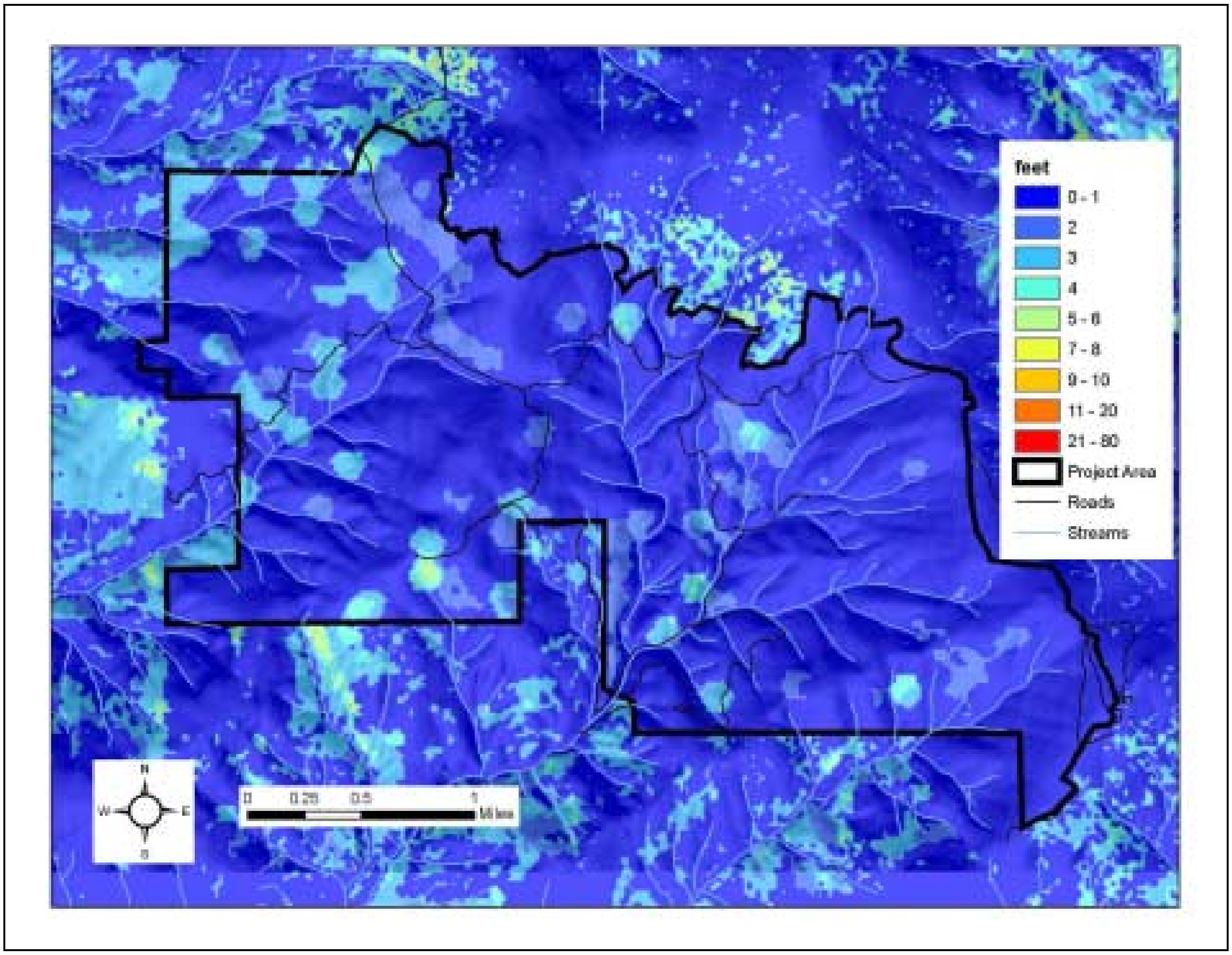

Figure 82. Pre-treatment flame lengths in the Mt. Spokane project area, modeled for mild weather suitable for controlled burning with an unconditioned moderate moisture scenario.

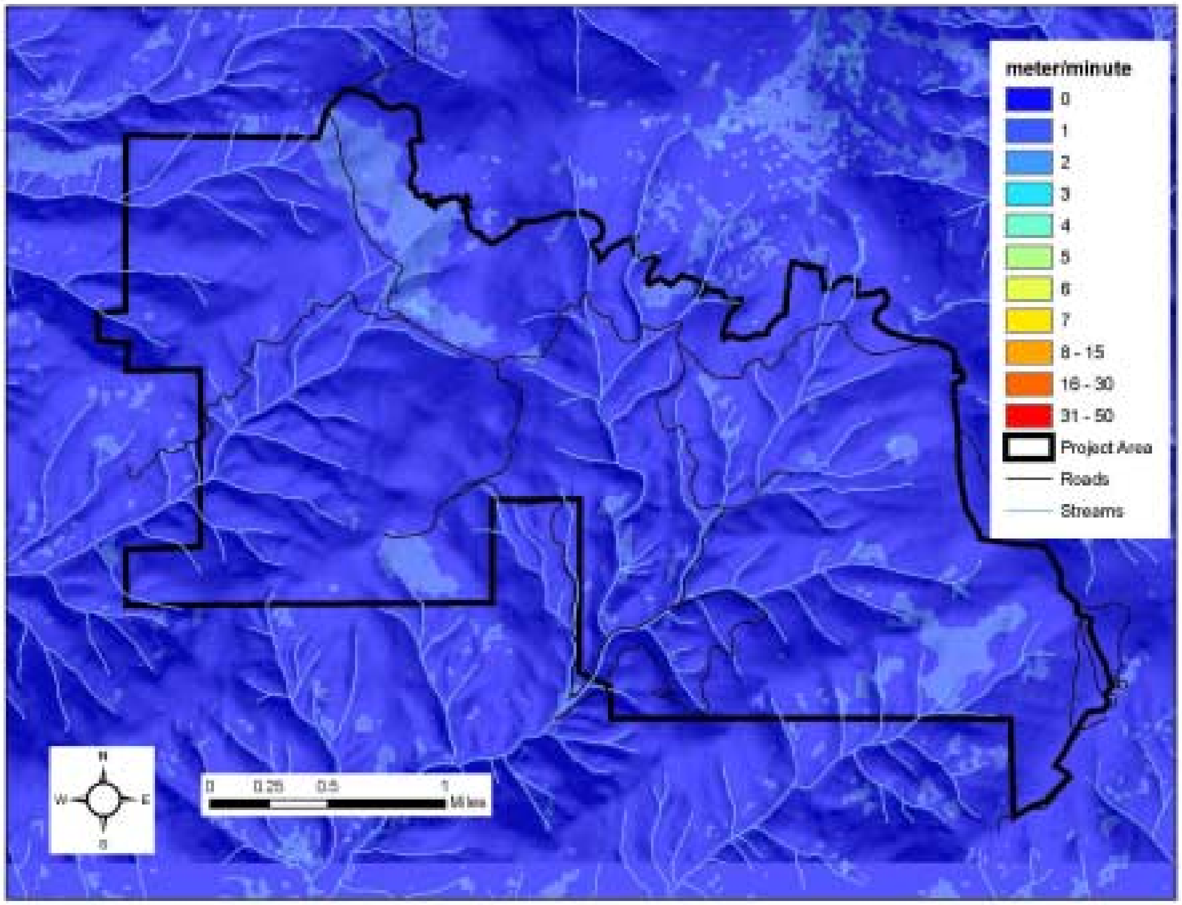

Figure 83. Pre-treatment rate of spread in the Mt. Spokane project area, modeled for mild weather suitable for controlled burning with an unconditioned moderate moisture scenario. 1m = approximately 3 ft.

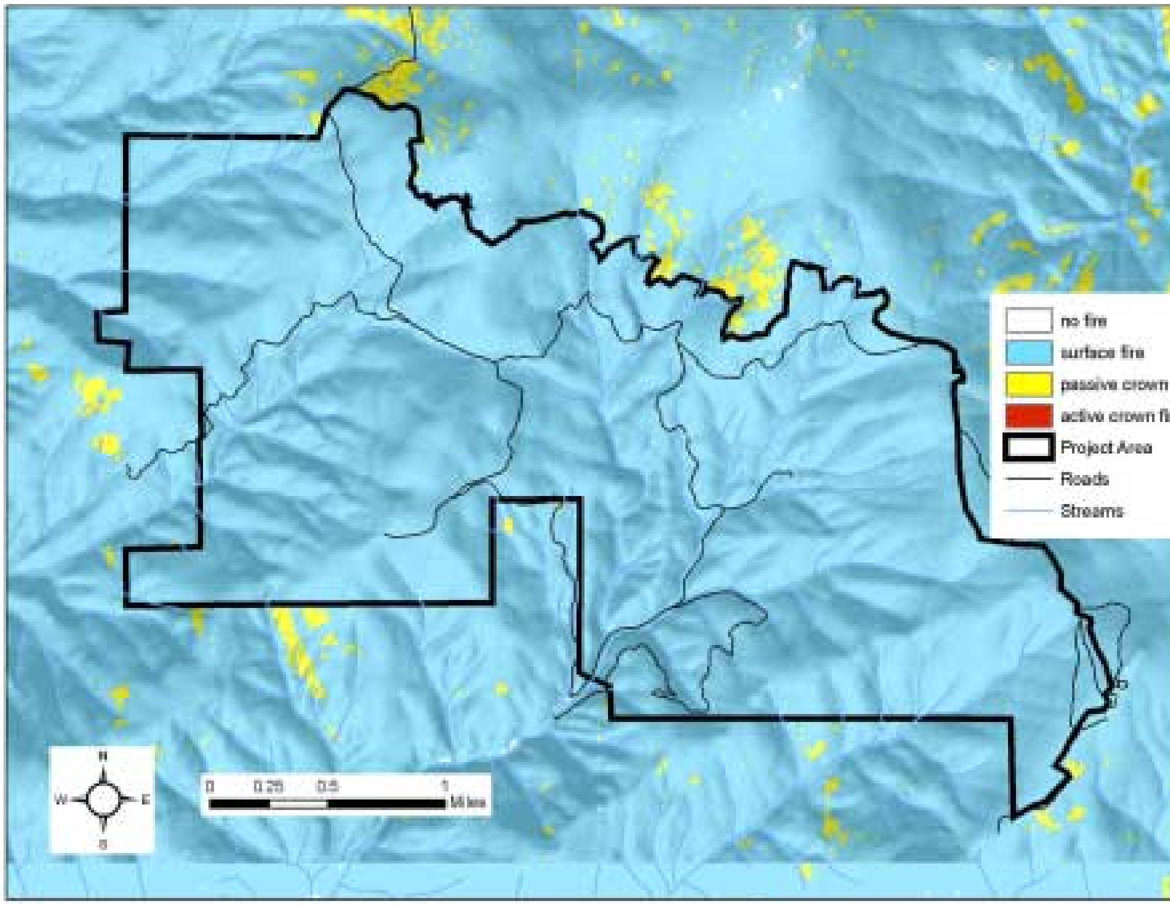

Figure 84. Pre-treatment crown fire potential in the Mt. Spokane project area, modeled for mild weather suitable for controlled burning with an unconditioned moderate moisture scenario.

See Appendix H for more results from the use of FlamMap.

Predicting dynamic spatial fire behavior using FARSITE

FARSITE was used to predict dynamic fire behavior over the Mt. Spokane landscape. As discussed above, we created landscape files for the park landscape combining data from outside the project area obtained from the national LANDFIRE program and much more rigorously collected and assembled data from our forest survey in the project area. This was done so that we could model fires that started outside of the project area. We also used all the fire weather data, fuel moisture data and wind data described in sections above to provide input information for the fire simulations. Numerous simulations were run under different weather conditions, varying wind configurations and fuel moisture conditions. One example is presented in Figures 85 and 86. We also ran simulations to assess the effect of various treatment options and used the results to refine our design of fuel treatments in the project area.

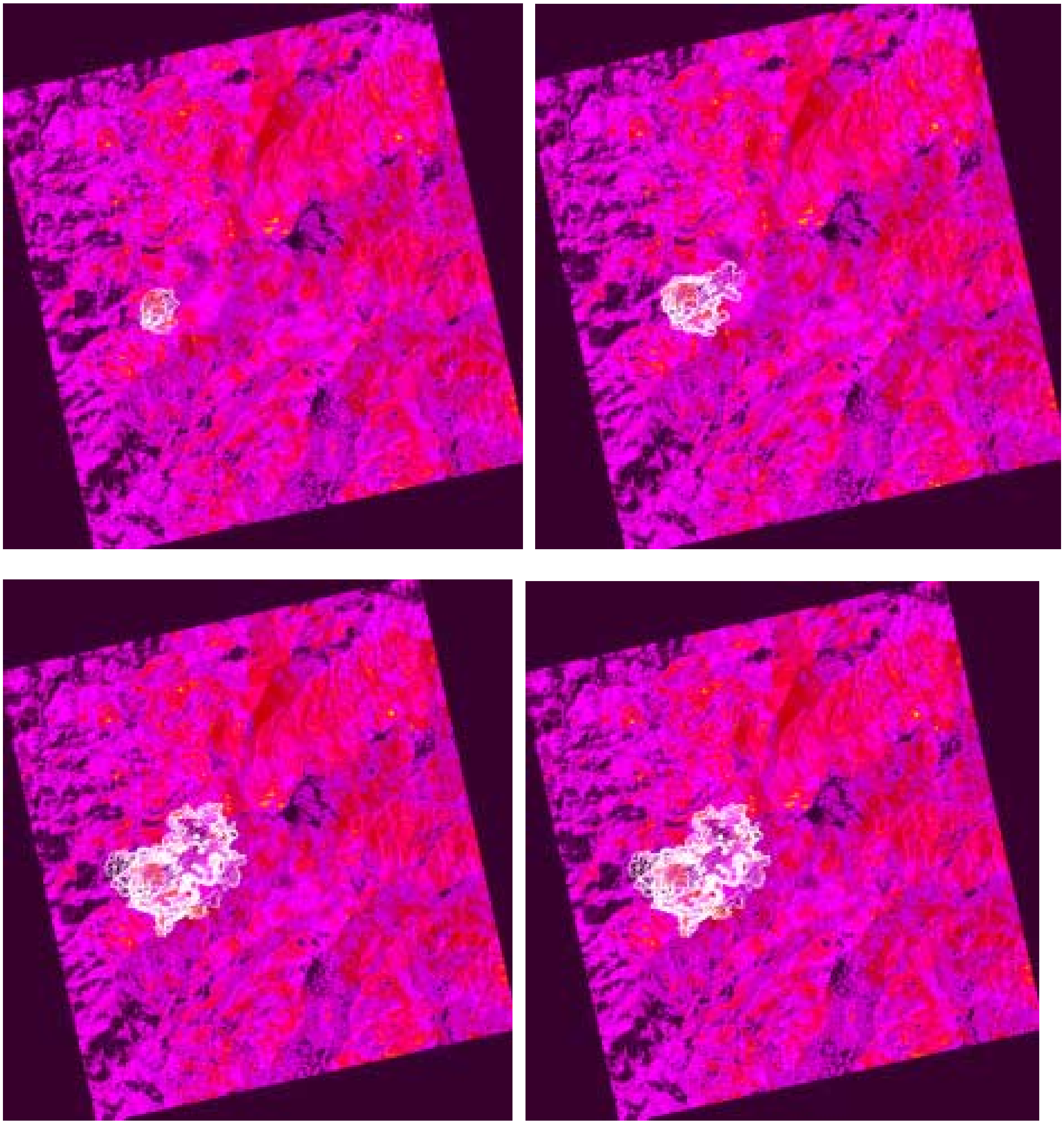

Figure 85. FARSITE simulation of a fire starting southwest of the park entrance under extreme summer weather conditions. White lines indicate the fire boundary as it spreads at a 30-minute interval. The sequence of images represents the spread of a wildfire over a four day period, with snapshots taken each day. Areas where the white lines bunch up represent areas where the fires move very slowly.

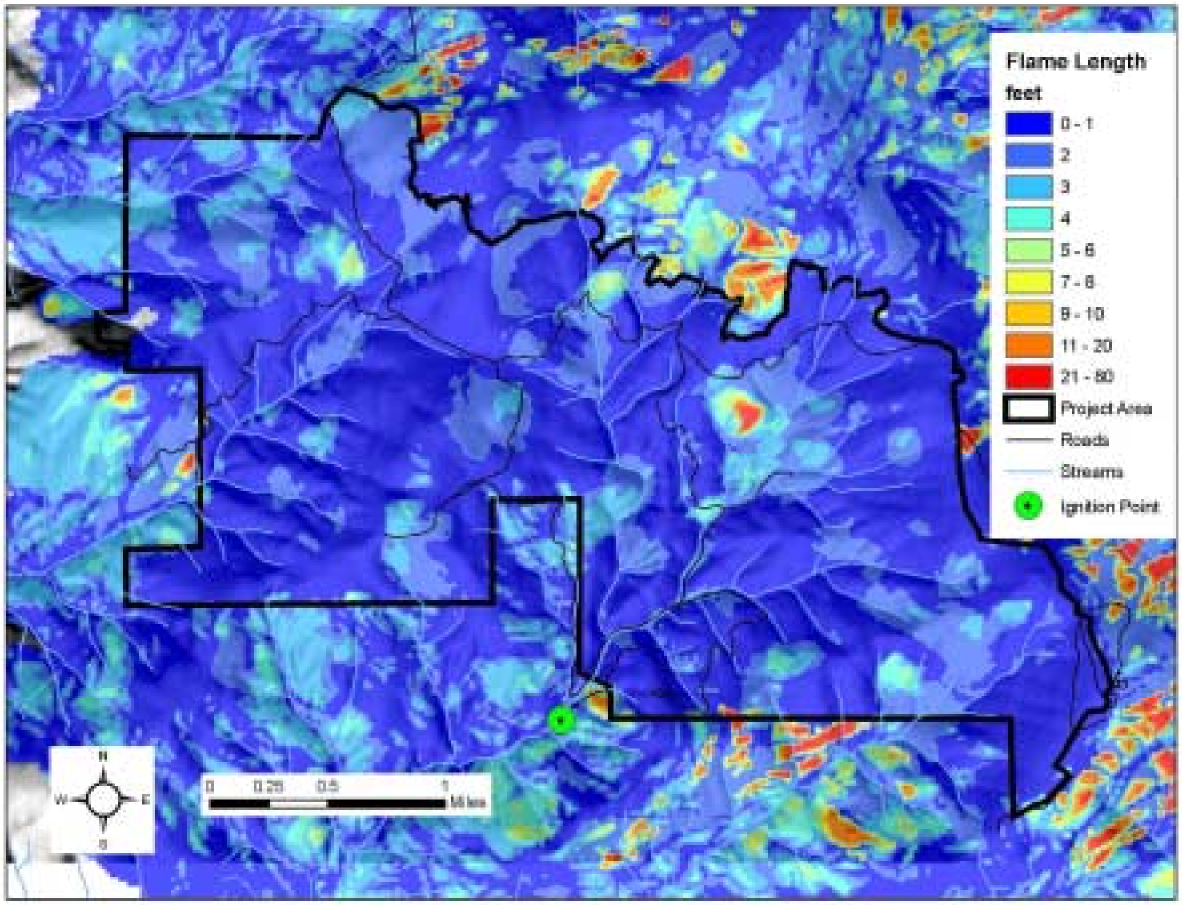

Figure 86. FARSITE simulation of flame lengths from a fire starting south west of the park entrance in hot August conditions.

Fire Behavior Modeling Discussion

Limitations of the fire behavior fuel models

Some stands could not be definitively classified into a fuel model due to a lack of quantitative fuel load data available from the field survey (survey protocols where limit to select variables that worked for many, but not all of the models). This was corrected by subsampling a number of plots for key fuel parameters (litter and duff), but gaps remain for effective fire behavior analysis to occur as a prelude to developing burn plans (see Recommendations).

In planning projects that may involve fuel reduction, it is important to consider that all currently available fire behavior software programs are based on the assumption that fuels are spread evenly across the ground. Because forests are heterogeneous, there is always a gap between the amount of detail desired and that available from field sampling and remote sensing. In general, the sampling scheme detail was adequate for trees and live understory species, but inadequate for dead fuels.

Data gaps were controlled somewhat by knowing when more detail was necessary, and by knowing which variables were most important. In addition to the use of limited subsampling to obtain details not included on the plots, we also used comparative studies such as the LANDFIRE Project (Rollins and Frame 2006) to confirm our fire behavior predictions. We also used different analytical tools to verify outputs, and cross-verified this through consultation with a fire behavior specialist.

The final classification of fuel models was based on finding a match with the most similar fire behavior fuel model (Scott and Burgan 2005), rather than developing custom fuel models specifically for this project. Either of these alternatives has the potential to produce unrealistic predictions. For instance, a number of plots with large logs and moderate loads of forest litter were classified as fuel model TL7 (large downed logs with heavy load forest litter), because there was no fuel model with large logs and moderate low litter. On the other hand, trying to create a custom fuel model would have required more field time and analysis (see Recommendations).

Several stands had a mix of different fuel models within and between the plots. The process of grouping sets of plots into similar areas can result in mischaracterizing parts of some stands when they are heterogeneous, such as in units 9, 11, 16 and set 146. Some amount of misclassification is expected as an unavoidable consequence of the trade-off between having more detailed sampling and the cost of such sampling. For this project, and most projects outside of academia, the relative degree of difference between fire behavior predictions for the stands is more important than the absolute accuracy of those predictions (Keane 2000).

The fire behavior outputs from FlamMap changed abruptly along the boundary of some adjacent fuel models. This produced obvious artifacts in the output, related to the resolution of the data. The resolution of the data is tied to the sampling efficiency, which was already intensive. An effective way to improve the data resolution without increasing sampling density would be to develop more detailed, custom fuel models and moisture scenarios representative of this area, particularly where areas formerly dominated by conifers are being overtaken by small grand fir and tall shrubs. This would require gathering more information in the field plots related to fuel characteristics.

Fire behavior in the project area

Based on modeling with FlamMap and FARSITE, the Mt. Spokane project area has a low crown fire potential, even under extreme summer weather. During extreme fire weather in the project area, flame lengths of less than 4 feet and fire spreading rates of less than 2 feet per minute are predicted to predominate. In reviewing fire history of the project area, no large fires are recorded, however large fires have occurred in the general vicinity. It is possible that observation of the few large fires in the project area may be an artifact of long fire return intervals, fires that burned nearby in northern Idaho in 1910 may have been the largest fires ever witnessed by white men in the contiguous United States. It is also possible that fires are damped out by the relatively high humidity on Mt. Spokane, compared with other areas in eastern Washington. During our visits, we noticed that fine fuels did not tend to dry out very well.

FlamMap predicts the fire behavior in the Mt. Spokane project area to be limited to surface fires during spring or summer weather conditions.

One of the most common fuel models in Mt. Spokane State Park that contributes to the low crown fire potential is fuel model TL3 (moderate load conifer-litter). A typical stand with this fuel model might have a canopy cover of over 80% with many trees were over 100 feet tall, and with a canopy base height of around 25 feet. Under the summer weather conditions, FlamMap predicted this fuel model would burn as a surface fire with 2-foot flame lengths. In this fuel model, fire is carried primarily by litter, needles and moderate loads of dead woody debris, with little or no contribution to fire behavior from shrubs, grasses or herbaceous plants. Under cooler weather conditions at Mt. Spokane State Park, fuel model TL3 may not have enough dry fuel to carry fire evenly during prescribed fire activities. Controlled burns may require creation of additional surface fuels, e.g. through cutting lower limbs or thinning, in order to sustain even burning and unbroken fire lines.

The canopy base height accounts for a large part of crown fire potential, because crown fire tends to occur when the flames overlap the lower branches of the tree crowns. Even with flame lengths several times higher in our models, crown fires would not be likely in the project area, although surface mortality could be high.

Even during summer fire weather exceeding the 98th percentile, the generally high crown base heights in Mt. Spokane project area would make crown fire an infrequent event in the forests and climates of today. Nevertheless, there are rare events that occur during extreme weather conditions that could cause the forests at Mt. Spokane to burn in an active crown fire. Also, as young grand fir encroachment progresses in the understories, the crown base heights will lower and passive crown fire potential will increase.

The low crown fire potential can serve as a guide to restoration efforts aimed at restoring a functional ecosystem. The species in decline at Mt. Spokane tend to be those adapted to periodic fire, including ponderosa pine, western larch and lodgepole pine, while relatively fire-intolerant species such as grand fir are increasing. This indicates that this ecosystem was formerly maintained by periodic surface fires (low intensity burns) that are no longer being allowed to burn. The historic function of fire would have been primarily to eliminate small, fire-intolerant species from gaining a competitive advantage. Without this function, grand fir and other fire-intolerant species will continue to increase, and this may establish further maladaptive trends such as competitive exclusion, loss of diversity and susceptibility to disease. In addition to this fact, there are many other functions of fire that go beyond this simple ecosystem model, that make a compelling argument for the progressive reintroduction of fire at Mt. Spokane. The first step in this process is a set of treatments that are outline in the subsequent forest plan section of this report. Difficulties can be foreseen in the re-introduction of fire, including access, smoke production and non-specific mortality that need to be acknowledged and addressed.

Evaluation of Forest Health Conditions in the Project Area

Forest Health Issues at Mt. Spokane

We looked at potential forest health issues in the project area. Using our field derived data, and other data sources for the project area, we examined characteristic forest health indicators such as: plant community diversity, diversity of successional states, diversity of tree species, variation in abundance of snags and coarse woody debris; the occurrence and abundance of rare plants and/or rare vegetation communities; invasive species presence and abundance; insect and disease mortality levels; and the potential for departure from historic forest conditions. We examined wildlife habitat conditions for wildlife species of concern and developed comprehensive models for the habitat conditions for three of the most important species. We also carefully examined the fire hazards and modeled wildfire behavior in the study area. Based on all of these evaluations, we have been able to formulate an evaluation of the forest health condition of the project area.

Diversity of forest conditions at Mt. Spokane

While conducting our field surveys we were struck by the diversity of forest conditions in the project area. Figure 87 provides examples of the range of conditions in the project area. While the matrix vegetation in the project area is typically comprised of mature, mixed conifer forests in the grand-fir series (Table 3, Figure 12), a large degree of successional diversity permeates the forested landscape, ranging from early successional forest development to late-successional old growth forests. A wide range of plant communities also exist (Tables 3 and 15, Figure 12). Due to a complex history of disturbance events, including natural and human induced disturbance cycles, and due to complex topographical variation and soil characteristics, the forests of Mt. Spokane State Park are extremely heterogeneous. This mix of forest conditions typically occurs in relatively small patches of less than 75 acres in size. The result is a forest landscape that contains a diversity of ecological functions and characteristics. This condition allows the forest to withstand a range of disturbance events while still allowing for inter-habitat wildlife interactions in the park. For some species that require large intact tracts of a particular forest condition for certain critical life stages, the high diversity of conditions located in relatively small patches may not provide ideal habitat. However, for the majority of forest-dwelling species the conditions appear to offer adequate to good habitat opportunities.

Vegetation Community Diversity at Mount Spokane

We encountered a high diversity of vegetation communities (plant associations and forest series) in the project area (Table 15, Figure 89). As with the diversity of forest conditions discussed previously, the diversity of plant associations can also be attributed to a complex history of disturbance events, including natural and human induced disturbance cycles, and complex topographical variation and soil characteristics. As would be expected, there appears to be a strong relationship between forest series occurrence and elevation. There is also a strong link between plant association occurrence and aspect and landform. However, it was beyond the scope of this project to analyze these relationships.

Figure 87. Examples of the diversity of forest conditions occurring in the project area.

Based on our forest survey, there are 7 vegetation series and 16 dominant plant associations found in the project area. Two of these associations, western hemlock/bear grass (*Tsuga heterophylla/Xerophyllum tenax*) and western hemlock/rusty menziesia (*Tsuga heterophylla / Menziesia ferruginea)* have global rarity rankings of G2, which means that these plant communities are "imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction throughout its range (6 to 20 occurrences or few remaining individuals or acres)." (Washington Natural Heritage Program, NatureServe). The subalpine fir/cascade azalea/beargrass (*Abies lasiocarpa/Rhododendron albiflorum/Xerophyllum tenax*) plant association found in the project is not rare globally, but it does have a state ranking of S3, which means that it is considered to be "rare or uncommon in the state (typically 21 to 100 occurrences)" and "vulnerable in the state or province due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation" (Washington Natural Heritage Program and NatureServe). The locations of the sensitive plant associations are provided in Figure 88. Table 15 and Figure 89 provide a look at the relative abundance of these and other plant associations and forest series in the project area. Table 3, in a previous section, provides more information on the sixteen plant associations found in the project area.

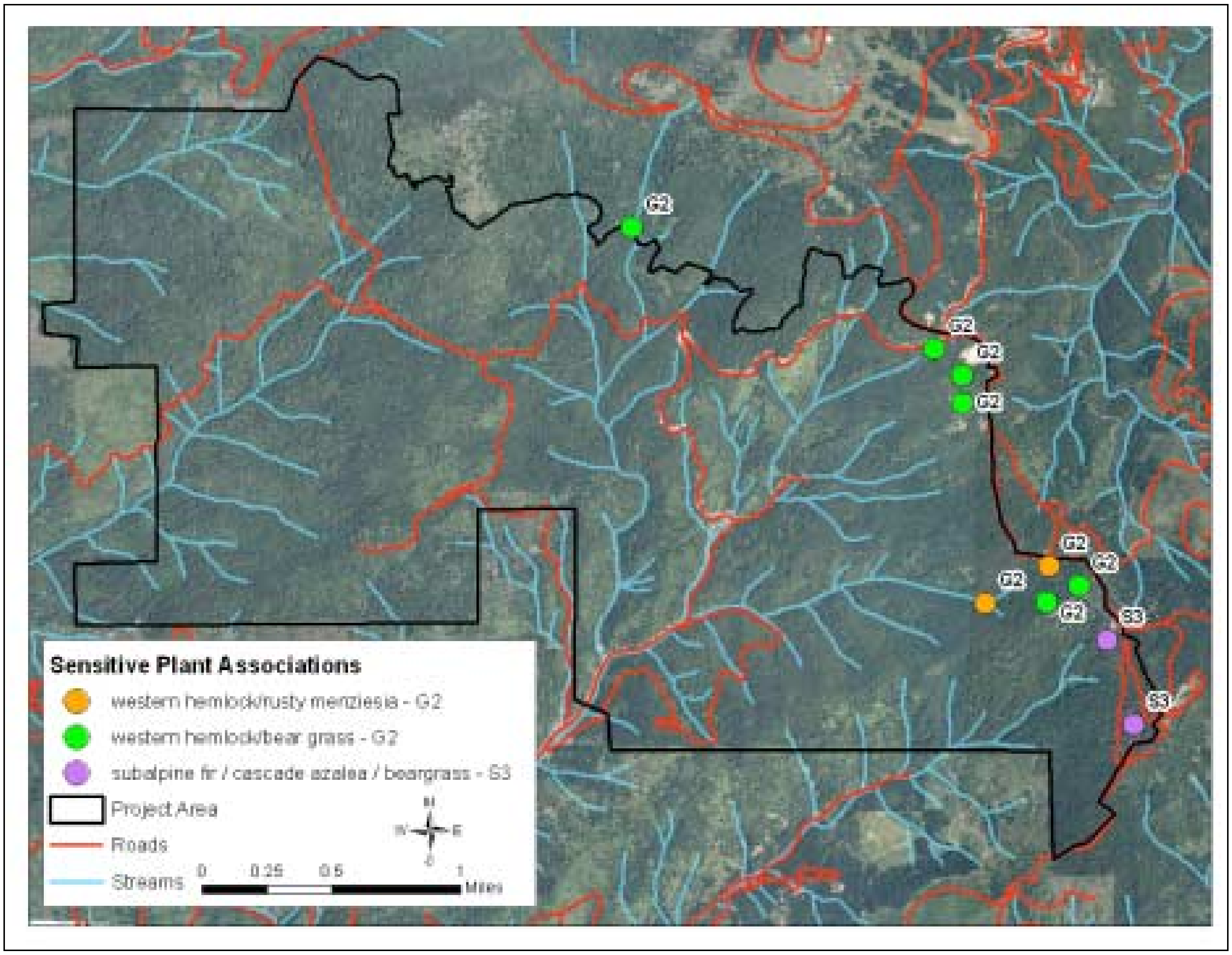

Figure 88. Location of G2 and S3 ranked plant associations observed in survey plots in the project area.

Table 15. Number of plots in each plant association and forest series occurring in the project area (most frequently encountered associations noted in red). See Table 3 for a key to vegetation codes.

Series	Plant Associations	# of Plots	Plots in Series
ABGR	ABGR/ACGLD/CLUN	105	241
	ABGR/PHMA	48	
	ABGR/VAME/CLUN	88	
ABLA2	ABLA2/RHAL/XETE	2	3
	ABLA2/VAME	1	
ALSI	ALSI/Mesic Forb	2	2
CARU	CARU-FEID	2	2
PSME	PSME/PHMA	3	3
THPL	THPL/CLUN	16	18
	THPL/VAME	2	
TSHE	TSHE/CLUN	124	137
	TSHE/GYDR	5	
	TSHE/MEFE	2	
	TSHE/XETE	6	

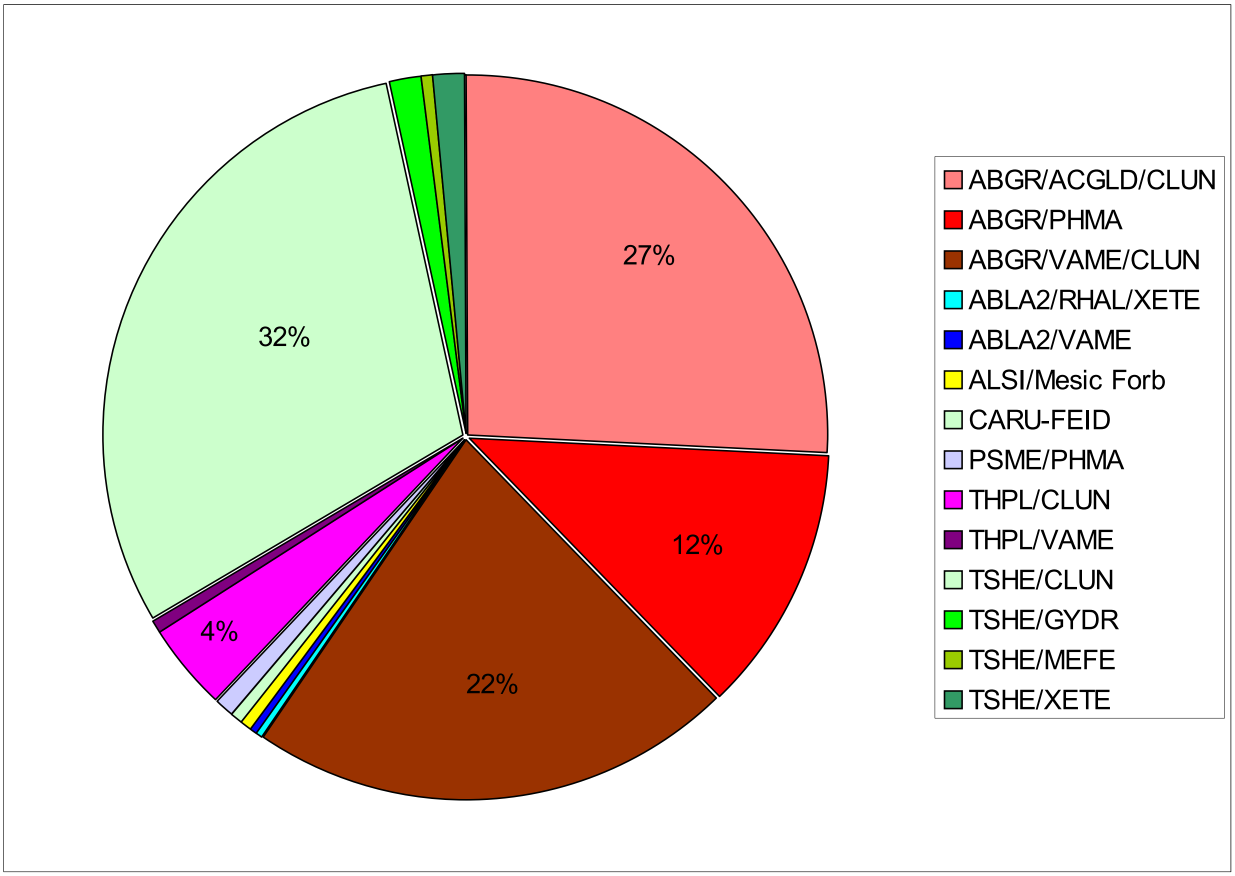

Figure 89. Pie chart of the abundance of plant association occurrence in the project area (based on encounters at plots). See Table 3 for a key to the vegetation codes.

Rare plants and high quality representative vegetation communities

We looked at the Washington Department of Natural Resources Natural Heritage Program (WA DNR NHP) data on rare plants and high quality representative vegetation communities. Figure 90 displays all the occurrences currently tracked by WA DNR NHP in the project area. No rare plant occurrences have been identified in the project area. We found the tracked vegetation communities to be more extensive in the park than what is listed by the WA DNR NHP GIS data. Care should be taken when using the NHP database on Mt. Spokane State Park because it is often based on very limited fieldwork and sporadic reported sightings. We did not conduct a rare plant survey or a comprehensive botanical inventory of the project area as part of this project.

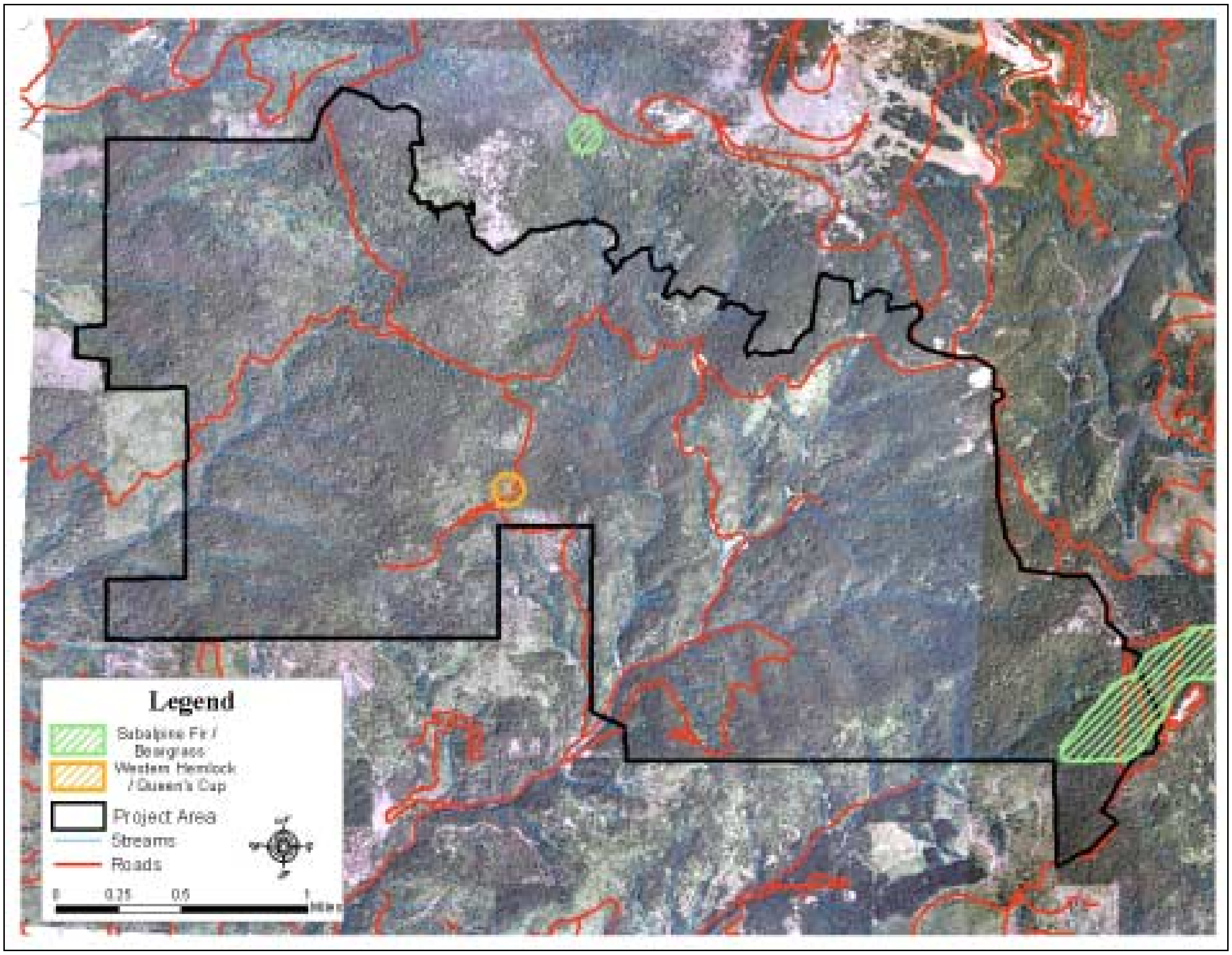

Figure 90. Map providing all locations of sensitive plants and vegetation community data from the WA DNR Natural Heritage Program in the project area.

Non-native Plant Species Presence

We did not conduct a systematic inventory of invasive species during this project; however, we did note non-native species during fieldwork (Table 16). Almost all occurrences and infestations of exotic or invasive plant species occur along the transportation network in the project area. Few invasive exotic plants were found in the forests away from the edge of roads or trails. We did find a few weeds in young forests that had regenerated after logging and fire about 50 years ago. The presence of invasive species appears to be dependent upon site disturbances that removed the native vegetation and exposed the soil surface to direct sunlight and weed seeds. This argues for care in forest management activities that involve ground disturbing activities, as these management actions could encourage migration of the weeds into the forest interior.

Table 16. Non-native plant species found in the project area during forest surveys.

Common Name	Scientific Name	CODE	Family
Canada thistle	*Cirsium arvense* (L.) Scop.	CIAR4	Asteraceae
common mullein	*Verbascum thapsus* L.	VETH	Scrophulariaceae
common St. Johnswort	*Hypericum perforatum* L.	HYPE	Clusiaceae
Dalmatian toadflax	*Linaria dalmatica* (L.) P. Mill.	LIDA	Scrophulariaceae
hairy catsear	*Hypochaeris radicata* L.	HYRA3	Asteraceae
Scouler's St. Johnswort	*Hypericum formosum* Kunth = *Hypericum scouleri* Hook.	HYFO	Clusiaceae
spotted knapweed	*Centaurea maculosa* auct. non Lam. [misapplied] >>*Centaurea stoebe* ssp. *micranthos*	CEMA4	Asteraceae
wall-lettuce	*Lactuca muralis* (L.) Fresen. = *Mycelis muralis* (L.) Dumort.	LAMU	Asteraceae
yellow hawkweek	*Hieracium* sp. L.	HIERA	Asteraceae

Compared to other state parks where we have conducted botanical and ecological surveys, Mt. Spokane appears to have much less of a problem with non-native plant invasions. This is probably due to its relatively high elevation and the good ecological health of many of its plant communities.

Insects and Disease

Each year, all forested federal, state and private land in Oregon and Washington is aerially surveyed for insect and disease damage. This survey is flown cooperatively by the Region 6 US Forest Service, Forest Insects and Diseases group; the Oregon Department of Forestry, Insect and Disease Section; and the Washington Department of Natural Resources. These data are collected to determine regional insect and disease trends and to serve as an indicator to land owners/managers of insect and disease activity in their area. We refer to the GIS data created by this survey as "Insects and Disease" data.

We reviewed the Insects and Disease data from 2000 – 2006 to get an idea of the mortality rates in the project area. Figure 91 illustrates the mortality rates recorded in the Insects and Disease GIS data.

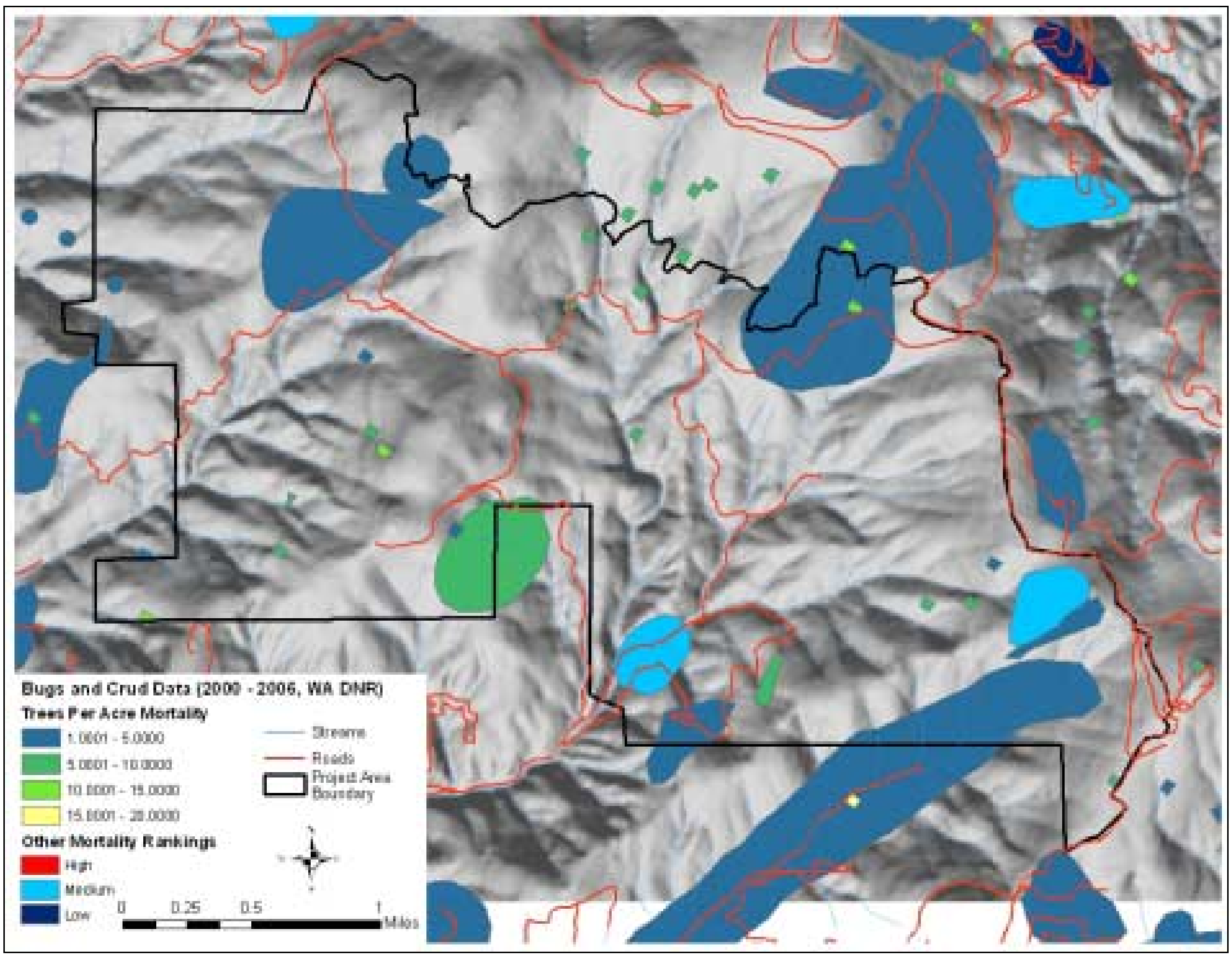

Figure 91. Map of DNR Insects and Disease data for the Mount Spokane area from 2000 – 2006.

Although parts of the project area have active forest mortality agents, most of the documented mortality appears to be within a normal range that coincides with good forest health. We did not see many large patches of current high mortality rates caused by any specific agent in the project area. The highest mortality rate for a large polygon in the project area showed less than 10 trees killed per acre, and in this case those trees were older lodgepole pines that normally drop out of a forest stand at this forest succession stage.

From the Insects and Disease data we created a list of the most extensive mortality agents in Mt. Spokane State Park by year:

2000: Douglas-fir beetle
2001: Douglas-fir beetle
2002: Douglas-fir beetle
2003: mountain pine beetle (lodgepole pine)
2004: fir engraver
2005: fir engraver
2006: fir engraver

The following is a discussion of these three specific agents and their roles in forest ecology.

Douglas-fir beetle (Dendroctonus pseudotsugae)

Douglas-fir beetles accelerate the rate of decomposition of down host material by introducing decay fungi and increasing access to the wood for other agents of deterioration. In the case of infestation of standing trees, Douglas-fir beetles help create gaps in the forest and cause changes in species composition and structure in stands containing large Douglas-firs. They often kill individual Douglas-firs weakened by other agents (dwarf mistletoe, root pathogens, drought). Figure 92 illustrates an area (not in Mount Spokane) where Douglas-fir beetle has killed trees in a stand.

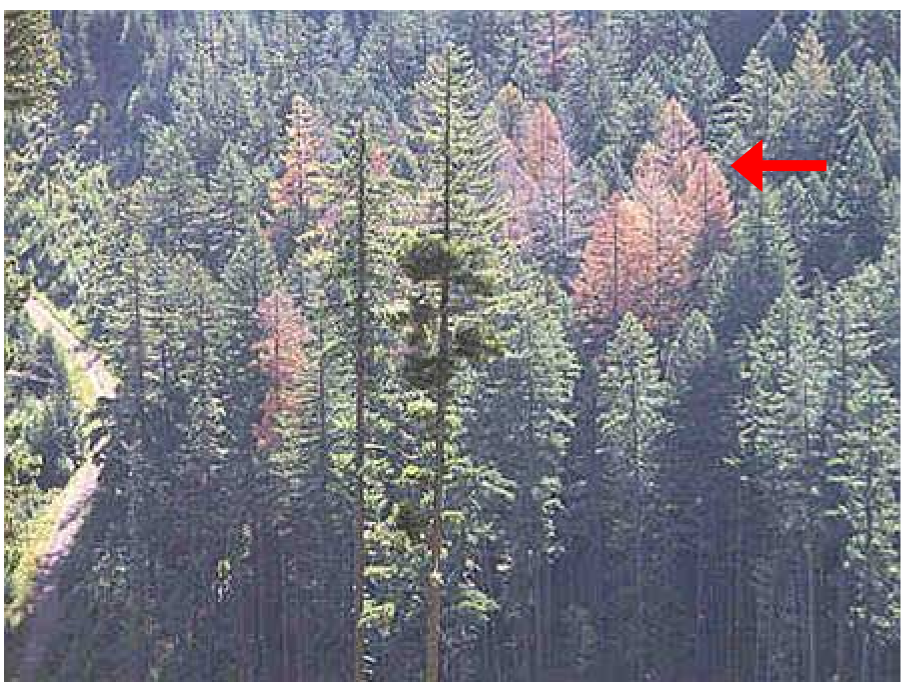

Figure 92. Example of forest where Douglas-fir beetle has killed trees (red arrow is pointing at some of the dead trees killed by Douglas-fir beetle).

Mountain Pine Beetle (Dendroctonus ponderosae)

Mountain pine beetle (MPB) attacks lodgepole, ponderosa, and western white pines. Outbreaks occur in lodgepole pine stands that contain high densities of large-diameter trees or in dense stands of pole-sized ponderosa pine. Successful attacks introduce blue stain fungi into the sapwood, which stop the flow of sap near the entrance hole. If a large number of attacks are successful, the tree will die by cutting off the movement of sap in the tree. MPB is likely to cause the highest mortality in lodgepole pine in the project area in the coming decade due to the large number of lodgepole pine stands currently moving into the most susceptible age classes. Because lodgepole pine stands occur in relatively small patches distributed throughout the matrix of other forest types it is unlikely that large-scale pine die-offs will occur due to MPB, although localized events can be expected where dense stands of large diameter lodgepole pines occur. Such events should be considered normal and not a threat to overall forest health. Figure 93 illustrates the classic sign of mountain pine beetle attacking a lodgepole pine bole.

Figure 93. A good example of mountain pine beetle activity in lodgepole pine boles (red arrow is pointing at the pitch tubes) (photo not from Mount Spokane).

Fir Engraver (Scolytus ventralis)

The fir engraver primarily attacks white fir, grand fir, and red fir. It also occasionally attacks Douglas-fir, subalpine fir, mountain hemlock, and Engelmann spruce. In addition to infesting standing green trees, the fir engraver can infest freshly cut logs and recent wind-throws.

There is a chance that large-scale, high-mortality events could occur due to this agent in the project area. Due to the increasing amounts of grand fir stem density and the loss of other conifer diversity in some parts of the project area, a large-scale fir engraver outbreak is possible, and this risk is likely to increase. The recommended forest treatments proposed in this plan were designed to help decrease the risk of a large-scale fir engraver outbreak occurring in the project area. Figure 94 provides an example of a classic sign of fir engraver activity in a forest.

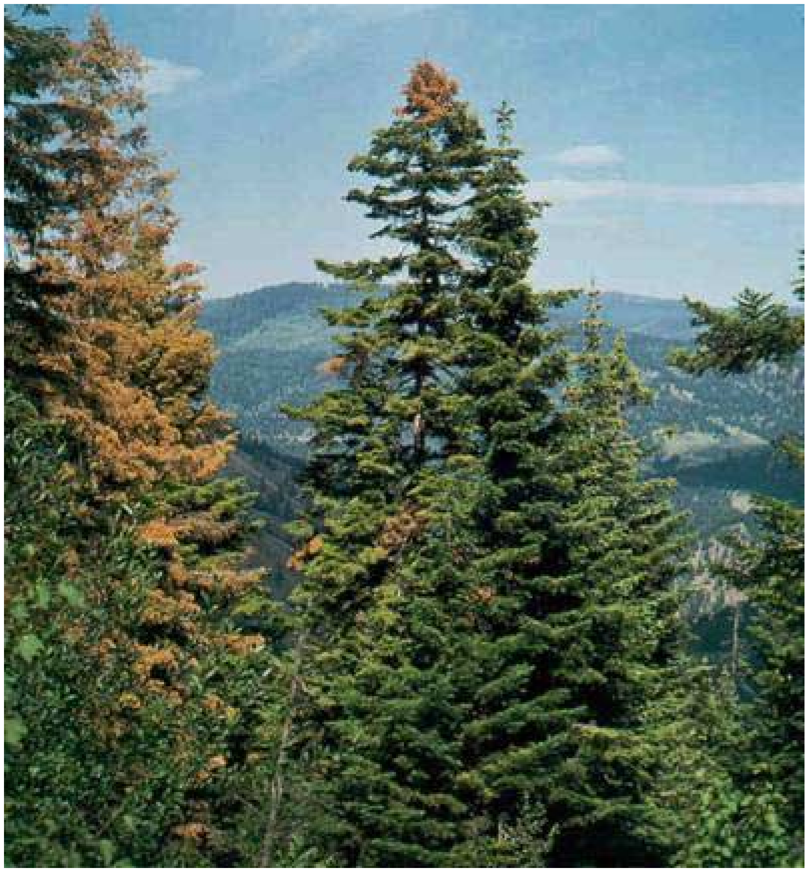

Figure 94. An example of the signs of fir engraver activity (photo not from Mount Spokane).

Potential for Departure from Historic Conditions

In ecosystem and wildland management, the amount of departure of a current landscape condition from known or hypothesized historic conditions is considered an important indicator of overall ecosystem health. Of course, measuring the distance of departure between an actual defined area and idealized historical conditions can be very difficult and misleading. False judgments about what historical conditions were actually like, and what forces were at play to create and maintain those conditions can cause misinterpretations about the health of current conditions, and subsequently, this can lead managers to undergo unnecessary or even harmful management activities. We hope to avoid the pitfalls of bad interpretations of historic conditions by looking at the most obvious indicators of historic conditions and seeing if they are replicating themselves on the current landscape.

In the case of forest health, it is the trees and logs that speak volumes with regards to historic conditions. The oldest trees that predate European settlement can tell us much about historic stand conditions. The species of old trees on a site are an indication of the type of disturbance that led to stand establishment. The growth rings and fire scars in each tree give us an idea of how conditions progressed throughout the life of that tree. Logs are a record of the date and type of intermediate disturbances. Even sites without any old trees are informative as this indicates that something has happened that removed or prohibited old trees for establishing.

In the project area there are many forest stands that contain old trees, some well over 300 years old. Stands with old trees in them tend to be more diverse, and they often contain fire-resistant species. One phenomenon we observed in the project area is that even though stands might have a high diversity of conifer species in the overstory, there was limited regeneration of fire-resistant, shade-intolerant species, particularly in the oldest forests that had never been heavily logged. Conifer regeneration in the project area is essentially limited to western hemlock, western red-cedar, and most notably, grand fir. Although ponderosa pine, Douglas-fir, and western larch occur quite regularly in the forest overstory, these species are rarely regenerating. This seems to be an indication that forest ecosystems have departed from historic conditions.

We believe that the potential exists for many forest stands in the park to shift away from being diverse, fire-adapted forests toward becoming less diverse forests that are more susceptible to stand replacement. It seems logical that fire suppression in the greater Mount Spokane area (Figure 63 shows these fire starts) has encouraged this potential; however, we cannot say definitively how the mechanisms of this perceived change are occurring (e.g., climatic cycles or shifts may be a contributing factor).

Forest Health in the Project Area from a Wildlife Habitat Perspective

The forests in the Mt. Spokane State Park project area contain many habitat attributes that are important to wildlife suitability. This forest health assessment found a diversity of forest vegetation types and successional stages that provide habitat for many different species across multiple guilds in the park. While historical logging and interruption of the natural fire cycle has affected many vegetation communities in the project area, most areas remain within the bounds of historic successional patterns and provide key habitat conditions for native species. Importantly, we found exotic species presence to be very low throughout non-developed parts of the project area, which is a good sign of healthy ecosystem processes. We also observed wildlife directly and indirectly, confirming use of the area for those species. Observed wildlife included moose, bear, raptors, cavity nesters, and migrating songbirds.

One area of concern for habitat capability are areas deficient in coarse woody debris and snag presence and density, the largest of which is shown in Figure 95. Logging and fire removed much of the legacy trees and large woody debris once present in this area, leading to regeneration with high amounts of young, even-aged grand fir. Little structural or compositional diversity exists within some patches of this area. Although these areas may provide important habitat conditions for some wildlife species that require early successional forest types, the interior of the patches are lacking in diversity. While small patches add to the landscape diversity, large patches decrease diversity at the stand level.

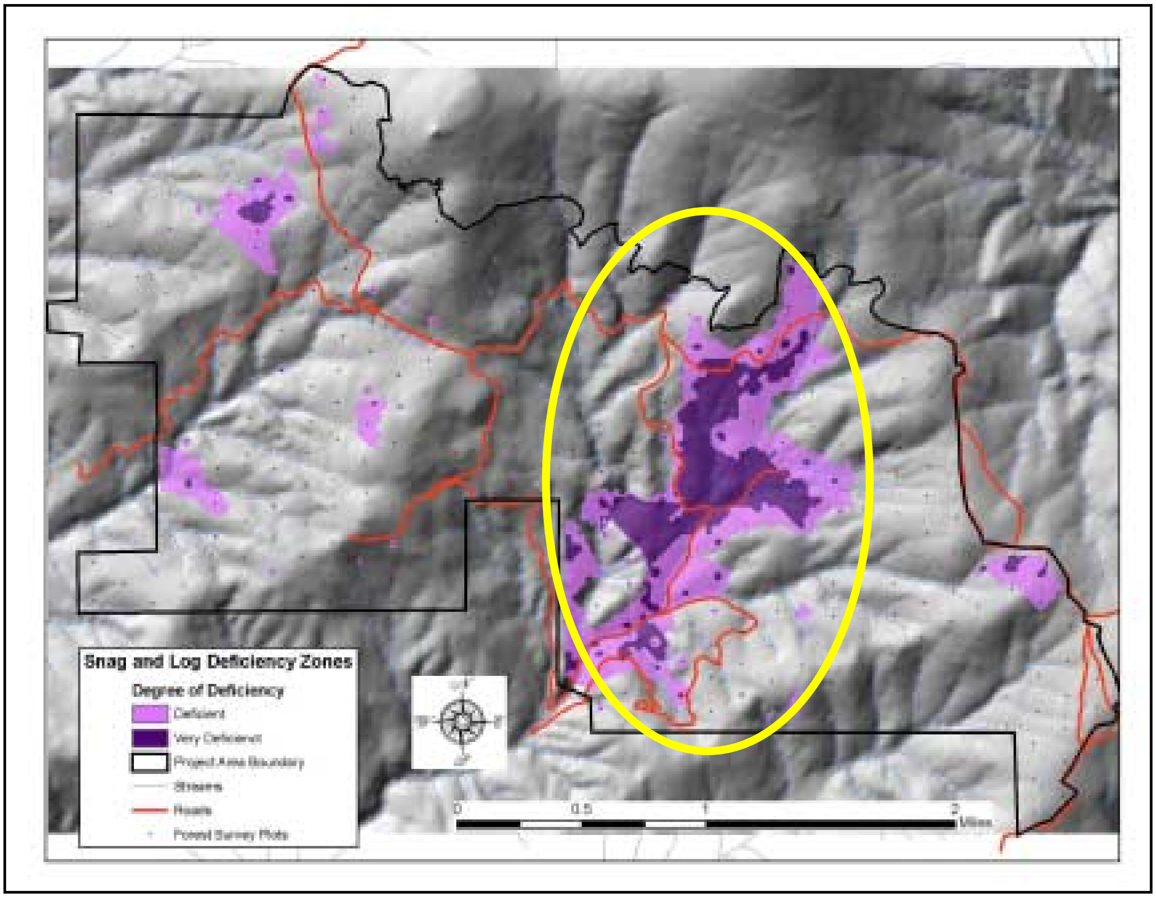

Figure 95. Area of highest concern (in yellow circle) for current wildlife habitat conditions in the project area based on the analysis of snag and log deficiency.

While habitat conditions of the stands shown in Figure 95 could be actively modified, the overall good habitat conditions in the project area (high vegetation structural and compositional diversity) do not merit extensive direct intervention on behalf of improving wildlife values. Instead, forest management goals should focus on conservation of existing habitat conditions in most areas while allowing natural succession to alter habitat conditions. Overall habitat conditions will be maintained or even improve under a conservative forest management strategy that allows natural succession and ecosystem processes to occur in the undeveloped areas of the park. An exception to this occurs in areas where it is may be desirable to regenerate shade-intolerant, fire resistant tree species (e.g. ponderosa pine, Douglas-fir or western larch). Restoration of forests containing more of these species may also create habitats for wildlife species that are now scarce in the present landscape. The areas of the park that may be most suitable for treatments are those based on criteria other than wildlife habitat values. In these areas wildlife values may be improved through retention and creation of more coarse woody debris and large snags (Pilliod and Bull 2006).

In areas where forest prescriptions are proposed (see section entitled An Integrated Plan to Maintain Forest Health and Reduce Fire Risk below), the effects on general wildlife habitat will be marginal to beneficial based on the prescription being implemented. In most cases the majority of species using the treatment units are relatively common in the landscape. Displacement of wildlife by any particular treatment is likely to be temporary and have no significant impact on the health of that species' population. Impacts will be limited in size and will be mitigated by proximity to the adjacent untreated forests. Animals that are temporarily displaced by treatments will have a refuge in the surrounding, non-treated landscape. Only a few proposed treatment areas will be actively treated each year, so only a very small percentage of the park's area would be disrupted by treatments on any given year. In addition, the proposed treatments were designed to retain critical habitat attributes such as large coarse woody debris and snags, and to protect and promote heterogeneous stand conditions. The habitats of the post-treatment areas should be suitable for recolonization by native wildlife species within weeks to months after completion of activities.

Forest Health in the Project Area from a Wildfire Hazard Perspective

Our fire behavior modeling indicated that under average weather circumstances, wildfire hazards are low in the project area at Mt. Spokane. Under most weather conditions, it would be difficult to achieve surface fire flame lengths over two feet in the project area. Even under more extreme fire weather, flame lengths would rarely exceed five feet. This, coupled with the relatively high canopy base height of most stands within the park, results in relatively low risk of torching and passive crown fire initiation. The moist understories in many stands also contribute to reduced fire hazards. Under very extreme fire weather conditions or severe regional drought, wildfire hazards could become a concern. Under these rare circumstances, both passive and active crown fire could spread across the project area and into other parts of the park. Reduction and fragmenting of hazardous fuels can help reduce the likelihood of large crown fires during these extreme fire events.

Overall Forest Health of the Project Area

In our evaluation of the forest health of the project area we identified many factors that are indicators of the relative ecosystem health of the project area. As discussed earlier, forest health is a human concept that depends on the perspective of different observers. The following set of ecosystem criteria were developed by Pacific Biodiversity Institute to serve as a report card of forest health in the project area. These grades are subjective, however, the field data and analyses reported above suggest that these grades are reflective of conditions on the ground.

Report card on indicators of forest health in project area

- Diversity, persistence and resilience of plant communities: A
- Presence, persistence and resilience of globally imperiled plant communities: A+
- Diversity of successional stages and forest structure: B-
- Persistence of pre-settlement tree species diversity: C
- Persistence of fire-resistant trees: D
- Density and cover of understory trees: D
- Excessive tree mortality: A
- Absence of non-native plant species: B+
- Absence of non-native animal species: A
- Absence of history of major human-induced stand and ground disturbing events: D
- Persistence of natural disturbance regime - fire: F
- Persistence of natural disturbance regime - wind: A
- Persistence of natural disturbance regime - insects and disease: A
- Abnormal levels of insect or disease outbreaks: A
- Adequate wildlife habitat for species of concern: B+
- Adequate wildlife habitat for forest dwelling species: B+
- Excessive current hazards related to wildfire spread and severity: B+

The overall forest health in the project area is good and park management does not need to be concerned about a forest health "crisis" at Mt. Spokane. We did not encounter any red-flag areas where the forest health of the project area was imminently threatened. Overall tree mortality rates are normal and the diversity of successional classes and vegetation communities contribute to overall forest health. Exotic species are not affecting much habitat in the forest communities. There are numerous stands with old growth characteristics occurring in the project area, increasing the area's overall ecological significance. Wildlife habitat is adequate for most wildlife species including species of concern. Our overall assessment of the forest health of the project area is very positive. However, we did identify one primary area where improvements can be made.

One Primary Forest Health Issue

The excessive density of young grand fir in the understory of some stands is the primary forest health issue that we have identified. The dense grand fir understories and high levels of grand fir regeneration create the potential for the loss of fire-resistant, shade-intolerant tree species, the possibility of increasing susceptibility to fir engraver mortality and the potential for development of ladder fuels that would carry a surface fire into the tree crowns. Many parts of the project area have small grand fir saplings in excess of 800 stems per acre. One of the forest survey plots exceeded 4,000 trees per acre of grand fir. These young trees compete for nutrients and water with older ponderosa pine, Douglas-fir, and western larch. They inhibit the ability of the fire-resistant tree species to reestablish. By stressing large grand-fir and creating a more homogenous forest composition of primarily grand fir, fir engraver outbreaks can expand to larger areas and create abnormal levels of mortality. Figure 96 provides an example of grand fir encroachment. The smaller grand fir are co-opting soil nutrients, moisture and growing space at the expense of the legacy tree and its potential progeny. The ladder fuels have increased the potential for flames to reach into the legacy tree's crown during a wildfire.

In addition to this overriding, primary issue, there are secondary issues that are discussed in the preceding sections and addressed in the subsequent forest health plan section of this report. These secondary issues include the need to create fuel breaks to slow the spread of wildfire, create more snags and CWD in some places; and the need to regenerate more shade-intolerant species (which, in part, is related to the primary issue.

Figure 96. An example of grand fir encroachment around an old ponderosa pine.

We performed a spatial analysis based on our field-derived data to indicate areas where young tree encroachment is occurring that may be increasing crown fire potential and loss of shade-intolerant tree species and their associated understories. Figures 97 and 98 illustrate the density of all small trees less than 4 inches DBH and the density of grand-fir trees 4 to 8 inches DBH. These are two of the key inputs used to perform the spatial analysis of forest health. Figure 99 illustrates where grand fir encroachment is influencing the regeneration of other forest species.

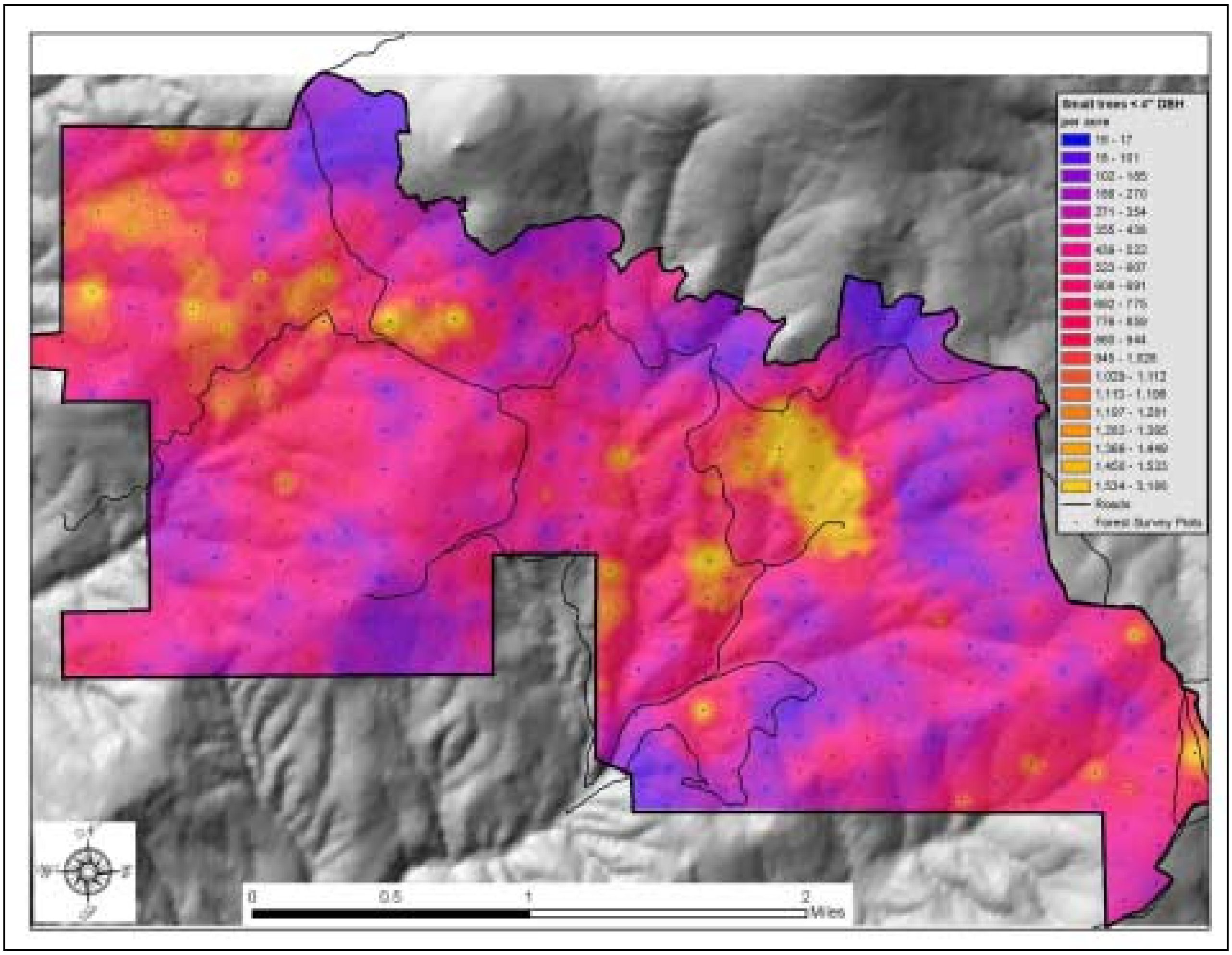

Figure 97. Density of small trees (mostly grand fir less than 4 inches DBH) in the project area. Density units are trees per acre.

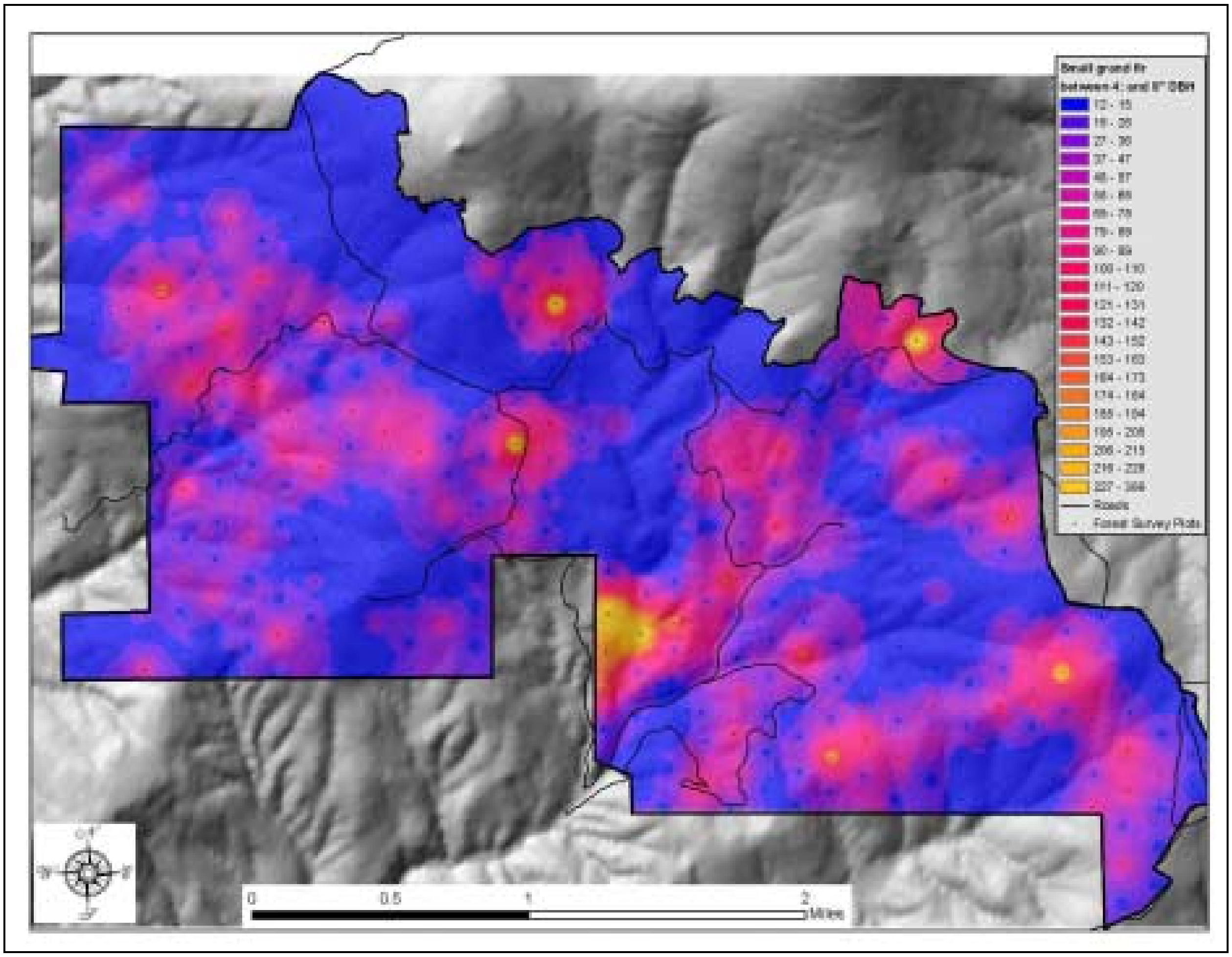

Figure 98. Density of small grand fir between 4 and 8 inches DBH in the project area. Density units are in trees per acre.

Figure 99. Examples of high densities of small grand fir with no regeneration by other species.

A GIS algorithm was developed to calculate to priority zones where forest health might be improved (Figure 100). These two zones are based on presence of fire-resistant legacy tree species (ponderosa pine, western larch and Douglas-fir) and presence of small grand fir encroaching and competing with the legacy tree species. All the values in the formula use the number of trees per acre, except for the cover of small trees which is average percent cover.

The definitions of the variables used in the algorithm are as follows:

- PIPO refers to a GIS raster surface containing the number of ponderosa pine trees on a per acre basis
- PIPO+PSME+LAOC refers to a GIS raster surface containing the number of fire resistant conifer trees and is the sum of the Douglas fir, western larch and ponderosa pine trees on a per acre basis.
- SMALL TREE NUMBER is a GIS raster surface containing the number of small trees less than 4 inches DBH of all species on a per acre basis.
- SMALL TREE COVER is a GIS raster surface containing the percent cover of small trees less than 4 inches DBH of all species.

- SMALL ABGR is a GIS raster surface containing the number of small grand fir trees 4 to 8 inches DBH on a per acre basis.
- PRIORITY ZONE 1 is a GIS raster surface containing the first forest health priority zone
- PRIORITY ZONE 2 is a GIS raster surface containing the second forest health priority zone
- COMBINED FOREST HEALTH PRIORITIES is a grid combined forest health priority zones

PRIORITY ZONE 1 = exists where (PIPO > 0.5 or PIPO+PSME+LAOC > 20) and (SMALL TREE NUMBER > 200 and SMALL TREE COVER > 10) or SMALL ABGR > 40)

PRIORITY ZONE 2 = exists where (PIPO > 1 or PIPO+PSME+LAOC > 50) and (SMALL TREE NUMBER > 350 and SMALL TREE COVER > 15) or SMALL ABGR > 60)

COMBINED FOREST HEALTH PRIORITIES = PRIORITY ZONE 1 + PRIORITY ZONE 2

An ESRI Arc Macro Language (AML) script used to implement this algorithm is listed in Appendix J.

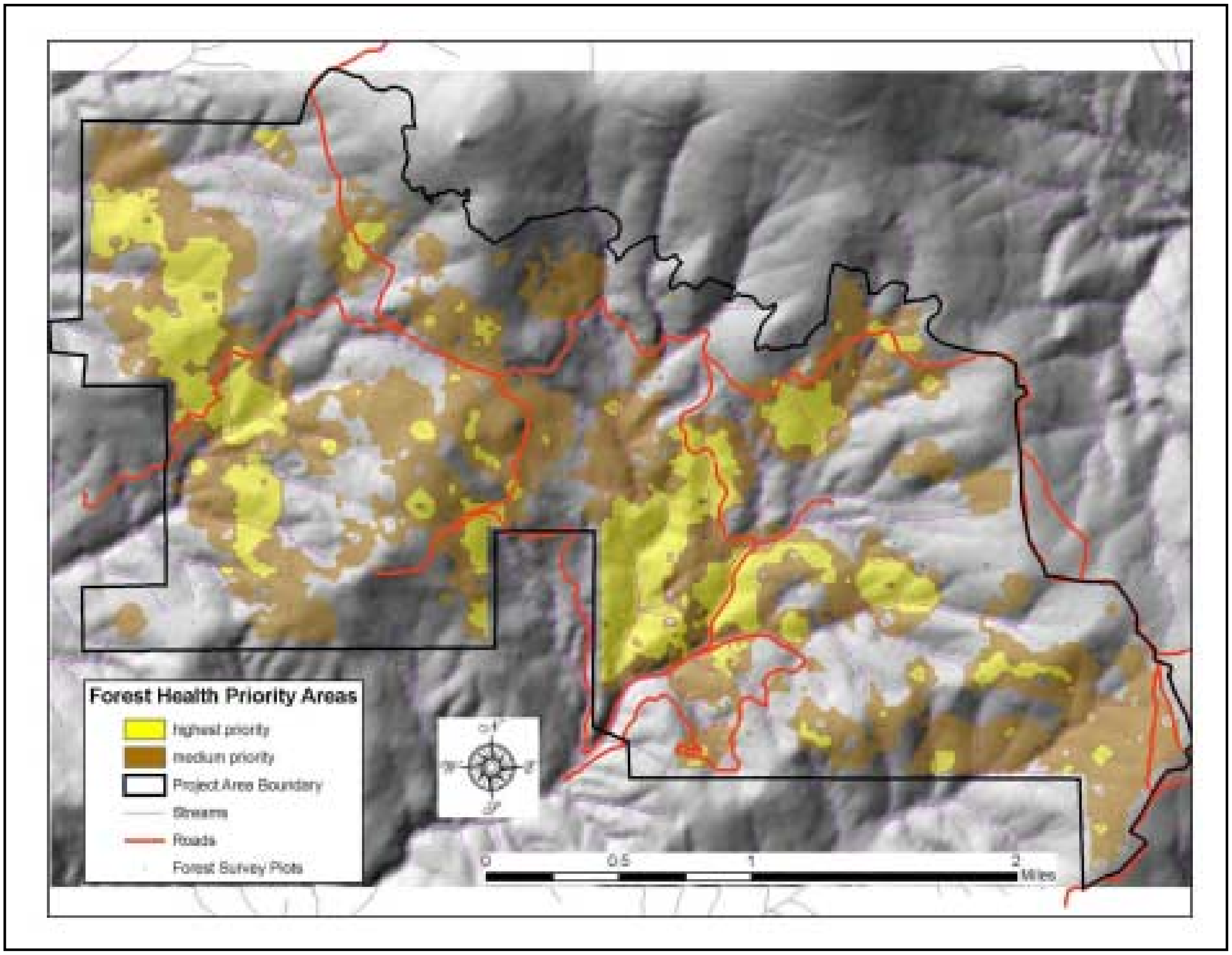

Figure 100. Areas of moderate to high risk of losing historic ponderosa pine, western larch, and Douglas-fir dominated forests due to grand fir encroachment.

An Integrated Plan to Maintain Forest Health, Rehabilitate Habitat, and Reduce Fire Risk

Our overall assessment of forest health in the project area indicates that much of the area is in relatively good health and does not need extensive treatment. However, we have identified areas where forest health can be improved, wildlife habitat elements supplemented and fire hazards reduced. We address these issues in this integrated forest plan. We have designed strategic fuel treatments, which can help reduce the risk of stand-replacing wildfires burning through large areas of the park – one of the primary objectives of Washington State Parks. Other objectives of this plan are to: "create a forest mosaic rich in structure and vegetation diversity, where the vast majority of stems are healthy; protect and create habitat for a diversity of native plants and animals; protect cultural resources of statewide or regional significance; provide a safe and aesthetically pleasing environment for visitors; and, inform the public of these forest health efforts" (Mt. Spokane Forest Health RFP 2006).

Ten general treatment options applied to 45 potential *treatment units* comprising 1,470 acres have been developed. These treatment units are located in six general zones that we identify as being *priority zones (or regions)* for active forest management. We also propose a schedule for treating each of the 45 units during a 15 year timeframe. Treatment of all the proposed units is not mandatory for the overall forest health plan to succeed. It is also important to note that forest conditions in many of the treatment units are quite diverse and, thus, any particular treatment option may not necessarily be applicable for uniform application across a given unit. In many cases, certain areas should remain untreated or with only localized treatment in specifically targeted areas.

The location of treatment units and treatment options selected for units is a result of our comprehensive forest health assessment combined with practical planning aspects and many other ecological and environmental considerations. For example, most of our treatment areas are located on or near the existing road network. This is due to six factors:

1. Ecological impacts of building new roads can be substantial and result in harm to forest health and ecological integrity (Gucinski et al. 2000, Morrison 1975, Morrison 2007, Trombulak and Frissell 2000, USDA Forest Service 1999, USDA Forest Service 2000).
2. The vast majority of wildfires are human caused and are started next to roads (Morrison 2007), therefore fire hazard reduction is most effective if it focuses on the potential ignition zone along road corridors (Morrison 2005, 2006; Morrison and Smith 2005).
3. Practical dimensions of accessing areas in a cost effective manner. Areas adjacent to existing roads can be readily accessed without incurring large access costs.
4. Our assessment of wildfire behavior indicated that many of the areas that were predicted by spatial fire modeling to have the highest flame lengths happened to be near the existing road system (Figure 79).
5. Our assessment of forest health issues indicates that many of the areas with greatest degree of grand fir encroachment and competition with fire-resistant, shade-intolerant trees occur near the existing road system (Figure 100).
6. Our assessment of wildlife habitat conditions indicates that many of the areas with greatest opportunity for augmentation of snags and CWD occur near the existing road system (Figure 95).

Other considerations in the location of treatment units and treatment options include the influence of park infrastructure, such as electrical transmission lines and buildings. In addition, the overall good condition of the forest vegetation and wildlife habitat suggests that aggressive suite of treatments touching all stands in the project area is not warranted. Furthermore, the existing road network crisscrosses the project area, creating opportunities for treatments applied along these corridors to slow the spread of crown fires under extreme fire conditions. Finally, aesthetic and recreational issues are considered. Treatment unit locations and treatment options that will enhance wildlife habitat and promote early-successional forest types are given priority.

Our overall goal is to maintain a diverse mixed conifer forest at Mt. Spokane that supports high quality habitat for a variety of wildlife species and to encourage the development of fire-adapted forests, while maintaining recreational values. The forest health plan is designed to treat the highest priority areas over a fifteen-year period using a variety of treatment types including prescribed fire and mechanical prescriptions. Many areas require only minimal treatment or no treatment. Some of the treatment units are proposed for treatment after the initial five-year time period. This forest health plan should not be considered a rigid plan of action. Our intention is that adaptive management approaches will be implemented through the plan period and that Washington State Parks will learn from the experience of implementing this plan, and will modify timing or treatments to best achieve the objectives outlined below. The objectives are the most important part of the plan and there are numerous means for achieving these objectives.

The eventual success of this forest health plan relies largely on careful implementation, monitoring and maintenance. It is essential for Washington Parks to utilize highly qualified and experienced crew managers to oversee implementation of the treatments outlined below. It is also important to carefully monitor treatment areas before, immediately after and in the following years to better learn what works and how to fine-tune treatments in the future. It is essential to acknowledge that there are no “one-shot” solutions to forest health problems. Long-term monitoring and regular maintenance of treated areas are essential to achieving the specific objectives of the treatments we have developed in the outline below:

Forest Health Treatment Objectives

1. Reverse the trend of forests in the project area moving toward significantly denser grand fir forests.
2. Reduce the risk of catastrophic stand replacement wildfires in Mt. Spokane State Park.
3. Further the development of late successional forests.
4. Protect existing legacy trees of ponderosa pine, western white pine, western larch and Douglas-fir.
5. Encourage the development of more fire-resistant forests through gradual conversion of grand fir dominated forests to domination by relatively shade-intolerant ponderosa pine, western white pine, western larch and Douglas-fir forests.
6. Create opportunities for recruitment of ponderosa pine, western white pine, western larch and Douglas-fir.
7. Encourage the growth of lush deciduous shrub and tree species (e.g. Douglas maple, Sitka alder, Scouler's willow, aspen, birch, cottonwood) in stands. These species have a fire-retardant effect due to their high live fuel moisture content. Increasing their prevalence in forest stands at the park will reduce fire hazard. Deciduous trees are important for browse and provide nesting and denning habitats.

8. Increase the number of large snags in identified snag augmentation priority areas to improve habitat for snag dependent species.
9. Augment coarse woody debris to improve wildlife habitat in areas where CWD is currently deficient.
10. Encourage the development of forest stand conditions that can be easily maintained by regular use of prescribed fire with little need for pre-treatment.
11. Reduce possibilities for large lodgepole pine dominated stands forming in the park after prescribed fire or wildfire.

Approach

Our approach to conducting forest health treatments is conservative, as we believe that many treatments can easily do more harm than good (Dombeck 2001, Morrison et al. 2001). There are numerous examples across the western United States where forest treatments have resulted in increased fire hazards, and where large acreages of treated areas have burned in stand-replacing wildfires soon after the treatments (Graham 2003, Morrison et al. 2000, Morrison et al. 2001, Morrison and Harma 2002, Harma and Morrison 2003a, Harma and Morrison 2003b, Morrison 2005). Forest health treatments that are not carefully designed and implemented can also result in forest stands moving along unintended successional pathways. More aggressive forest health treatments can increase fire hazards and the risk of unintended changes in forest stand composition and structure. Therefore, most of our treatment options are relatively conservative. We propose leaving nearly two thirds of the project area untreated during the next 15 to 20 year period, because as noted earlier, these areas generally support healthy forest conditions. Most of the treatment options use prescribed fire either alone or in conjunction with some limited mechanical treatments. It is our professional opinion that forest health issues, which have largely resulted from fire exclusion policies, are best addressed by the reintroduction of prescribed fire.

A guiding principle in the development of many of our treatments was to be preemptive wherever possible. This was especially true in areas that are just beginning to exhibit grand fir encroachment into stands that were historically dominated by fire-resistant tree species (e.g., ponderosa pine and western larch). Although these stands may not currently suffer from severe forest health problems, they can be treated now at relatively minimal costs compared to waiting until the grand fir has come to heavily dominate the understory. It is better to restore forests to a more fire-resistant condition in the near-term, than to wait until conditions deteriorate, requiring the application of more complex, more expensive and potentially less successful future treatments. We also propose treatments in some areas that currently have severe and complex problems with grand fir encroachment and other forest health issues. We recommend that Washington State Parks approach these more difficult areas cautiously and make sure that sufficient resources and oversight is in place to successfully implement the treatment option chosen for the area. It is important to remember that forest health treatments can do more harm than good, if not carefully chosen, implemented, monitored and maintained.

Another guiding principle was that existing forest canopies should be left largely intact. Reductions in canopy cover and canopy bulk density are limited except where it is necessary to break canopy fuel continuity to impede the potential spread of crown fire. Forest canopies should be left largely intact to provide shade and mitigate the effect of wind in a fire event. Intact forest canopies also help prevent lofted embers from igniting dry fuels on the forest floor, since the embers are intercepted by the live canopy, which is difficult to ignite. Intact forest canopies also provide wildlife habitat - a primary objective of this project. Also, intact forest canopies add to the aesthetic and recreational experience of park users.

The shading and wind reduction effects of intact forest canopies are very significant in reducing fire risk (Countryman 1955). Opening of the canopy can adversely affect forest health and fire behavior in at least four ways. First, growth of understory vegetation is promoted due to increased sunlight reaching the forest floor. This can lead to an increase in small grand-fir seedings and their rapid development, which is counterproductive. Secondly, both fine and large fuels that are present below the canopy dry out more rapidly due to increased solar radiation and increased air circulation. Third, increased solar radiation resulting from canopy thinning creates a warmer fire weather microclimate. Fourth, during a wildfire, winds are able to penetrate the opened forest canopy more readily. These winds are able to push a fire through a cut stand much more rapidly than through an uncut forest. This fact is now well established and used extensively in fire modeling approaches. For instance, most of the stands in the project area have at least 70% canopy cover. Our fire behavior modeling analyses based on this level of canopy cover used a wind reduction factor of 0.10 (Figure 101).

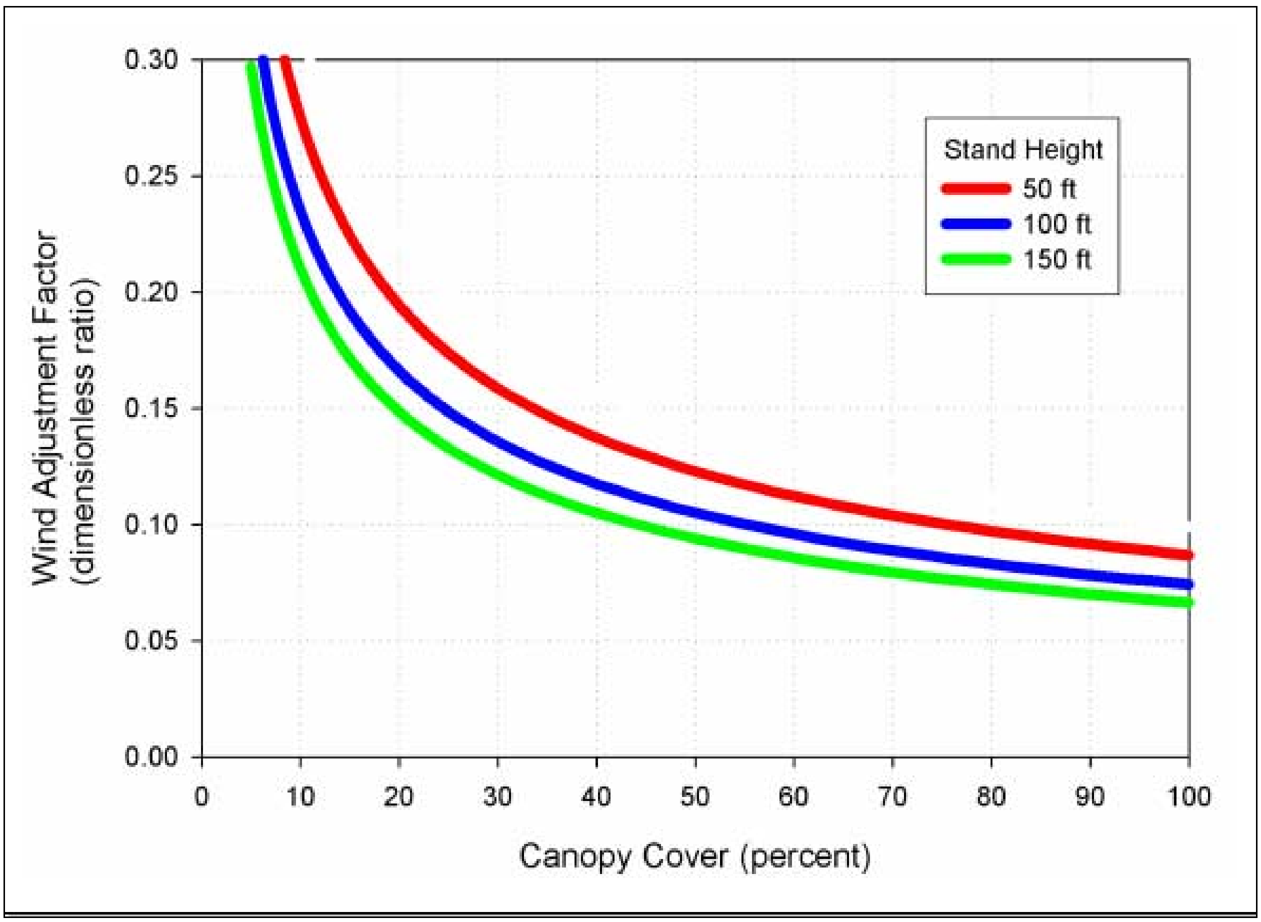

Figure 101. Wind adjustment factor illustrating the effect of increasing canopy cover on lowering mid-flame winds. (Finney 1998 and NEXUS software help documentation)

As with most management decisions, however, there is always a tradeoff. Reduction in canopy bulk density has been widely advocated as a means to reduce the potential for crown fire spread

(Agee 1996, Scott and Reinhardt 2001, Agee 2002, Peterson et al. 2005, Johnson et al. 2007). Reduction in canopy bulk density usually necessitates a reduction in canopy cover, which results in amplification of surface fire behavior. There is a trade-off between reduction in the potential for crown fire spread and the severity of surface fire. Our prescriptions attempt to balance these two factors by achieving only moderate reduction of canopy bulk density while maintaining relatively high levels of canopy cover. This is achieved by thinning of the smaller understory trees (thinning from below) while leaving most midstory and nearly all overstory trees. We will use prescribed fire and manual or mechanical thinning to accomplish thinning from below.

In much of the project area snags and logs are abundant and provide optimal habitat for the species that require coarse woody debris for a portion of their life cycle. But, areas deficient in these two habitat elements exist in the study area (Figure 95). The treatments that we propose in these areas will augment both snags and logs through several mechanisms. First, some mortality of standing live trees is predicted as a consequence of prescribed fire. The FOFEM analysis of prescribed burns in the project area indicates that 3 to 50% mortality of the mid size and larger trees in a stand can be expected as a result of prescribed fire (Table 14). This mortality will create standing snags, which will eventually fall and become logs on the forest floor. This is nearly identical to the natural cycle of snag and log creation. In areas where snags and/or logs are not adequate and sufficient snags and/or logs will not be created as a result of prescribed fire they can be created by girdling of selected live trees to create snags or by felling of live trees to create logs. Preferably, these will be created by killing shade-tolerant, thin barked species such as grand fir or western hemlock.

As discussed in previous sections of this report, past logging in the project area, combined with fire exclusion, has resulted in dramatic decreases in fire-resistant tree species such as ponderosa pine, Douglas-fir, and western larch. Our approach in the forest health treatment units is to promote the reestablishment of these species where they once naturally occurred, and to protect existing trees of these species where possible. Some treatment options specifically focus on protection of these species, while others incorporate actions aimed at both protection and creation of favorable site conditions for the reestablishment of these fire-resistant species. Our overall goal is to maintain a diverse mix of forest types at Mt. Spokane that supports high quality habitat for a variety of wildlife species and welcomes recreational usage, while encouraging the redevelopment of more fire-adapted forests.

Use of spatial fire modeling to aid in locating treatment units and treatment types

We used the spatial fire models (FlamMap and FARSITE) to help us evaluate the effects of both treatment location and treatment type on the spread and severity of wildfire across the project area and the greater Mt. Spokane landscape. Our investigation of weather conditions in the vicinity of Mt. Spokane revealed that prevailing winds normally blow from the southwest during extreme fire weather. Our investigation of fire occurrence in the vicinity of the project area revealed that relatively few fires have started within the state park; most fires have started outside the park (Figure 63). These two factors suggest that the most likely wildfire to threaten Mt. Spokane State Park would start west of the park on private lands and then spread into the park driven by winds from the southwest. We used FARSITE to model such a fire and simulated the effect of several fuel treatment types implemented in various locations across the project area. Figure 102 illustrates one of these simulations.

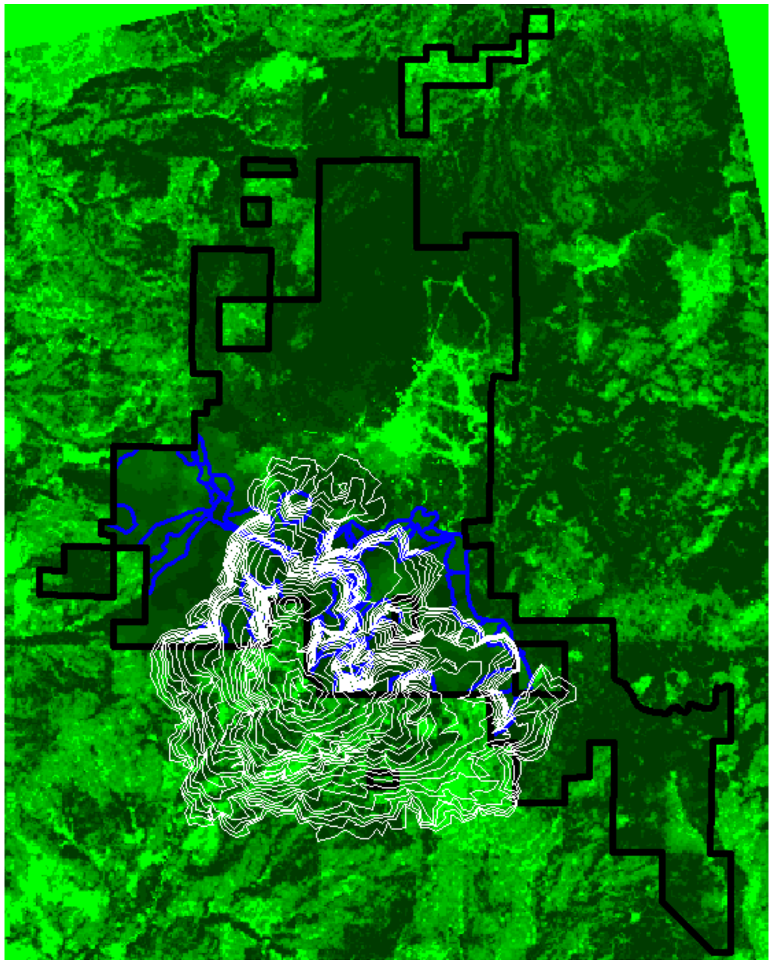

Figure 102. FARSITE simulation of a wildfire burning under the August 1991 firestorm conditions and its interaction with proposed treatment units. The background image is a display of canopy cover increasing from light green to dark green. The thick black line is the park boundary, the blue lines are the boundaries of proposed treatment units and the white lines indicate the fire progression. Each white line represents 2 hours of time.

The simulation was started near the highway south of the park boundary. This simulation shows how the Treatment Units (bounded by blue lines) cause the wildfire to slow or stop. Each white line indicates 2 hours of fire progression. Where the lines are close together, the fire is slowing or stopping. The treatment units (explained below) form a barrier for fire spread further up the mountain, except where fire burns through a gap where treatments have not yet been prescribed.

These simulations, combined with the result of other fire models applied to the project area (and some common sense), indicated a set of treatments and locations that would impede the spread of such a fire across the Mt. Spokane landscape. This leads to the development of a strategy based on a series of zones, with treatments in the first three zones (described below) forming a barrier to fire spread up the mountain and to other areas of the state park. Treatments in the other zones were designed to limit fire spread within the project area. The treatment zones, treatment types and unit locations are discussed further below. The use of spatial fire modeling in developing the forest plan is discussed in more detail below.

Treatment Zones (Regions)

As we developed the forest plant for the project area, we divided the study area into six zones for the application of forest health treatments (Figure 103). The zones were created to aid in an initial prioritization of the landscape based on infrastructure and property boundaries. We developed six zones within which to design treatments that would meet the project's goals and objectives. Treatment of areas in Zone 1 is considered higher priority than treatment of areas in Zone 2. The zones focus on various parts of the existing road system or the park/private land boundary on the west and south side of the project area. We recommend that treatments commence in Zone 1 during the first year of implementation. In later years, treatments may be conducted in multiple zones at once. However, Zone 5 is a lower priority that should be deferred until later in the planning period. We do not recommend any treatment in Zone 6 during the planning period, except in a few limited situations, where part of a treatment unit is located adjacent to a higher priority zone.

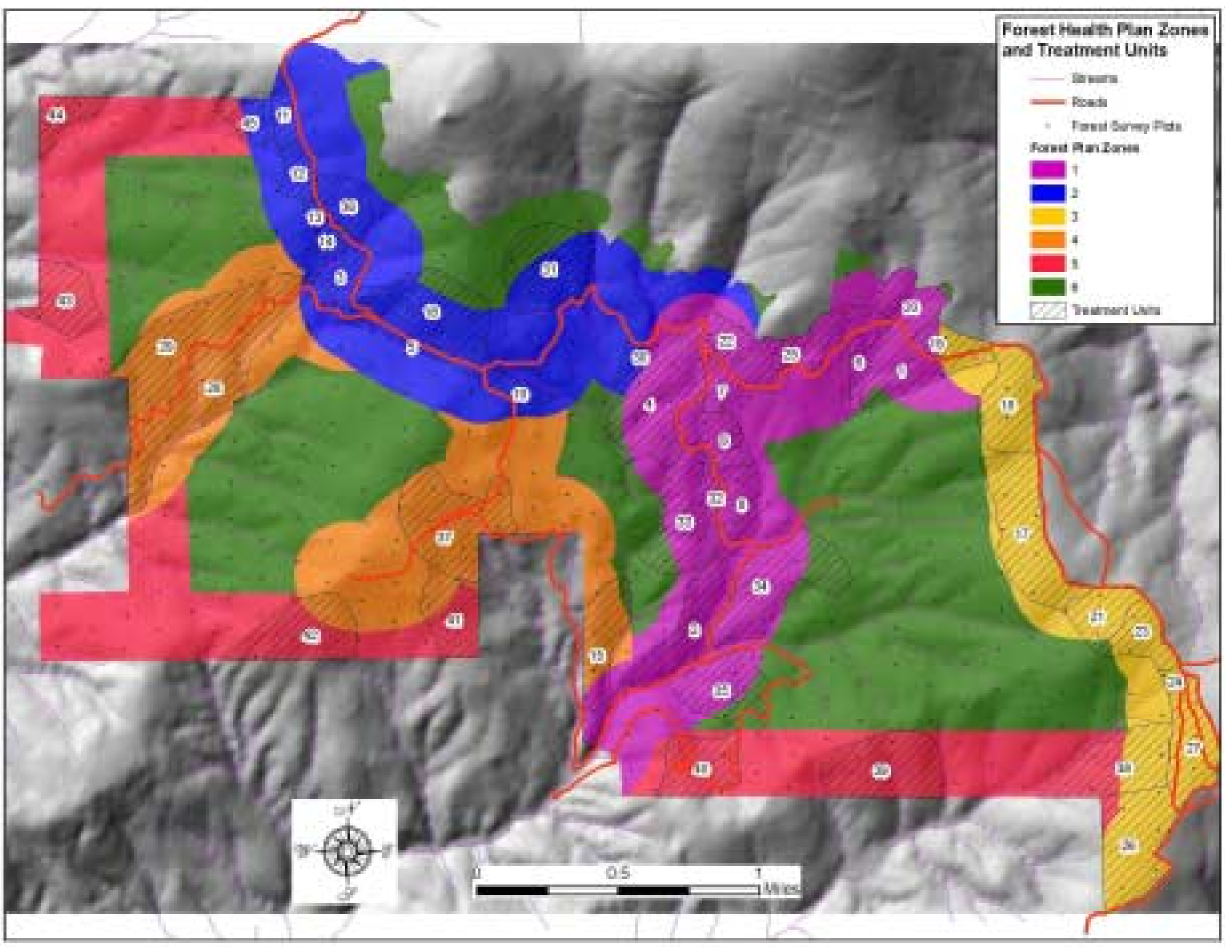

Figure 103. Forest plan zones and proposed treatment units.

Zone 1.

The first zone occurs along the main paved road in the project area. The objectives of treatments in this zone are to break up the continuity of fuels so that fires that start in the lower part of the mountain encounter depleted fuels as they go upslope. Another objective within this zone is to improve conditions for establishment of fire-resistant tree species and reduce stress on old fire-resistant trees that are surrounded by competing young grand fir. Treatments in this zone will also help create more snags and large logs that benefit wildlife species. Finally, these treatments will reduce the chance that human-caused fires will spread beyond the road right-of-way by treating potentially flammable areas along the main road.

Zone 2.
The second zone occurs along the Mt. Kit Carson Loop Road. The objectives for treatments in this zone are the same as in Zone 1, but are considered somewhat lower priority due to reduced amounts of human travel owing to road closures. This is an important treatment zone designed to block wildfires starting west of the park from spreading to the east and up the mountain.

Zone 3.
The third zone occurs along the ridge road running south through the cross-country ski area from the Selkirk Lodge. The objectives for treatments in this zone are the same as in Zone 1, but are considered somewhat lower priority due to reduced amounts of human travel (road closures). It is also the highest elevation zone, with the highest precipitation and coldest temperatures in the project area. Because of these climatic factors, the forests in this zone are less altered by the effects of fire exclusion and their condition is closer to the normal range of historic variability. This is an important treatment zone designed to block wildfires starting south of the park from spread to the northeast and up the mountain. It also blocks fires that start east of the park on private timberlands from moving to the west and into the project area.

Zone 4.
The fourth zone occurs along the Mt. Spokane Day Road running west from the Mt. Kit Carson Loop Road to the park boundary, and the spur road running south from Smith Gap. This area has some of the best remaining old-growth forest in the project area, with large, old ponderosa pines, Douglas-firs and western larches. The objectives for treatments in this zone are the same as in Zone 1, but are considered somewhat lower priority due to reduced amounts of human travel on account of road closures. Treatments in this zone will help to impede the spread of wildfire within the project area.

Zone 5.
The fifth zone occurs along the park boundary where it abuts private land on the south and west sides of the park. This area also has some old-growth forests with large, old ponderosa pines, Douglas-firs and western larches. The objectives for treatments in this zone are the same as in Zone 1, but are considered somewhat lower priority due to reduced amounts of human travel because of the absence of park roads. Access to treatments in this zone would require cooperation of existing land owners and would concentrate on areas that are readily accessible from the existing private road network outside the park. Treatments in this zone will help to impede the spread of wildfires originating south and west of the park.

Zone 6.
The sixth zone consists of the interior portion of the study area that is not as readily accessible from the current road system. Although a few forest health issues exist in some parts of this zone, the overall forest health is good. The objective of slowing or stopping the spread of fire throughout the park can be accomplished without treating this zone. Access to this zone to conduct treatments would often require building new roads, which is well documented to cause ecological damage (Gucinski et al. 2000, Morrison 1975, Morrison 2007, Trombulak and Frissell

2000, USDA Forest Service 1999, USDA Forest Service 2000). Cost for treatments in this zone would also be much greater than in the other five zones due to the inaccessibility of these areas.

Restrictions that apply to all treatments

Before addressing the various treatment options that are outlined below, we recommend that the following restrictions be applied to all treatments occurring in the project area except in exceptional circumstances where management objectives or forest conditions indicate modification of the restrictions is appropriate. We recommend that sound justification should be developed before modifying these restrictions.

- No cutting of large diameter (exceeding 24 inch DBH) mature and old-growth trees.
- No cutting of ponderosa pine, western larch or western white pine unless dense patches occur where inter-tree competition would impede development of a mature stand composed of these species.
- No cutting of Douglas-fir, unless Douglas-fir stems occur at a density over 100 trees per acre, and then, no cutting of trees over 12 inch DBH.
- No construction of new roads.
- No use of mechanized harvesting equipment on slopes greater than 20%.
- No skidding of logs on slopes greater than 30%.
- No skidding of logs on any slope where long-term soil damage could result.

Treatment Types

We have considered a wide variety of potential forest management treatments to alleviate various forest health issues and to improve wildlife habitat and recreational experiences in the project area at Mt. Spokane. Our exploration of treatment types has included extensive surveys of the existing literature on forest health treatments (Agee 1996, Agee 2002, Brown 2001, Graham 2003, Johnson et al. 2007, Lane 1995, Mutch 1994, Omi and Joyce 2003, Peterson et al. 2005, Swanson 2000, Tiedemann 2000, Winter 2002), and consultation with several foresters, fire specialists and wildlife biologists. This section describes ten types of treatments (or "treatment options") that appear to be best suited to the project goal and objectives, and the issues and needs in the project area.

Each treatment option considers a wide range of issues and objectives. The existing forest condition and the location of the stand from a landscape perspective are both important initial considerations when deciding on what particular treatment type (or option) is appropriate for a stand. In developing these treatment options and applying them to particular stands we considered all the project's primary objectives: creating a forest mosaic rich in structure and vegetation diversity, reducing the risk of catastrophic wildfire, protecting and creating habitat for a diversity of native plants and animals, protecting cultural resources of statewide or regional significance and providing a safe and aesthetically pleasing environment for visitors (Project Goals section).

These ten treatment types (or options) are mapped in Figure 117 and listed below. Each treatment type is also described below in more detail.

1. Minimal active management – relies on natural successional processes and natural disturbance processes.
2. Prescribed fire with minimal pretreatment.
3. Prescribed fire with significant manual pretreatment.

4. Limited hand piling and burning of fuel accumulations.
5. Protection of legacy trees through focused thinning of small grand fir around legacy trees and pile burning in a limited area.
6. Extensive non-commercial thinning of small grand fir with protection of largest trees and all legacy trees (ponderosa pine, Douglas-fir and western larch) followed by pile burning and/or prescribed fire.
7. Extensive non-commercial thinning of small grand fir with protection of the largest trees and all legacy trees (ponderosa pine, Douglas-fir and western larch) followed by mechanical chipping and/or mastication of treatment slash.
8. Combined non-commercial thinning of small trees and commercial thinning of grand fir, western hemlock, and lodgepole pine followed by pile burning and/or prescribed fire.
9. Road zone treatment - designed to create shaded fuel breaks along roads through commercial harvest of selected species, reduction in canopy bulk density, thinning of young grand fir and use of prescribed fire.
10. Chipping and/or mastication - mowing and chipping and/or mastication of small trees in accessible areas along roads and trails.

Option (Treatment Type) 1 - Minimal active management – rely on natural succession processes and natural disturbance processes to alleviate forest health issues

This option may be preferable as the only treatment or the principal treatment for many of the treatment units. In some cases the majority of a treatment unit is in good forest health and does not require active management (Figure 104). In other cases the treatment unit possesses such complicated health issues and/or other planning complications that we feel active management may not be a viable solution (Figure 105). In these cases, treatments can do more harm than good. Wildlife habitat value, access constraints, riparian zones, human development, and slope steepness are all factors that contribute to consideration of using Option 1 for a given area.

Most of the stands that are designated in this plan for Option 1 are mature or late-successional forests. These stands have already moved through the stem-exclusion phase of forest stand development. They either currently have late successional forest characteristics or are in the process of developing these characteristics. Option 1 will allow these successional processes to proceed and in time the mature stands and the current late successional stands will have similar structural appearance.

When Option 1 is applied to a young, early-successional stand, the stand will naturally thin itself over time as it moves through the stem-exclusion phase of forest stand development. With time, most of the young trees will die from competition for moisture, nutrients and sunlight. The old, fire-resistant, legacy trees may eventually die because of the intense competition for moisture and nutrients from the young trees (principally grand fir in the project area). Wildlife habitat conditions will gradually improve with time and understory diversity will increase, because surviving trees will become larger, eventually creating large snags and logs. However, 100 to 200 years of succession may be necessary to attain optimal development of habitat components for some sensitive wildlife species. Wildfire hazards associated with surface fires in most young dense conifer stands in the project area will remain fairly low for at least the next 20 years. Active crown fire potential will remain high in dense young stands during extreme fire weather conditions during most of the successional period and perhaps beyond.

Irrespective of age, the high canopy cover and overlapping tree canopies of most of the stands in the project area will afford some degree of protection from fire ignition by spotting embers, as burning embers would be intercepted by the green canopy and fail contact dry surface fuels. This applies to all Option 1 stands in the project area with high canopy cover.

We recommend encouragement of human use and enjoyment of these Option 1 forest stands, while discouraging potentially destructive activities such as woodcutting, camping or campfires. Where possible, wildfires should be allowed to burn through these areas, with control and suppression areas concentrated at key points near active treatment areas and along road networks.

Eventually, the goal of this forest plan is to reintroduce fire to most of the stands in the project area as an important ecosystem process. Option 1 stands were determined to be lower priority for active reintroduction of fire than stands designated for other treatment options.

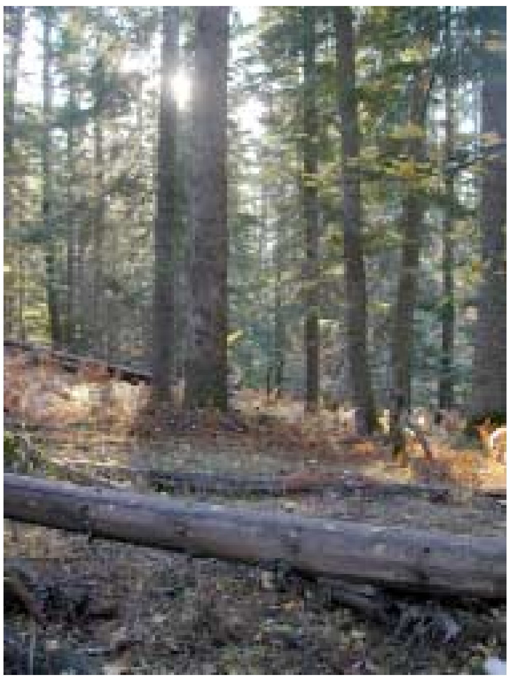

Figure 104. Photo of Plot 251 in western portion of project area where forest health is excellent and no treatments are needed.

Photo of Plot 317 on the edge of the project area. This is an there was extensive insect mortality over a and now there is a high loading of logs on and standing snags. There are also many fir seedling and saplings. While this area from treatment, there are many this stand that make treatment expensive unsuccessful.

Figure 105. northwest area where decade ago the ground young grand might benefit complexities in and potentially

Objectives for Treatment Option 1

Resource Objectives
To the extent possible maintain natural disturbance processes and successional processes. Allow these natural processes to gradually (or quickly in the case of some disturbance processes) transform the forests in the Treatment Unit. Eventually, if natural processes are allowed to operate, the stands in the Treatment Unit will move toward late-successional forest condition or toward a forest that resembles a historic post-disturbance forest.

Option 2 - Prescribed fire with minimal pretreatment

This treatment option uses prescribed fire to achieve resource objectives without significant pretreatment. This treatment option may be optimal for stands where some fuel reduction is desirable for fuel break purposes (e.g. zones 1 to 3 above) and where forest health conditions have not deteriorated to the point where extensive pre-treatment is needed. Figure 106 illustrates such a stand in an area we recommend for application of this treatment option. This option requires sufficient fine fuels to carry a fire under a late spring or early fall burn scenario. Canopy base heights must be high enough to avoid excessive torching and initiation of crown fire during burning operations. Prescribed burns would be conducted to produce 0.5 to 2 foot flame lengths. See Figure 107 for example photos of this type of treatment.

This treatment option should be applied repeatedly to the selected stands. During the 15-year project period, two applications may be needed to achieve objectives. Subsequently, application of this treatment every 15 to 20 years is desirable in many stands.

Figure 106. Forest conditions at Plot 73 where we recommend application of treatment option 2.

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Figure 107. Example photos of an Option 2 prescribed burn (photos taken from a prescribed fire in a mixed conifer forest in California).

In areas where public use is high and aesthetics are of concern, litter and flammable duff can be raked away from large logs to prevent them from igniting and charring during the burn. This will help to reduce smoke production, and limit the duration of the burn. Rearrangement of coarse fuels will also be done in places where coarse woody debris is in short supply to protect wildlife habitat. The fire crew should be instructed not to ignite large logs.

Likewise, raking of litter accumulations and fine fuels away from select old-growth legacy trees and large snags could help protect them from the effects of fire. This technique has recently been successfully implemented at the Sinlahekin Wildlife Area in Okanogan County. Surveying for and marking suitable trees and snags for protection in the treatment area would need to be conducted. Conversely, it may be desirable to rake litter and pile debris around the base of some of the larger grand firs in the stand to increase the probability that they will be killed in the burn and create high quality snags. The use of volunteers should be explored to help with efforts to protect legacy trees or create snags by pre-burn raking of litter and fuels.

Prescribed Fire Treatment Plan

Fire lines would primarily consist of existing roads, and prepared hand lines around the unit where roads are not adequate to contain fire in the unit. Prescribed fires would be ignited in across-slope strips progressing from a high point and moving down slope. The prescribed fire would be ignited during predictable winds and the crew would start on the windward side of the unit and progress toward the wind, thereby minimizing smoke inhalation problems. The burns could be undertaken during a variety of weather conditions, but the best conditions would probably occur in the late spring, when duff and coarse woody debris moisture levels would be adequate to avoid significant consumption of duff and large logs. The prescription requires dry enough conditions for the fire to spread and consume adequate surface fuels however. The burn should be ignited during weather conditions when surface flame lengths of 0.5 to 2 feet can be maintained.

Objectives for Treatment Option 2

Resource Objectives	Prescribed Fire Objectives
1. Reduce surface fine fuels and break up fuel continuity, thereby reducing potential wildfire intensity and severity, while enhancing suppression effectiveness and moving toward a more sustainable fire regime.	1a. Fuel Reduction: 70-100% reduction of 0-3 inch diameter fuels, with less than 30% reduction of >3 inch diameter fuels. 1b. Scorch lower live limbs of >10 inch DBH trees up to 8-10 feet above ground level. Increase canopy base height in cases where it is currently low.
2a. Reduce density of very small grand firs so that high densities of small and medium size grand fir do not develop as in other areas of the park. 2b. Maintain high overstory canopy cover and shift overstory composition to more western larch, Douglas-fir and ponderosa pine	2a. Kill small grand fir through cambium kill and moderate canopy scorch. 2b. Limit mortality to larger trees by maintaining prescribed flame lengths and in some cases, raking fuels away from selected trees.
3. Snag creation and protection	3a. Create new large snags via fire kill of a few medium to large trees (see Figure 78 and Table 14 above). This will eventually augment CWD (see #4 below). 3b. Where practical, protect existing large snags by avoiding direct ignition during prescribed burning activities.
4. Large CWD creation and protection 5. Encourage understory growth (herbs and shrubs) that provide important wildlife habitat.	4. Where practical, protect existing large logs by raking litter away from them and avoiding direct ignition. 5. Provided burn is not too hot, resprouting of shrubs should occur and a seedbed developed.

Option 3 - Use of prescribed fire with significant manual pretreatment

This treatment option uses prescribed fire with significant pretreatment (manipulation of fuel strata with hand held tools) at least 3 months prior to burning to achieve resource objectives. This option should be used where there are insufficient fine fuels to carry a fire under a late spring or early fall burn that would produce 0.5 to 3 foot flame lengths, or in cases where there is a need to pre-treat an area to increase canopy base height or reduce ladder fuels. The objective of this option is to put enough fine fuels down on the forest floor to carry a fire under weather conditions where the targeted flame length can be maintained during spring and early fall burning periods. If needed, canopy base heights would be increased by selective pruning so that they are high enough to avoid excessive torching and initiation of passive crown fire during burning operations. Small grand fir (less than 6 inch DBH) could also be hand thinned and spread on the forest floor to provide fine fuels to help carry a fire under moderate weather conditions. The number of grand firs that would be thinned would depend on the amount of dry fuel needed for optimal fire spread. In areas with very dense grand fir seedlings and saplings, only 10 to 25% would be thinned. The rest would be left as live trees that would mostly be killed during the prescribed fire. An example of such a stand is illustrated in Figures 108 and 109). The light hand thinning and burning would occur during the summer and the subsequent prescribed fire could either occur later that autumn or during the following late spring after snowmelt, when the fine fuels have dried sufficiently to carry a fire.

This treatment option should be applied repeatedly to the selected stands. During the 15-year project period, two applications may be needed to achieve objectives. Subsequently, application of this treatment every 15 to 20 years is desirable in many stands.

Figure 108. Forest conditions in Plot 145 where some thinning of small grand fir would help create a fuelbed for prescribed fire.

As in Treatment Option 2, where active retention of large logs is an issue, the litter and flammable duff can be raked away from these logs to prevent them from igniting and charring. This protects the aesthetics of the logs and leaves them in place for their wildlife value. This would be done where CWD is needed to meet wildlife objectives and in areas where logs provide aesthetic values. The fire crews would be instructed not to ignite large logs.

Likewise, raking of litter accumulations and fine fuels away from selected old-growth legacy trees and large snags could help protect them from being killed or consumed during the burn. Conversely, it may be desirable to rake litter and pile debris around the base of some of the larger grand firs in the stand to increase the probability that they will be killed in the burn and create high quality snags. The use of volunteers should be explored to help with efforts to protect legacy trees and create snags by raking of litter and piling of debris.

Prescribed Fire Treatment Plan

Fire lines would be prepared around the units so that are sufficient to contain fire inside the unit. Existing roads can be used as fire lines, where present. Pre-treatments will be done at least 3 months before burning by selectively pruning lower branches from trees where predominant canopy base height is less than 8 feet or where additional fine fuels are needed to carry a fire. Young grand fir less than 6 inches DBH will be thinned where needed to provide adequate fine fuel to carry a fire (Figure 109). Prescribed fires would be ignited in across-slope strips progressing from a high point and moving down slope. The prescribed fire would be ignited during predictable winds and the crew would start on the windward side of the unit and progress toward the wind, thereby minimizing smoke inhalation problems. The burns could be undertaken during a variety of weather conditions, but the best conditions would probably occur in the late spring, when duff and coarse woody debris moisture levels are still adequate to avoid significant duff consumption and large log consumption. The prescription requires enough dry fuels and weather suitable for the fire to spread and consume surface fuels. The burn should be ignited during weather conditions when surface flame lengths of 0.5 to 3 feet can be maintained.

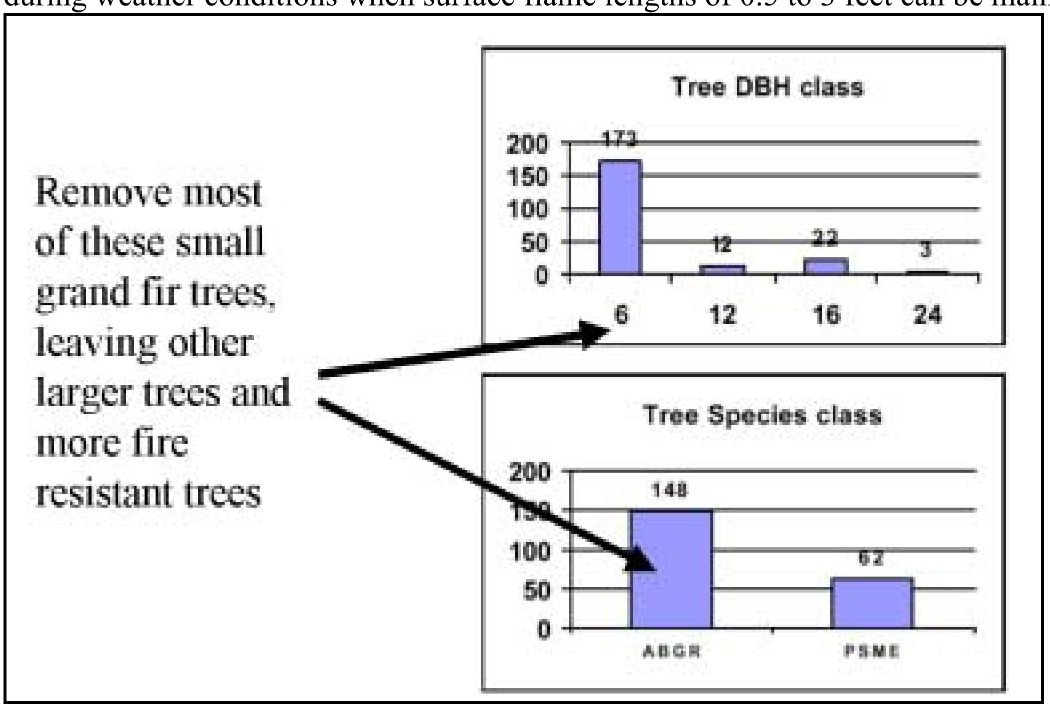

Figure 109. Two of the objectives of treatments in the Option 3 treatment of Unit 2: removal of most of the small trees and most of the grand fir (ABGR).

Objectives for Treatment Option 3

Resource Objectives	Prescribed Fire Objectives
1. Reduce surface fine fuels and break up fuel continuity, thereby reducing potential wildfire intensity and severity, while enhancing suppression effectiveness and moving toward a more sustainable fire regime.	1a. Fuel Reduction: 70-100% reduction of 0-3 inch diameter fuels, with less than 30% reduction of >3 inch diameter fuels. 1b. Scorch lower live limbs of >10 inch DBH trees up to 8-10 feet above ground level. Increase canopy base height in cases where it is currently low.
2a. Reduce density of very small grand firs so that high densities of small and medium size grand fir does not develop as in other areas of the park. 2b. Maintain high overstory canopy cover and shift overstory composition to more western larch and Douglas-fir. 2c. Reduce ladder fuels that may be present.	2. Kill small grand fir through cambium kill and moderate canopy scorch, prevent mortality to larger trees by maintaining prescribed flame lengths.
3. Snag creation and protection	3a. Create new larger snags via fire kill of medium to large trees. If fuels are inadequate to kill trees, they can be hand piled in sufficient quantities around the base of selected trees to bring about mortality to that tree. Torching would need to be avoided. 3b. Where practical, protect existing large snags by avoiding direct ignition during prescribed burning activities.
4. Large CWD creation and protection	4. Where practical, protect existing large logs by raking litter away and avoiding direct ignition.

Option 4 - Limited hand piling and burning of fuel accumulations

There are some areas where prescribed fire is not recommended due to deep duff layers and/or presence of large amounts of coarse woody debris. Use of prescribed fire in these areas might cause the duff and/or coarse woody debris to ignite and to burn or smolder for long periods. Excessive mortality of the overstory trees might result from the long duration of heat exposure in close proximity to their root systems. Prescribed fire in these stands would also require long monitoring periods and would be excessively difficult to extinguish. Stands with these conditions are generally not very flammable and currently require little treatment. However, there are occasional jackpots (large accumulations) of fuel that could be identified, piled and then burned (Figure 110). Fuel concentrations would be located, consolidated, piled and covered with paper during the summer. It may be desirable to rake litter and pile debris around the base of some of the larger grand firs in the stand to increase the probability that they will be killed in the burn and create high quality snags. These covered piles would then be burned in late autumn or early winter. This treatment would increase the inherent fire-resistant nature of these stands and their value as a fuel break with minimal treatment. Little to no mechanical treatment would be expected with this treatment.

Figure 110. A fuel accumulation in Treatment Unit 4, plot 152 that is targeted for consolidation and pile burning.

Objectives for Treatment Option 4

Resource Objectives	Prescribed Fire Objectives
Reduce concentrations of fuels where significant fine and coarse fuels are mixed and could cause torching into the canopy during wildfire. The objective is to reduce potential wildfire intensity and severity, while enhancing suppression effectiveness.	Burn piles of concentrated fuels where necessary during late fall or early winter when little damage will occur to surrounding roots, trees and duff layers.

Option 5 - Protection of legacy trees through focused thinning and pile burning

In this treatment option, old fire-resistant legacy trees that are still reasonably healthy, but challenged with significant young grand fir competition (Figures 111-114) would be identified in the treatment unit. Much of the grand fir would be removed from around the base of these trees to eliminate competition and ladder fuels. The distance of thinning would be approximately 50 feet radius from the legacy tree's bole. Slash would be piled and burned near the thinning perimeter, away from the legacy tree's bole. It may be desirable to rake litter and pile debris around the base of some of the larger grand firs in the stand to increase the probability that they will be killed in the burn and create high quality snags. This would reduce damage to legacy tree's feeder roots and would stimulate regeneration of the fire-resistant, shade-intolerant tree species at a sufficient distance from the seed tree. One of our intentions is to stimulate natural regeneration of western larch, Douglas-fir and ponderosa pine in the cleared areas around the seed trees. Manual planting of desirable tree seedlings could be incorporated into this treatment to try to reestablish western larch, Douglas-fir and ponderosa pine recruitment if natural recruitment is not achieved.

Where seedlings or saplings of western larch, Douglas-fir and ponderosa pine are present in the treatment area, thinning would be conducted around these young trees to facilitate their release from the surrounding grand fir matrix.

Our recommendation is that these stands be treated after about five to ten years with prescribed fire using treatment Option 3. This would further the development of a more fire resistant forest. Some parts of the units could be left untreated and natural succession and disturbance processes would continue to operate, similar to Option 1.

Figure 111. In Option 5, the small grand firs growing around this group of western larch would be cut and piled away from the fire-resistant larch trees. The piled slash would then be burned in the autumn or early winter.

Figure 112. A stand we recommend treating using Option 5. Note large, legacy western larch at right surrounded by dense grand fir saplings and pole-size stems.

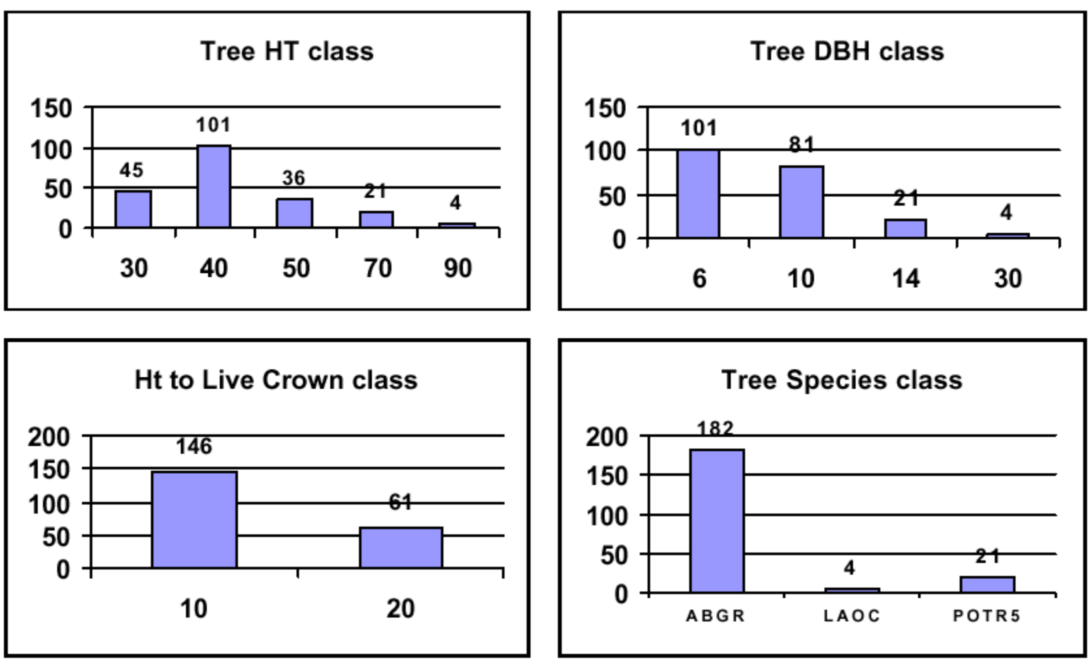

Figure 113. Tree data from Plot 130 in a stand we recommend treating with Option 5. Note presence of a few large western larch (LAOC) and many young grand fir (ABGR). In addition to the 6 inches DBH grand fir in the graph above, there are also 1,700 small grand firs per acre in this plot that are less than 4 inches DBH. All graphs have a Y-axis of trees per acre. Species codes are translated in Appendix C.

Figure 114. Photo of plot 130 in an area recommended for treatment with Option 5. Note one legacy western larch with large fire/logging scar surrounded by young, non-merchantable grand fir.

Objectives for Treatment Option 5

Resource Objectives	Thinning and Prescribed Fire Objectives
1a. Eliminate small grand fir around the base of large old-growth and mature fire-resistant trees so that these trees do not face competition for water and nutrients from encroaching grand fir. 1b. Encourage a shift in species composition toward more western larch, Douglas-fir, western white pine and ponderosa pine through creation of growing space and seedbeds for these species. Encourage native shrub and herb growth	1a. Cut and pile all grand fir growing in a radius of 50 feet from the base of large legacy tree species, leaving the larger trees and more fire-resistant species. 1b. Prepare the area around the base of these trees for subsequent use of prescribed fire to burn the piles of thinning slash.
2. Reduce surface woody fuels in areas where large legacy trees are present to reduce potential wildfire severity and the likelihood that these trees would die in a fire.	2. Fuel Reduction: 90-100% reduction of 0-3 inch diameter fuels and 60-70% reduction in fuels 3-6 inch diameter in the treated area around legacy trees.
3. Conserve existing large snags and CWD as important wildlife habitat elements	3. Avoid piling and burning around large snags and CWD (>12 inch DBH), pull smaller fuels away from these habitat elements.

Option 6 – Extensive non-commercial thinning of small grand fir with protection of all legacy trees followed by piling burning and/or prescribed fire

This treatment option would be conducted in some areas that have been identified as needing more aggressive treatment than Options 1 through 5. This option is similar to Option 3 and to Option 5, but involves removal of significantly more young grand fir (less than 6 inches DBH). Thinning would be employed, but no commercial volume would be generated due to the very limited merchantable wood that would be produced. The focus of this treatment would be to reduce grand fir competition with desirable species and replace the understory regeneration species mix with more fire-resistant, less shade-tolerant species such as western larch, western white pine, Douglas-fir and ponderosa pine (Figures 115 and 116). Thinning slash would be lopped and scattered in areas where surface fuels are not adequate to achieve 1 to 2 foot flame lengths during the subsequent prescribed burn. Thinning slash would be piled and covered with paper in areas where large accumulations exist and abundant existing fine fuels cover the ground surface. These piles would be burned in late fall or early winter after the thinning. A subsequent prescribed burn would then be used to reduce activity fuels and help to further reduce the youngest and smallest of the grand fir component of the stand. The goal is not to eliminate grand fir from the stand, but to allow sufficient space for fire-resistant trees to grow and regenerate. The objective of this treatment is to move the forest composition and structure toward historic conditions prior to the effects of logging and fire exclusion. There would be some reduction in canopy cover from the understory and midstory of the stand, but an overstory canopy would be maintained. The understory and midstory canopy would be targeted to retain 50% to 70% canopy cover following treatment. Thinning could be more intensive in areas where patches of shade-intolerant legacy trees are present. Canopy bulk density would also be reduced to be between 0.1 and 0.08 kg/m^3 by thinning of 4-6 inch DBH grand fir and through the use of prescribed fire, which will kill some of the remaining grand fir. During the period that the thinning slash is dry and fire weather conditions are high or extreme, the stand would be at great risk for catastrophic wildfire. It is important to burn the slash generated by thinning within a year of the thinning treatment to minimize the risk of wildfire.

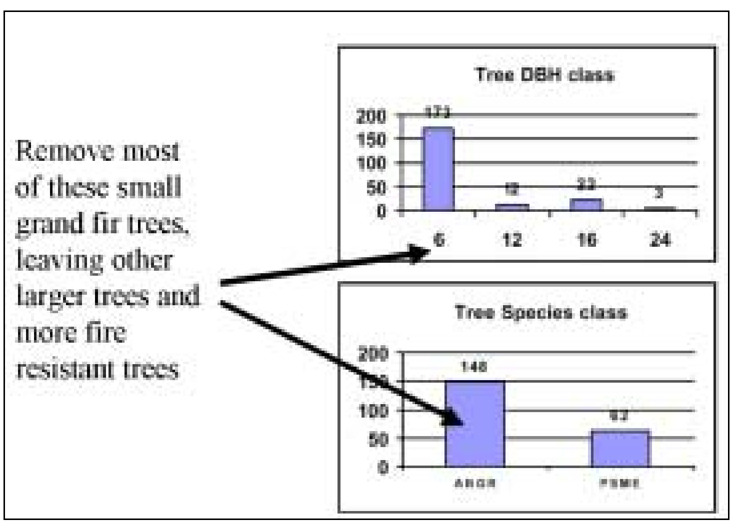

Figure 115. Option 6 involves thinning of small grand fir to reduce competition on large fire-resistant species like the 24 inch DBH Douglas-fir identified in this graph. All graphs have a Y-axis of trees per acre. ABGR= grand fir; PSME = Douglas-fir.

Figure 116. Forest conditions at Plot 182 where extensive thinning of small grand fir is recommended.

Objectives for Treatment Option 6

Resource Objectives	Thinning and Prescribed Fire Objectives
1a. Dramatically reduce density of small grand firs to levels that will reduce competition and allow for more rapid development of late-successional forest conditions. 1b. Shift species composition toward western larch, Douglas-fir, western white pine and ponderosa pine through release of desirable young stems and establishment of favorable seedbeds. 1c. Maintain existing overstory canopy cover and establish conditions where overstory composition will shift to more fire-resistant species. 1d. Encourage native shrub/herb growth in understory to create additional food, cover, and structure for wildlife	1a. Thin 1-7 inch DBH grand fir, leaving larger trees and more fire-resistant species. Thin some patches more heavily, especially where legacy trees are present. 1b. Pile burn large concentrations of fuel, lop and scatter fuels from thinning in places where surface fuels are not adequate to carry a prescribed fire. 1c. Prepare stand for subsequent use of prescribed fire, removing trees that would be risky to try to kill with prescribed fire.
2. Reduce surface woody fuels and break up continuity of fuels, thereby reducing potential wildfire intensity and severity, while enhancing suppression effectiveness and moving towards a more sustainable fire regime.	2a. Fuel Reduction: 70-100% reduction of 0-3 inch diameter fuels, with less than 30% reduction of >3 inch diameter fuels. 2b. Scorch lower live limbs of >10 inch DBH trees up to 8-10 feet above ground level. Increase canopy base height in cases where it is currently low. 2c. Kill small grand fir through cambium kill and moderate canopy scorch. Prevent excessive mortality to larger trees by maintaining prescribed flame lengths.
3a. Snag creation and protection. 3b. Large CWD creation and protection.	3a. Where practical, protect existing large snags and CWD by avoiding direct ignition during prescribed burning activities. 3b. Consider raking litter away from some large logs where aesthetics and wildlife habitat conditions dictate protection of these logs. 3c. Consider creation of a few snags through girdling of or herbicide applications to moderate to larger size trees. First consideration should be given to treating grand firs, as this will remove a significant seed source, open the canopy to encourage growth and development of shade-intolerant species, and grand firs tend to make excellent snags given their soft wood and tendency to stand for long periods of time.

Option 7 - Non-commercial thinning of small grand fir with protection of all legacy trees (ponderosa pine, Douglas-fir, western white pine and western larch) followed by mechanical chipping and/or mastication of treatment slash (no prescribed burn)

This treatment option is similar to Option 6 except all thinning slash would be chipped and/or masticated rather than burned. Prescribed fire would not be used. This treatment can be used in areas selected for removal of small grand fir and/or lodgepole pine. It can also be used in areas where treatment is desired but the use of prescribed fire is not desirable due to proximity to infrastructure, power lines, aesthetics, or other factors. We do not currently recommend this treatment option for any of the proposed treatment units, but it should be considered as a secondary option if prescribed fire is ruled out for any reason. During the period that the thinning slash is dry and fire weather conditions are high or extreme, the stand is at great risk for catastrophic wildfire. As discussed in Option 6, it is important to treat thinning slash soon after thinning to minimize the risk of wildfire. In this case mastication may be possible immediately after thinning or as part of the thinning process.

Objectives for Treatment Option 7

Resource Objectives	Thinning and Prescribed Fire Objectives
1. Reduce density of small grand fir to levels that reduce competition with fire-resistant legacy tree species and allow for more rapid development of late-successional forest conditions.	1. Thin grand fir and lodgepole pine 2-8 inches DBH, leaving any fire-resistant species.
	2. Through mechanical chipping and/or mastication, treat the thinning slash and some small trees (< 2 inches DBH) that can be masticated.

Option 7 was not chosen as a primary treatment option for any treatment unit. It is offered in various treatment units as an alternative option if use of prescribed fire is determined to be unacceptable for various reasons.

Option 8 - Combine non-commercial thinning of small trees, commercial thinning of selected larger trees, pile burning and/or prescribed fire

This treatment option is the most aggressive treatment option considered in this forest planning document. It is not appropriate in most areas due to one or more of the following factors:

- Aggressive treatment is not needed and less aggressive treatment options are available that will achieve objectives more successfully.
- Environmental constraints such as steep slopes, wet areas or riparian zones prohibit aggressive mechanical treatments and commercial harvest due to the potential to damage the residual stand and sensitive resources.
- There is a lack of sufficient merchantable trees, and the overall merchantable volume in the treatment units will not make any commercial harvest feasible.

Where appropriate, this treatment option involves a combination of commercial and non-commercial thinning and thorough, subsequent treatment of activity fuels and other fuels through the use of pile burning and prescribed fire. Selected young to mature grand fir, lodgepole pine, and western hemlock would be the primary species targeted for harvest from the treatment units. The revenue from the merchantable volume could help offset some of the costs associated with other aspects of the treatments described above.

This treatment option would be conducted in some areas that have been identified as needing more aggressive treatment than Options 1 through 7. This option is similar to Option 6 but involves removal of some larger (over 6 inches DBH) grand fir and lodgepole pine (possibly other species, including hemlock and Douglas-fir, although grand fir and lodgepole pine would be the primary targets). Commercial volume would be generated in areas where merchantable trees were targeted for thinning in adequate abundance. Like Treatment Option 6, the focus of this treatment is to reduce grand fir competition on desirable species and replace the understory grand fir with more fire-resistant, less shade-tolerant species such as western larch, western white pine, Douglas-fir and ponderosa pine. And example of an area that would be treated with this option is illustrated in Figures 117 and 118. In this stand there are some large remnant old-growth ponderosa pines, but there are also over 600 small grand fir trees (< 4 inches DBH) and a good number of merchantable 14-28 inch DBH grand firs. Unless many of these merchantable grand firs are removed from the stand, they will quickly reseed a new crop of young grand fir. Opening up growing space and creation of a seedbed will be necessary for successful reproduction of ponderosa pine.

Figure 117. Photo of Plot 282 where a combination of commercial and non-commercial thinning is recommended.

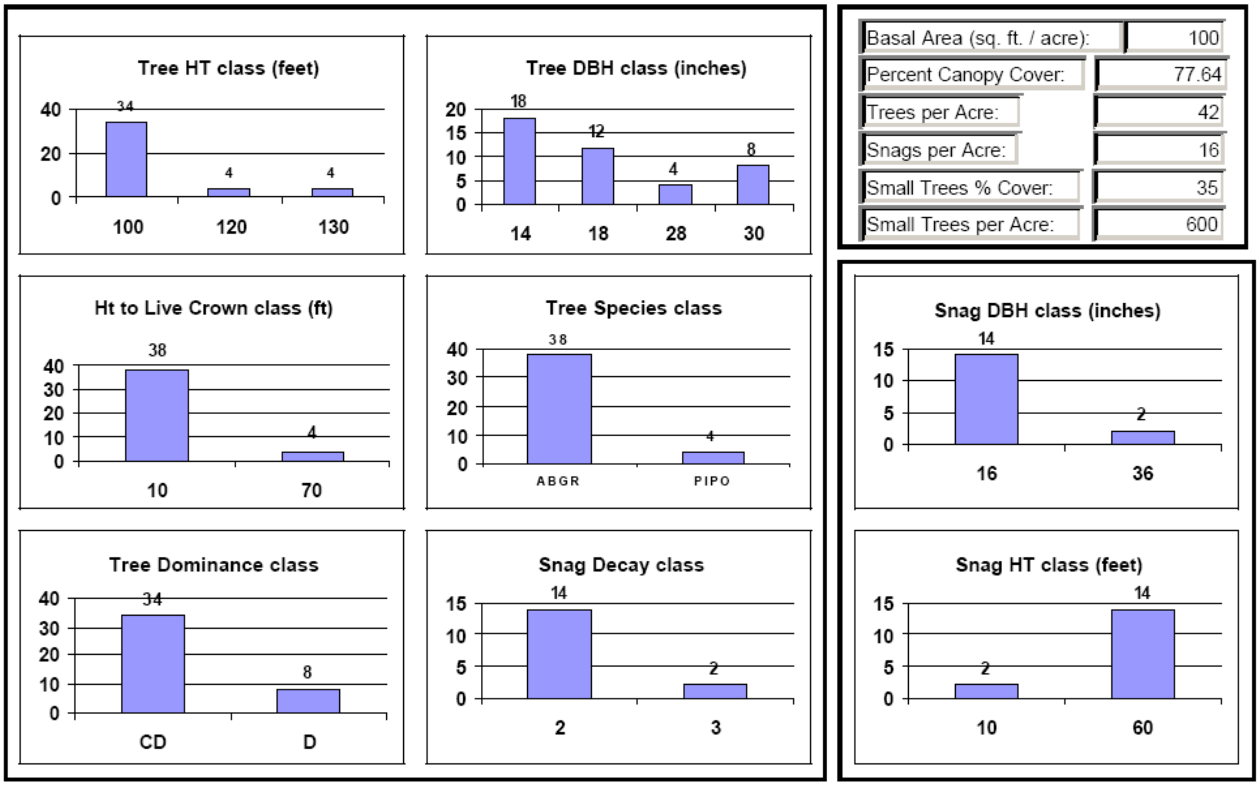

Figure 118. Forest conditions at Plot 282 where a combination of commercial and non-commercial thinning is recommended.

Option 8 would involve lopping and scattering of thinning slash in areas where surface fuels are not adequate to achieve 1 to 2 foot flame lengths during the subsequent prescribed burn. Thinning slash would be piled and covered with paper in areas where large accumulations exist and where abundant existing fine fuels cover the ground surface. It may be desirable to rake litter and pile debris around the base of some of the larger grand firs in the stand to increase the probability that they will be killed in the burn and create high quality snags. These piles would be burned in late fall or early winter conditions in the months following the thinning. A subsequent prescribed burn would then be used to reduce activity fuels and help to further reduce the youngest and smallest of the grand fir component of the stand.

The goal is not to eliminate grand fir from the stand, but to allow sufficient space for fire-resistant trees to grow and regenerate. The objective of this treatment is to move the forest composition and structure toward historic conditions that existed prior to the effects of logging and fire exclusion. There would be some reduction in canopy cover, but an overstory canopy would be maintained. The overstory and midstory coniferous canopy would be targeted to retain 60% to 80% canopy cover following treatment. Canopy bulk density would also be reduced to within a target of between 0.1 and 0.07 kg/m^3 by thinning of 4-20 inch DBH grand fir and lodgepole pine and through the use of prescribed fire, which will kill some of the remaining grand fir. During the period that the thinning slash is dry and fire weather conditions are high or extreme, the stand is at great risk for catastrophic wildfire. It is important to burn the slash generated by thinning within a year of the thinning treatment to minimize the risk of wildfire.

This treatment is intended to have long-term beneficial effects on sensitive wildlife species. It will only be applied to stands that have a high density of young and medium size grand fir that would otherwise choke out other tree species and most shrub and herbaceous diversity if the grand fir is allowed to progress. Goshawk flyways should be improved considerably after some of the understory and midstory trees are removed from the stand. This will improve goshawk foraging opportunities. One of the treatment objectives is to increase the number of large snags and logs in the stand through both active snag and log creation and through the long-term effects of prescribed fire. Thinning of the stand will also accelerate the growth of the remaining trees in the stand so that old-growth forest conditions are reached more rapidly. Thinning the grand fir will reduce competition for water and nutrients, which will reduce stress on existing old fire resistant trees, insuring their continued existence in the stand. All these factors should benefit a diverse suite of wildlife species.

Our intention is that if used, Option 8 will be very carefully implemented and will focus as much on protection of sensitive habitats, enhancement of wildlife habitat components and aesthetic considerations as it will on the other objectives of the treatment.

Summary of prescription

- Thin 4-20 inch DBH grand fir or lodgepole pine, leaving only those trees where no other larger conifers are present within a 50-foot radius. The target stand density is 100-150 TPA > 6 inches DBH. Select large trees should be girdled or poisoned to create large snags where few currently exist. Select large stems might also be felled and left in-place to recruit CWD where limited materials currently exist.
- Harvest merchantable logs from the thinning operation.
- Lop and scatter thinning slash where surface fuel loads are too low to achieve prescribed fire flame lengths of 1 to 2 feet. In areas where adequate surface fuels exist and large accumulations of thinning slash are present, hand pile the slash, and cover with paper prior to subsequent burning.
- Burn thinning slash piles under suitable late fall or early winter weather conditions.
- Conduct a subsequent spring prescribed burn to reduce surface fuels, kill smaller grand fir (not removed by thinning) and reduced ladder fuels. Schedule the burn so that 0.5 to 2 foot flame lengths are achieved. This will kill many of the remaining small grand firs and a few of the remaining 10-24 inch DBH trees to create snags. Snags reach optimal levels for the wildlife that we modeled at about 8 snags per acre (Appendix D), so this should be seen as a target level.

Objectives for Treatment Option 8

Resource Objectives	**Thinning and Prescribed Fire Objectives**
1a. Dramatically reduce density of small grand fir to levels that reduce competition and allow for more rapid development of late-successional forest conditions. 1b. Shift species composition toward western larch, Douglas-fir, ponderosa pine and western white pine. 1c. Maintain sufficient overstory and midstory canopy cover for wildlife habitat but open the stand sufficiently to establish conditions where overstory composition will shift to more western larch, ponderosa pine and Douglas-fir.	1a. Thin 4-20 inch DBH grand fir and lodgepole pine, leaving larger trees and more fire-resistant species. 1b. Harvest commercially valuable logs to help pay for treatment costs. 1c. Prepare stand for subsequent use of prescribed fire, removing trees that would be risky to try to kill with prescribed fire.
2. Reduce surface woody fuels and break up continuity of fuels, thereby reducing potential wildfire intensity and severity, while enhancing suppression effectiveness and moving towards a more sustainable fire regime.	2a. Fuel Reduction: 80-100% reduction of 0-3 inch diameter fuels, with less than 30% reduction of >3 inch diameter fuels. 2b. Scorch lower live limbs of >10 inch DBH trees up to 8-10 feet above ground level. Increase canopy base height in cases where it is currently low. 2c. Kill small grand fir through cambium kill and moderate canopy scorch. Prevent excessive mortality to larger trees by maintaining prescribed flame lengths.
3a. Snag creation. 3b. Immediate and eventual large CWD creation	3a. Where practical, protect existing large snags and CWD by avoiding direct ignition during prescribed burning activities. Consider girdling or poisoning select large trees to recruit snags where they currently do not exist. These snags will eventually contribute to unit CWD. . 3b. Consider felling select large diameter trees (especially those with low merchantability) to recruit CWD where few large logs exist.

Option 9 - Treatment of Areas Immediately Adjacent to Roads

Due to the ease of access, areas within 75 feet from the major roads in the project area present a unique opportunity for specialized treatments that would reduce overall landscape-level wildfire risk and in some cases improve forest health (Figure 119). Several factors exist in these areas that are worth noting:

- Reducing canopy cover and overall canopy bulk density in stands next to roads will create a break in the canopy that can bring crown fires down to the ground and make them more manageable for fire crews, while maintaining a shaded fuel break.
- The presence of the unburnable road surfaces and very low fuel loading in the road-right-of-way is a significant fuel break to slow moving surface fires.
- These areas are the most accessible to mechanical equipment and to forest health treatment crews.
- Removal of selected commercially valuable trees will help to achieve forest health objectives and/or reduce wildfire risk without complex logging and engineering or expensive equipment.
- In some cases, some of the highest densities of young trees have developed next to the road-right-of-way due to canopy openings created by the road, from seed beds reacting to soil disturbance from road construction and from reduced competition for nutrients, water and light next to the road.

Figure 119. Grand fir often grows densely at the edge of many forest roads.

Objectives for Treatment Option 9

Resource Objectives	Thinning and Prescribed Fire Objectives
1a. Dramatically reduce density of small grand fir to levels that reduce competition and allow for more rapid development of late-successional forest conditions. 1b. Shift species composition toward ponderosa pine, western larch and Douglas-fir. 1c. Maintain adequate overstory and midstory canopy cover and establish conditions where overstory composition will shift to more ponderosa pine, western larch and Douglas-fir.	1a. Thin grand fir, lodgepole pine, western hemlock and subalpine fir in the diameter range of 4-20 inch DBH, leaving larger more fire-resistant trees. 1b. Harvest commercially valuable logs to help pay for treatment costs. 1c. Prepare stand for subsequent use of prescribed fire, removing trees that would be risky to try to kill with prescribed fire
2a. Dramatically reduce surface woody fuels along roadsides and break up continuity of fuels, thereby reducing potential for wildfire starts to occur along roadsides and increase the effectiveness of roads as major firebreaks in the landscape. 2b. Enhance firefighter safety by creating wider fuelbreaks along roads and thereby enhance wildfire suppression effectiveness. 2c. Help move the landscape towards a more sustainable fire regime.	2a. Fuel Reduction: 90-100% reduction of 0-3 inch DBH diameter fuels. 2b. Scorch lower live limbs of >10 inch DBH trees up to 8-10 feet above ground level. Increase canopy base height in cases where it is currently low. 2c. Kill small grand fir through cambium kill and moderate canopy scorch. Prevent excessive mortality to larger trees by maintaining prescribed flame lengths.
3. Snag creation.	3. Where practical, protect existing large snags by avoiding direct ignition during prescribed burning activities.

The objective of this treatment option is to reduce fuel loading and reduce canopy bulk density along the road system using the roads as a firebreak and to provide additional safety for fire fighters that may at some time need to operate along these roads. Fuel reduction treatments along roads will also help reduce the possibility of human caused fires spreading from the road-right-of-way to the surrounding forest (Morrison 2007). Increased wildlife aversion to the main-road system due to reduced vegetation cover may occur, potentially interrupting some wildlife migration corridors and increasing edge effects into surrounding forest patches, but the amplitude of such effects should not be greatly increased from those effects currently caused by the main road system. Increased visibility due to fuel treatments may lessen the risks of wildlife-vehicle impacts. It is our intention that this treatment option be applied to most of the major roads in the project area.

This treatment option involves a combination of commercial and non-commercial thinning as well as follow-up treatments of activity fuels generated from thinning and other fuels in the road treatment zone through the use of pile burning and prescribed fire. Selected young to mature grand fir, lodgepole pine, and western hemlock could be harvested from the road treatment zone to achieve canopy bulk density reduction goals. The revenue from the merchantable volume in the road treatment zone could help to offset some of the costs of the other treatments.

Option 10 - Mowing and chipping of small trees in accessible areas along roads and trails

Dense stands of very young trees are becoming established along roads and trails near the Selkirk Lodge and in the main cross country ski area (Figure 120). This phenomenon is also occurring at other locations in the Park. Over time, these dense young pockets of trees will grow and contribute to increased wildfire hazards and will decrease the aesthetic and recreational values in the area. At this point, these young trees could easily be removed from the road right-of-way by mowing and chipping. If they are allowed to grow, removal will become more expensive.

Figure 120. Dense subalpine and grand fir seedlings growing along roadsides in Treatment Unit 16.

These very small young trees could easily be reduced by slightly expanding the area that is currently mowed for the cross-country ski trails. In this process, it is important to keep from creating more disturbed ground, as this will further encourage young fir seedling to germinate and grow. Seeding the roadsides with beargrass (*Xerophyllum tenax*), low shrubs or other low growing native plants would also be beneficial to help prevent further establishment of young fir seedlings in these areas.

Objectives for Treatment Option 10

Resource Objectives
1. Reduce the very high density of young grand fir and subalpine fir growing along roadways and cross-country ski trails. This will enhance fire protection of the area and will lead to long-term maintenance of aesthetics and views from the roads and trails. Replace fir seedlings with beargrass and other low growing native plants.

Considerations When Implementing Treatments

There are many ways to implement the treatment options outlined above. Since many of the treatments involve the use of prescribed fire, it will be necessary to utilize a prescribed fire specialist that can implement the prescribed fire part of the treatment option in a manner that is both safe and achieves the resource objectives defined for that option. Experienced prescribed fire crews will also be necessary to implement this forest health plan.

Some treatments involve non-commercial thinning of small grand fir trees. It is important that all personnel involved with thinning operations be trained in tree species identification so that the correct species are thinned. Thinning operations can be accomplished through hiring skilled thinning crews, or in some cases, volunteers can be trained to thin small trees. The park manager, Steve Christenson, mentioned that boy scouts and other volunteers frequently ask for projects that they can undertake that will help improve the condition of the park. Such volunteer crews will need careful training and supervision.

Changes in wood cutting policies in the park can aid overall forest health and wildlife habitat and can be used to achieve some of the objectives in Treatment Option 9. By requiring that wood cutters switch from cutting western larch and Douglas-fir snags to cutting selected live grand fir and lodgepole pine along the roads, wildlife habitat conditions will improve and some of the forest health objective will be achieved.

An Overview of the Treatment Units

The characteristics of the treatment units are illustrated in Figures 121-129. We have undertaken careful analysis and examination of each of the 45 treatment units. The treatment units vary considerably in their size, configuration, landscape position, forest characteristics, and in the treatment options that are recommended for the unit (justification for the selection of specific treatment options are addressed later in this section and in the following section, Description of Individual Treatment Units). The treatment unit boundaries often follow the boundaries of stands we delineated earlier in this project. However, in some cases stand boundaries are not followed if treatment constraints from implementation of prescribed fire or thinnings dictate an operationally more efficient boundary for the treatment unit. We have tried to locate treatment units in areas that our forest health assessment indicated as high priority for treatment either because of grand fir encroachment on legacy trees (Figure 123), an under-representation of snags and logs for wildlife habitat (Figure 124), and/or opportunities existed to reduce the risk of a crown fire spreading across large areas of the park landscape. (Figure 79 and related discussions of fire spread).

Figure 125 illustrates our recommended timing of the treatments. We urge Washington State Parks to start slowly with some of the easier treatments to implement and then as experience is gained to move to more challenging areas. Treatments in Zones 1-3 are prioritized in terms of timing over treatments in Zones 4 and 5.

The results of some of our spatial fire modeling of the effects of the treatments are illustrated in Figures 126-129. These are based on FlamMap simulations and indicate that both flame length and rate of spread are reduced significantly as a result of the proposed treatments being applied to the August 1991 firestorm weather conditions and fuel moisture conditions.

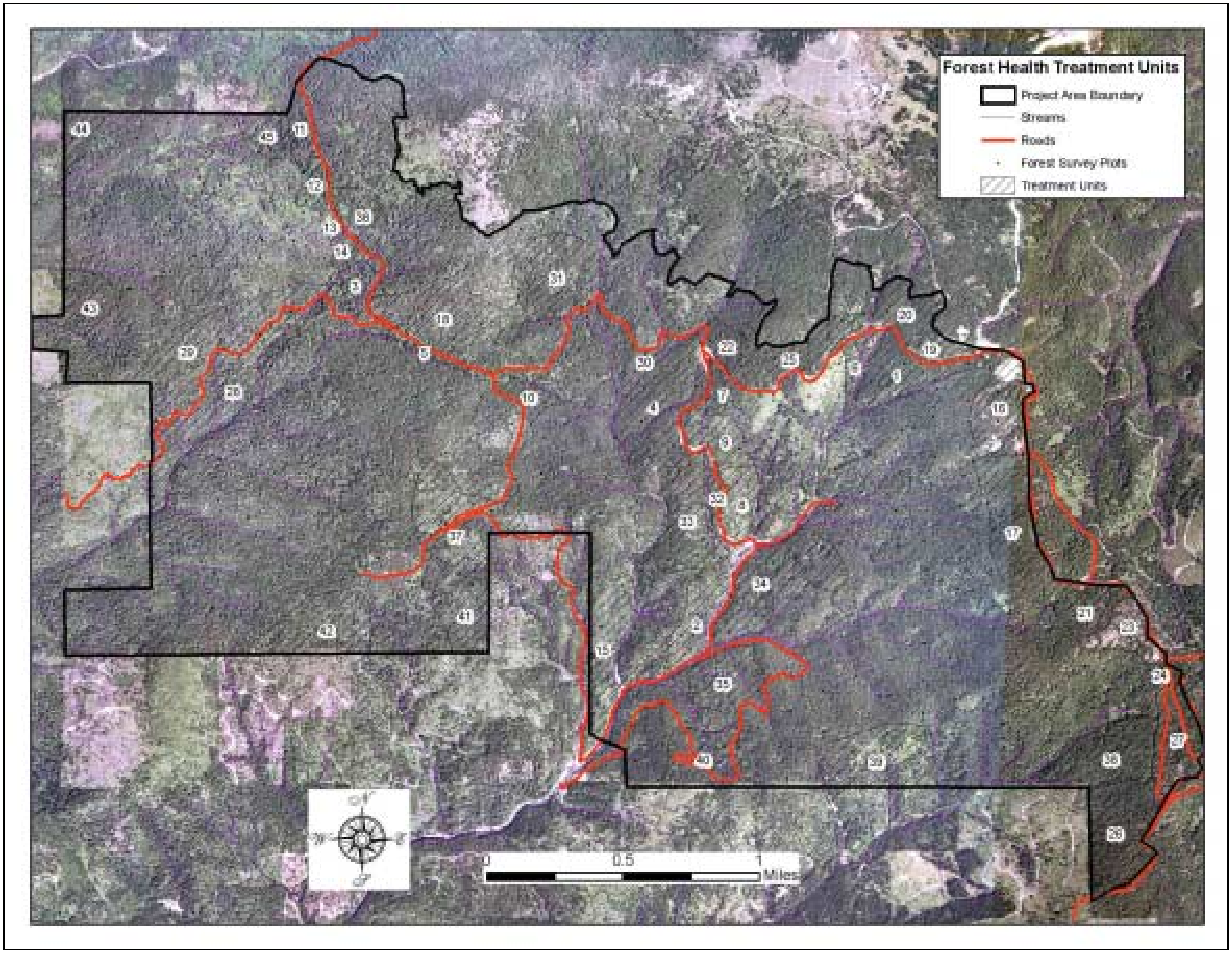

Figure 121. The 45 treatment units overlaid on an aerial photograph of the project area.

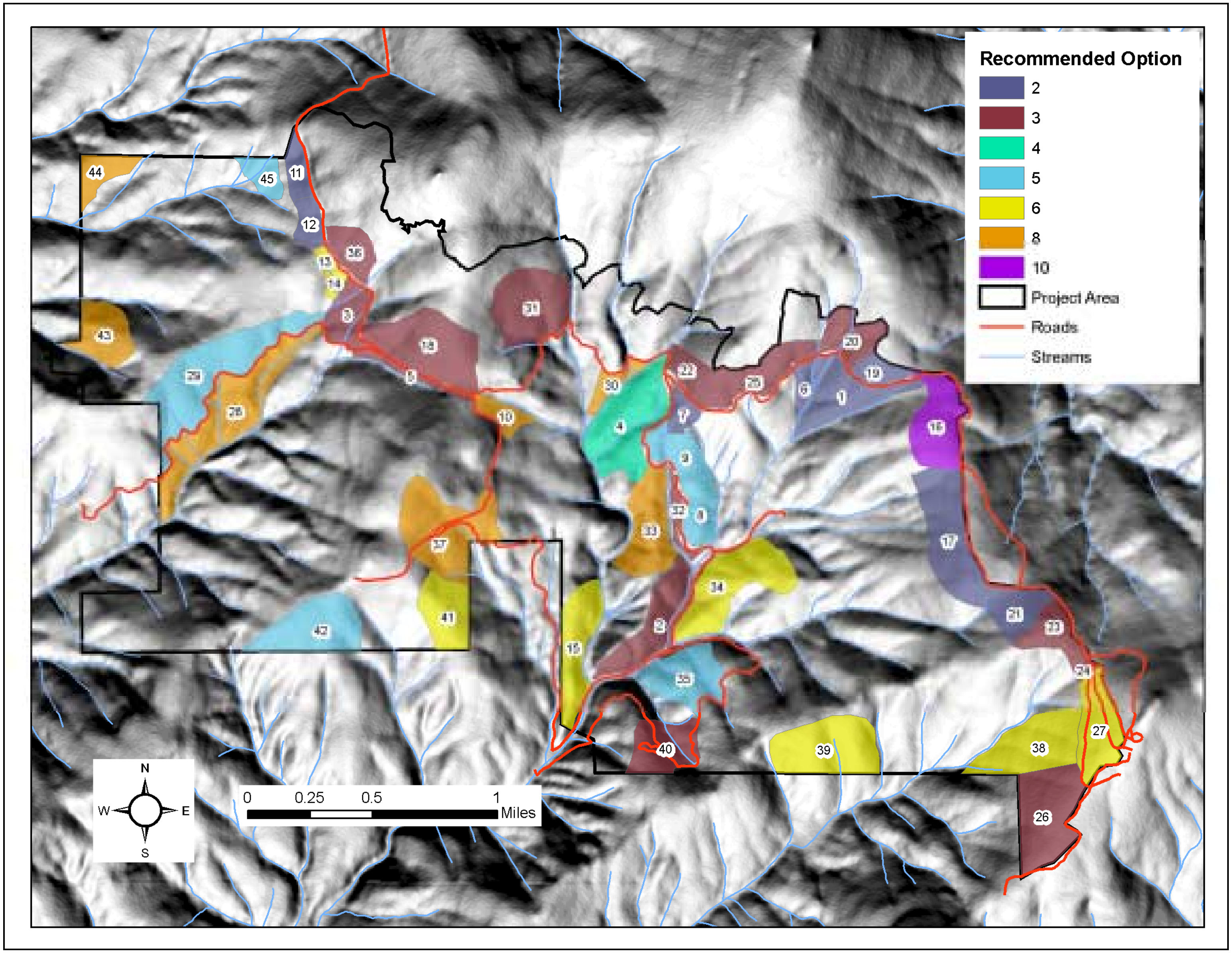

Figure 122. Recommended forest health treatment options for the 45 treatment units. Treatment option 1 pertains to areas outside the Treatment Units (no coloring). Treatment option 7 was only chosen as a secondary option for a few Treatment Units and is not illustrated.

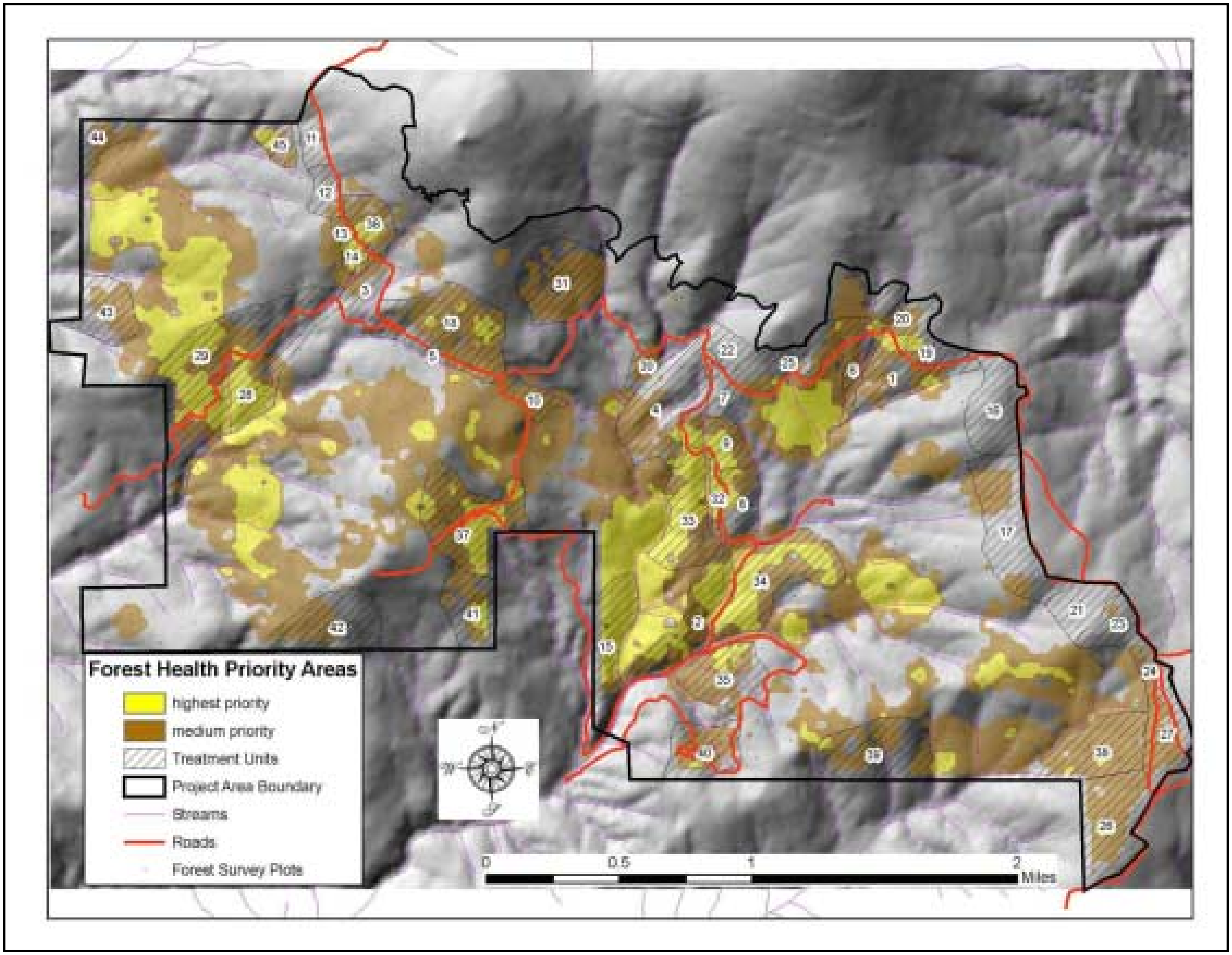

Figure 123. Treatment units overlaid on priority areas for forest health treatments to reduce the level of grand fir encroachment on legacy ponderosa pine, Douglas-fir and western larch.

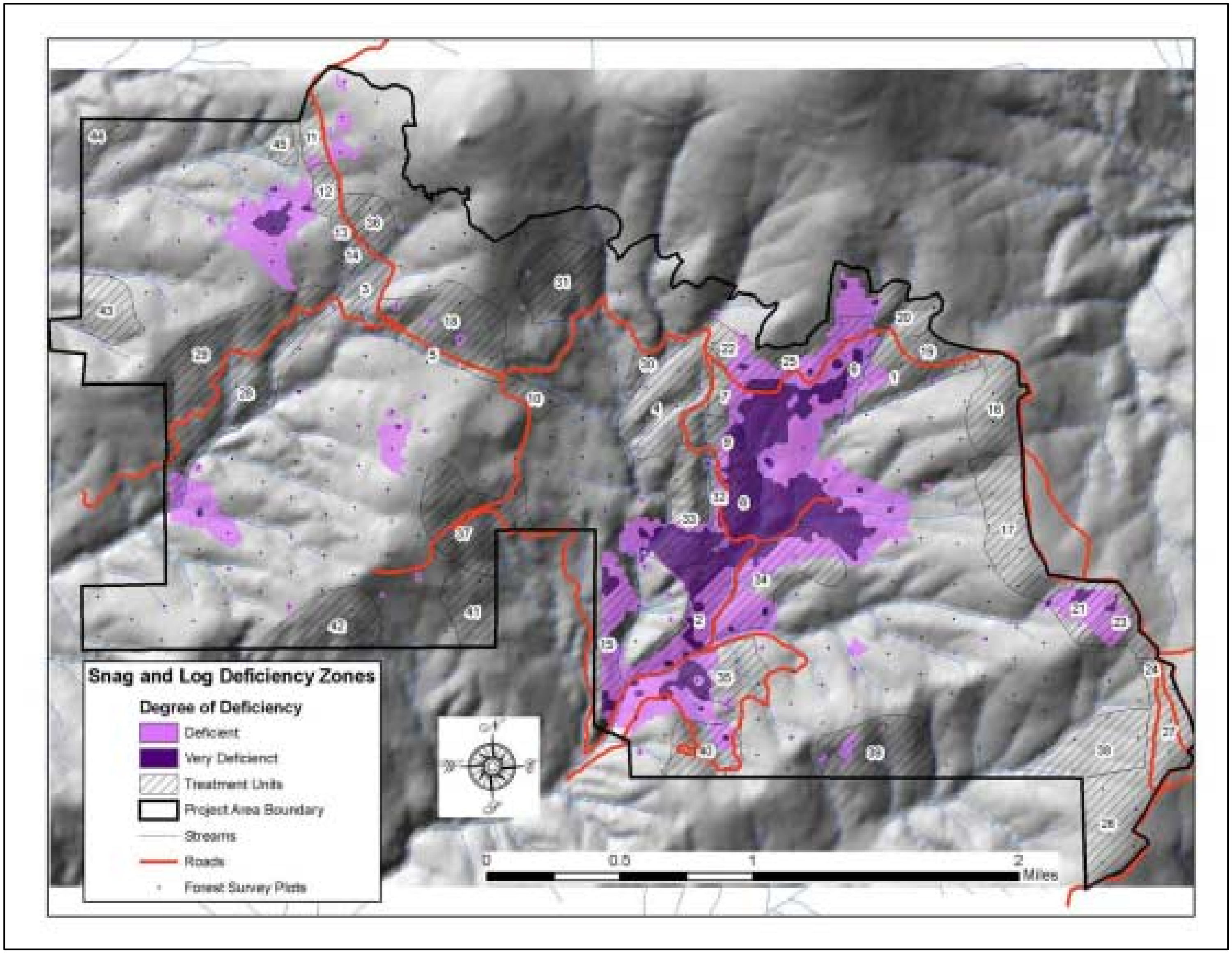

Figure 124. Treatment units overlaid on priority areas for enhancement of snags and / or CWD for wildlife habitat structural elements.

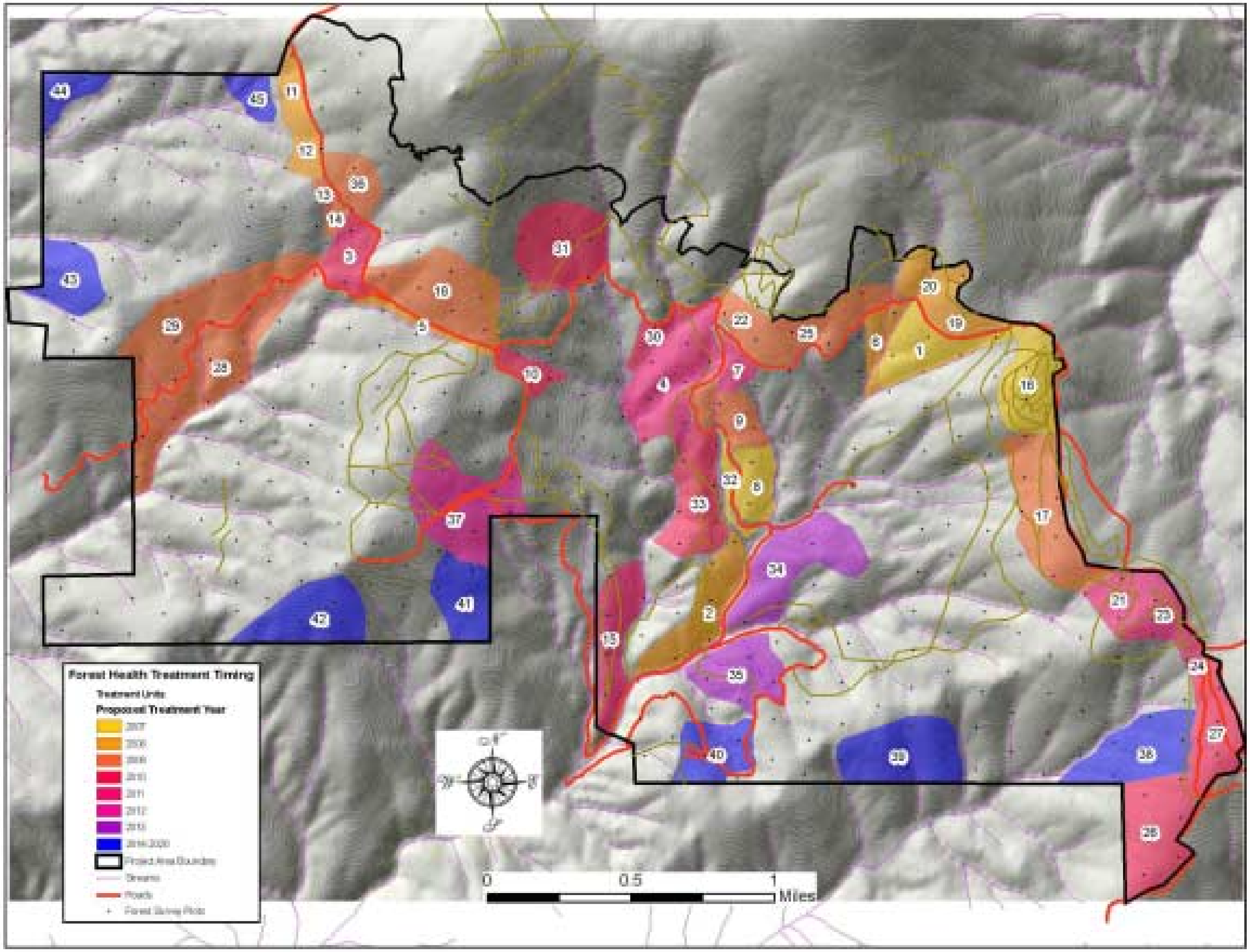

Figure 125. Proposed timing of treatments for the 45 treatment units.

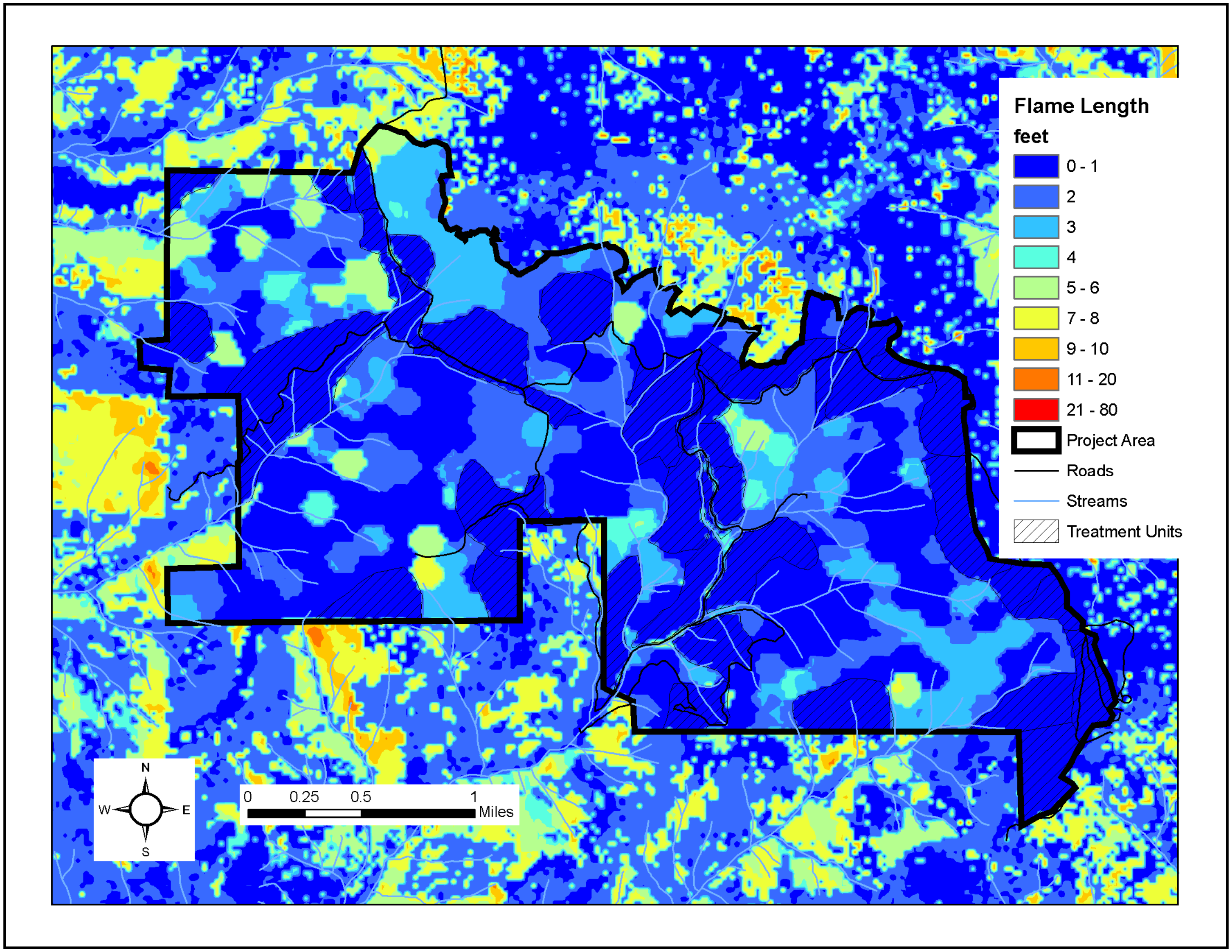

Figure 126. August 1991 firestorm simulation from FlamMap illustrating the effect of the treatment on wildfire flame length. After treatment the flame length in all treatment units is below 2 feet.

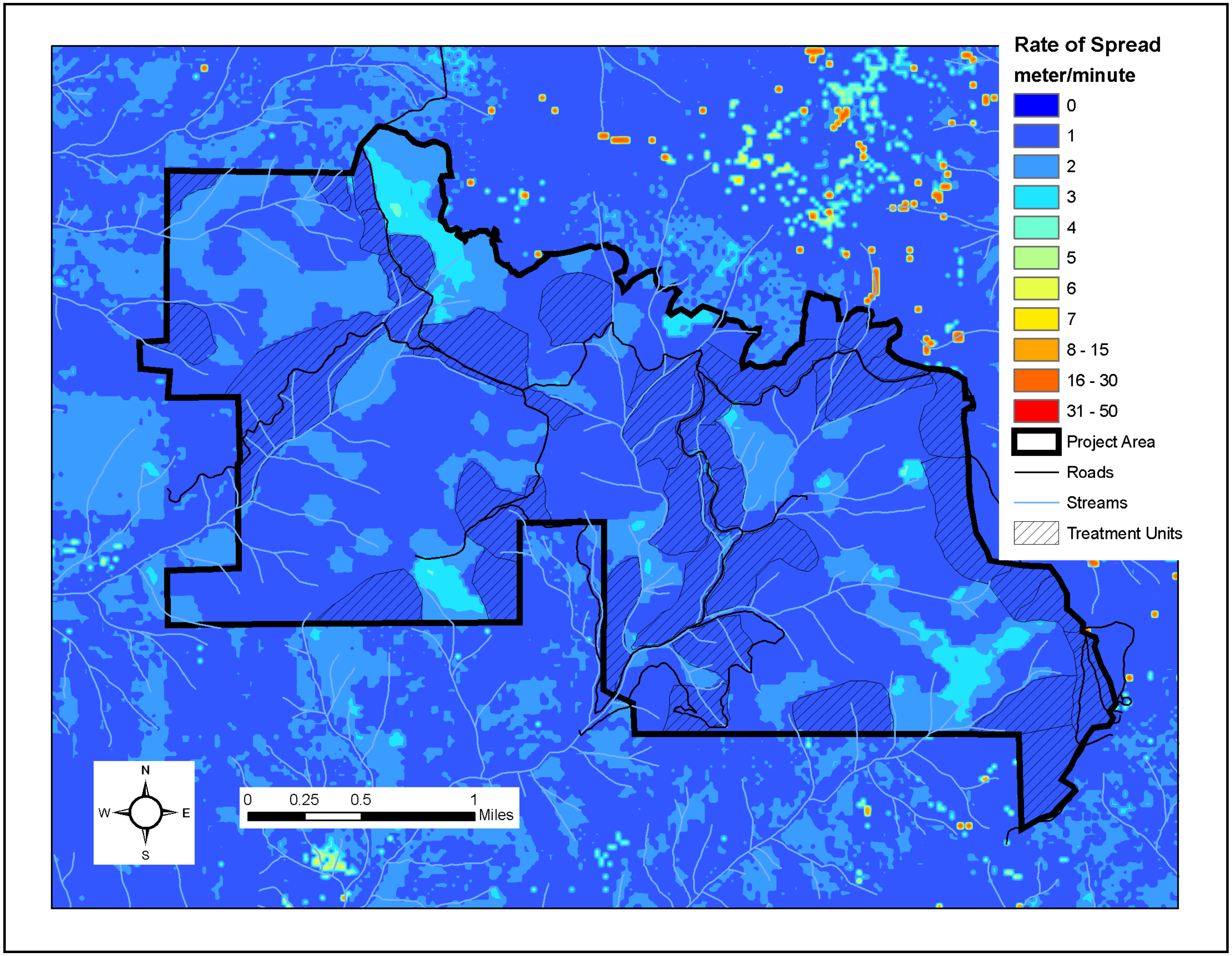

Figure 127. August 1991 firestorm simulation from FlamMap illustrating the effect of the treatment on rate of spread. After treatment the rate of spread in all treatment units is below 2 meters/minute.

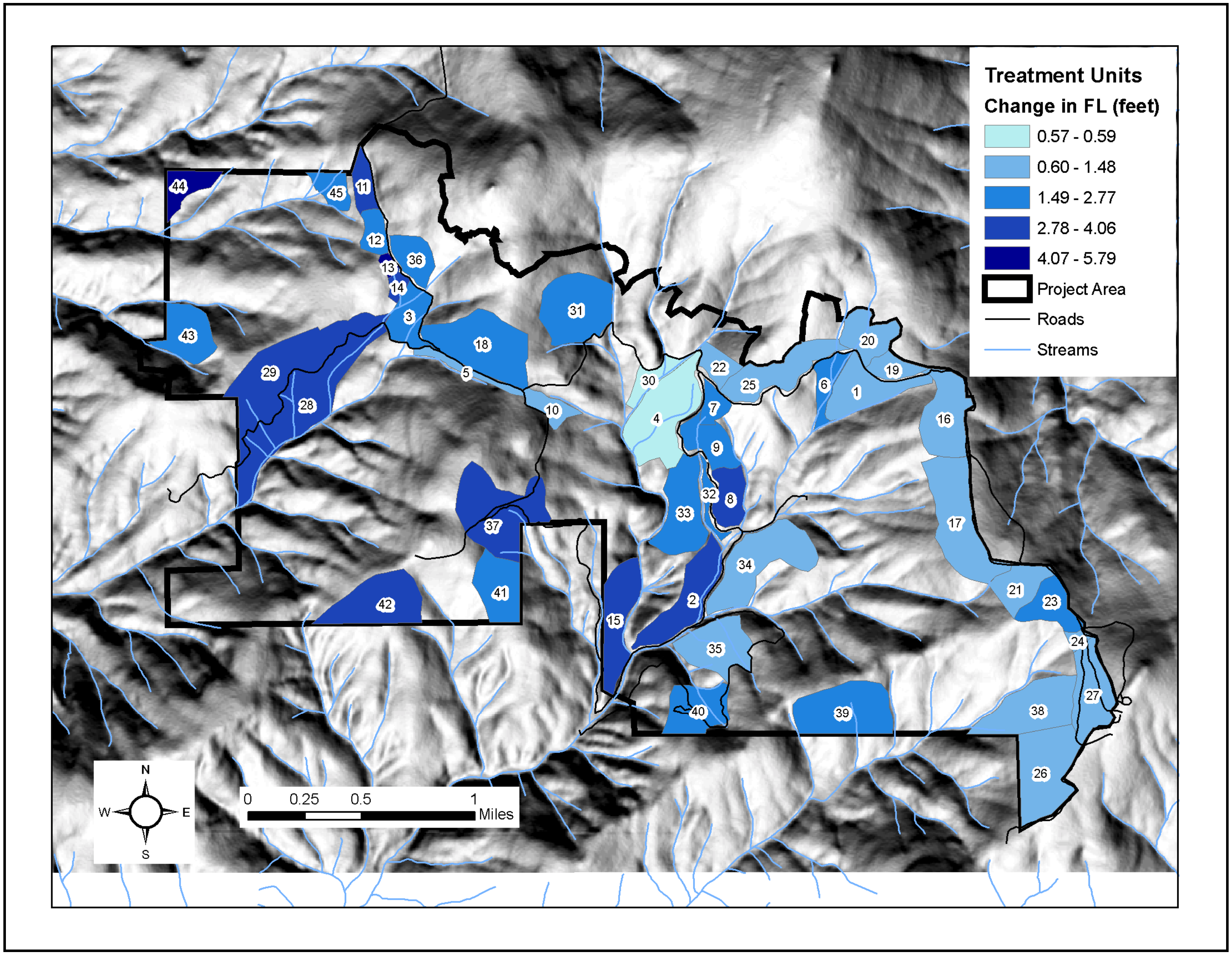

Figure 128. Decrease in wildfire flame length in each Treatment Units during August 1991 firestorm simulation conditions as a result of treatment. Flame lengths decreased 3 to 4 feet as a result of treatment in many units.

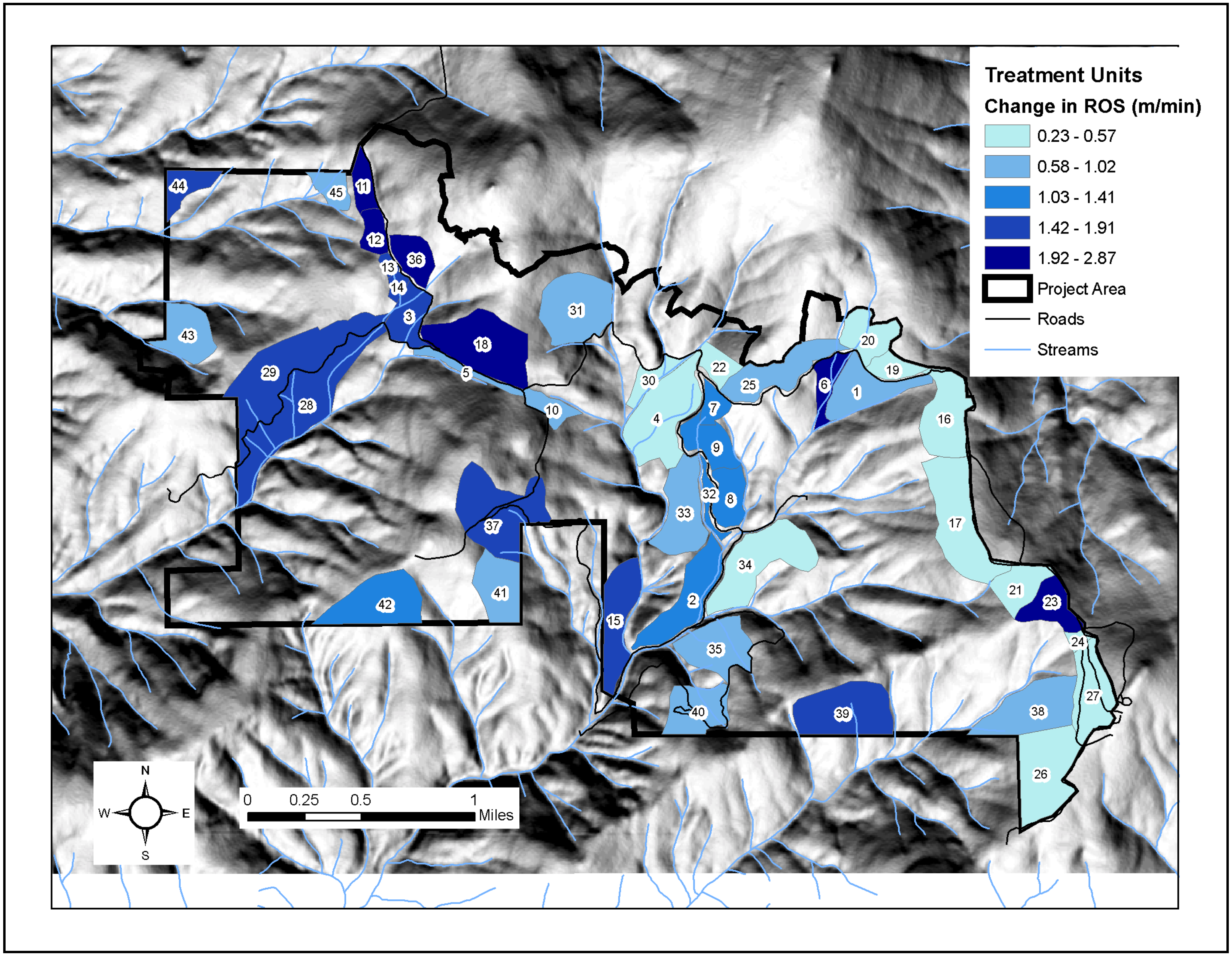

Figure 129. Decrease in fire rate of spread in each Treatment Units during August 1991 firestorm simulation conditions as a result of treatment. Rate of spread decreased by at least 1 meter/minute as a result of treatment in most units.

Table 17 lists the general characteristics of each unit and the treatment options recommended for that unit. The column labeled "1st Option" is our recommended treatment option for that unit. The column labeled "2nd Options" are alternative treatment options for that unit that should be considered in highly heterogeneous units, or could be chosen if Washington Parks staff decides that the first option is not desirable. No treatment (Option 1) is always an option for each unit. Many of the alternative options would achieve similar objectives to the recommended option, but might be more expensive or more impractical to implement. In some treatment units that have high heterogeneity it may be desirable to use more than one treatment option in the unit.

Table 17 also lists the timing (proposed year for the treatment) and the average slope steepness of the unit, which is a constraint on some treatment options. Figure 125 also depicts the proposed year of treatment for the various treatment units.

The average forest stand characteristics found in each unit are summarized in Table 18. Table 19 list some important wildlife habitat characteristics of the unit and the average forest health priority found in the unit in terms of the degree of grand fir encroachment and competition with fire-resistant tree species. ***It was using these two tables, along with Table 20 noted below and considerable reflection on the forest characteristics (the broader suite of information generated from the field survey) and project objectives, that we developed and assigned specific treatment options to the 45 treatment units.***

Table 20 lists some of the important fire behavior characteristics of the treatment units before and after the proposed treatments. The projected change in fire behavior due to treatment is also listed. This table is based on FlamMap runs that assume the fire weather conditions and fuel moisture conditions match that of the August 1991 firestorm. These data are also displayed visually in Figures 126-129.

Table 17. Treatment unit location and size, recommended treatment options, timing of implementation and mean slope steepness.

Unit #	Zone	1st Option	2nd Options	Acres	Year	slope (%)
1	1	2	1	35.6	1	40.0
2	1	3	5,1	42.4	2	39.6
3	2	3	5,1	23.7	4	22.8
4	1	4	1	61.0	5	25.0
5	2	3	6,1	11.1	2	27.0
6	1	2	1	16.4	2	37.3
7	1	2	1	10.5	5	29.0
8	1	5	3,1	20.9	1	26.6
9	1	5	3,1	22.9	3	24.2
10	2	8	6,1	13.0	4	29.4
11	2	2	1	13.1	2	47.3
12	2	2	1	12.7	2	32.6
13	2	6	8,1	3.4	3	15.4
14	2	6	5,1	5.7	3	23.0
15	1 & 4	6	5,1	40.5	5	38.7
16	3	10	3,7	41.8	1	18.7
17	3	2	1	63.4	3	31.3
18	2 & 6	3	2,1	63.0	3	39.4
19	3	2	3,1	12.1	2	29.6
20	1	3	2,1	24.0	2	34.6
21	3	2	3,1	23.1	5	23.9
22	1	3	1	13.0	3	37.9
23	3	3	2,1	22.9	5	20.7
24	3	3	6,1	4.0	5	22.8
25	1	3	1	38.9	3	34.1
26	3	3	2,1	55.8	4	30.6
27	3	6	3,1	36.8	4	27.7
28	4	8	6,5,1	77.8	3	29.1
29	4	5	8,3,1	79.6	3	26.8
30	2	8	3,1	13.5	4	25.3
31	2 & 6	3	2,1	52.9	4	38.5
32	1	3	7,1	6.7	1	22.4
33	1 & 5	8	6,5,1	43.5	4	31.6
34	1 & 5	6	8,1	58.7	7	29.4
35	1 & 5	5	3,1	39.1	7	27.7
36	2	3	2,1	19.6	3	35.1
37	4	8	5,6,1	67.3	6	31.2
38	3 & 5	6	8,3,1	49.6	10-15	39.6
39	5	6	8,3,1	55.8	10-15	37.7
40	5	3	6,8,1	33.5	10-15	30.0
41	5 & 4	6	8,5,1	32.5	10-15	31.6
42	5 & 4	5	3,1	48.1	10-15	29.3
43	5	8	6,5,1	30.5	10-15	38.8
44	5	8	6,5,1	16.8	10-15	20.5
45	5 & 2	5	3,1	13.5	10-15	31.6

Table 18. Treatment unit forest stand characteristics (see key on next page for abbreviations).

Unit #	cc	ch	cbh	cbd	ba	tpa	qmd	stcov	stpa	abgr8	maxdbh	pipo	savetrees
1	85	58	20	0.154	208.1	227	14.4	20.5	350	29.7	20.52	0.00	76.9
2	87	63	18	0.094	160.4	180	13.2	46.7	762	60.7	20.27	1.95	29.7
3	90	81	25	0.058	164.0	119	17.3	16.7	781	19.1	23.85	0.01	30.9
4	93	71	27	0.129	231.8	214	14.8	19.2	619	9.5	23.97	0.00	27.7
5	82	78	29	0.079	177.5	124	17.4	12.4	627	16.3	23.99	1.70	21.9
6	71	60	17	0.084	132.8	127	14.9	16.7	385	31.4	19.95	0.15	40.3
7	96	64	24	0.152	219.7	228	14.5	38.5	707	33.9	20.86	0.00	12.6
8	64	45	11	0.055	76.9	154	8.2	32.6	745	45.6	14.18	0.00	30.8
9	91	58	17	0.111	144.0	247	11.3	47.6	1040	57.6	17.66	0.00	50.3
10	92	71	27	0.097	170.5	158	15.1	20.1	619	54.7	22.35	0.00	38.8
11	79	67	27	0.073	154.9	120	15.1	6.1	123	0.0	20.15	6.09	38.1
12	65	59	22	0.038	79.8	74	11.4	27.3	285	0.3	16.00	0.00	23.9
13	74	73	31	0.051	100.5	156	11.4	28.2	896	1.2	16.38	0.00	31.6
14	84	78	29	0.058	135.4	169	14.0	20.5	853	7.9	19.96	0.00	71.3
15	92	55	16	0.109	156.8	288	10.8	28.5	728	124.1	19.85	4.19	52.7
16	79	57	21	0.121	164.7	204	12.4	4.7	308	19.6	19.46	0.00	19.2
17	85	70	24	0.111	210.8	189	15.0	14.6	360	33.4	22.38	0.00	33.2
18	76	73	30	0.070	153.2	102	18.1	20.0	967	9.4	23.40	2.49	23.7
19	83	50	19	0.196	200.2	287	11.9	6.1	266	48.8	19.69	0.00	63.7
20	81	56	17	0.198	193.3	296	13.2	5.5	104	102.4	20.38	0.00	28.7
21	68	59	15	0.095	149.5	161	14.8	9.4	573	36.2	18.04	0.00	10.4
22	83	67	29	0.139	269.7	169	15.4	7.0	146	3.4	23.68	0.00	19.5
23	59	59	15	0.069	109.8	115	16.2	17.2	787	22.7	17.05	0.00	16.5
24	68	66	23	0.060	130.1	97	16.2	4.1	823	14.6	20.26	0.00	26.0
25	85	68	23	0.117	202.1	162	15.8	21.1	462	25.8	20.90	0.17	43.2
26	84	62	19	0.097	154.3	168	13.4	18.4	436	30.8	22.36	0.01	35.2
27	70	62	24	0.088	132.9	137	13.6	13.0	1013	20.2	20.23	0.00	28.5
28	82	77	24	0.072	135.1	129	16.8	53.6	755	37.3	21.02	3.87	34.9
29	82	72	25	0.085	155.0	156	15.6	50.9	862	45.9	22.33	2.43	42.7
30	93	69	29	0.142	233.8	217	14.1	12.1	296	3.8	24.49	0.00	35.8
31	80	65	24	0.096	148.1	180	14.4	17.1	444	59.8	22.60	0.00	36.9
32	74	53	17	0.080	131.4	244	8.7	18.8	990	46.1	16.04	0.09	87.6
33	85	60	20	0.097	170.0	243	11.3	49.8	957	34.1	18.57	0.04	81.9
34	84	75	26	0.077	167.6	153	14.0	33.0	550	30.8	20.75	0.80	60.6
35	89	74	26	0.098	169.8	180	14.5	22.5	568	37.6	20.42	0.18	41.9
36	76	77	24	0.037	93.9	101	15.4	22.4	572	0.3	19.98	0.00	54.6
37	84	65	21	0.078	141.0	158	13.1	57.0	513	28.0	19.42	0.00	74.6
38	84	64	23	0.109	191.3	196	13.7	20.9	713	46.4	22.17	0.42	54.1
39	93	69	20	0.087	178.0	151	16.1	16.9	388	37.8	24.59	0.12	53.0
40	80	81	25	0.091	181.6	208	14.0	7.9	255	47.7	19.33	0.00	52.8
41	87	60	20	0.074	137.0	147	13.1	20.4	330	22.6	19.60	0.00	53.7
42	80	67	21	0.075	129.9	146	13.2	27.4	348	19.1	20.09	0.68	44.2
43	87	70	28	0.097	194.7	124	16.9	26.7	1020	15.9	25.50	0.08	29.0
44	78	72	36	0.091	192.8	218	14.2	18.0	526	14.6	23.41	0.00	36.4
45	83	72	32	0.058	173.9	120	15.6	28.3	583	4.5	18.53	2.44	25.7

Abbreviations used in Table Y

Unit #: Treatment unit number

Cc : forest canopy cover (%)

ch: canopy height (feet)

cbh: canopy base height (feet)

cbd: canopy bulk density (kg/cubic meter)

ba: basal area per acre (square feet per acre)

tpa: trees per acre (over 4 inch DBH) (number of trees)

qmd: quadratic mean diameter of trees over 4 inch DBH (inches)

stcov: percent cover of small trees less than or equal to 4 inch DBH (%)

stpa: number of small trees less than or equal to 4 inch DBH per acre (number of trees)

abgr8: number of small grand fir trees over 4 inch DBH but less than or equal to 8 inch DBH per acre (number of trees)

maxdbh: the average maximum diameter class, where the trees of this diameter class and higher diameter classes equal or exceed 8 trees per acre (inches)

pipo: the number of ponderosa pine trees per acre (number of trees)

savetrees: the number of fire-resistant trees (western larch, Douglas-fir and ponderosa pine) per acre (number of trees)

Table 19. Treatment unit habitat characteristics and forest health issue zone values (see key on next page for abbreviations).

Unit #	snags	cwdcov	cwdnum	shrubs	shrubdiv	slzones	fhzones
1	36.5	2.09	113	27	3.9	0.190	0.722
2	9.7	1.63	72	26	7.2	1.182	1.427
3	48.4	5.00	179	53	6.3	0.000	0.375
4	88.3	13.35	278	3	2.4	0.004	0.504
5	29.9	11.45	194	30	5.7	0.000	0.396
6	12.7	1.42	69	27	4.4	1.062	0.926
7	21.6	4.39	132	15	3.0	0.326	0.070
8	14.4	0.40	17	24	8.5	1.989	0.725
9	53.0	3.13	85	19	4.7	0.819	1.305
10	73.5	4.67	223	35	6.0	0.000	0.966
11	26.6	5.87	141	43	6.2	0.100	0.000
12	31.5	4.93	135	49	6.0	0.138	0.207
13	78.3	5.99	210	36	9.0	0.000	1.000
14	108.4	6.04	247	53	8.3	0.000	1.769
15	35.9	1.31	56	32	7.1	0.989	1.578
16	152.9	7.56	166	30	3.5	0.000	0.000
17	85.8	3.12	143	18	4.1	0.004	0.313
18	36.0	7.13	145	47	6.1	0.032	0.866
19	91.1	2.98	113	27	3.7	0.000	0.782
20	92.2	4.68	112	15	2.0	0.056	0.692
21	10.3	4.55	114	25	4.0	0.933	0.000
22	22.0	2.89	95	4	2.1	0.328	0.000
23	18.3	10.18	177	25	5.0	0.648	0.210
24	68.4	24.48	350	19	5.0	0.000	0.895
25	17.6	1.86	64	16	4.1	0.783	0.514
26	50.8	9.86	200	35	4.6	0.004	0.896
27	95.0	15.22	263	23	4.7	0.000	0.862
28	71.9	6.11	146	35	6.5	0.096	0.966
29	66.1	6.33	154	35	6.2	0.000	1.088
30	91.6	12.91	270	2	2.0	0.000	0.508
31	62.2	7.70	183	30	6.5	0.004	0.703
32	41.5	1.44	54	25	7.9	0.741	1.704
33	44.0	2.96	116	25	7.0	0.872	1.638
34	18.1	2.86	81	22	5.1	0.828	1.473
35	33.6	1.82	92	22	5.7	0.489	0.875
36	96.5	5.45	184	55	7.2	0.000	1.105
37	100.7	5.38	185	52	6.6	0.000	1.360
38	86.0	12.78	281	22	4.9	0.000	0.991
39	50.5	3.26	130	48	6.2	0.081	0.589
40	41.1	2.05	93	10	5.6	0.183	0.683
41	56.3	7.19	181	20	5.8	0.000	0.888
42	45.2	5.96	177	36	6.9	0.010	0.447
43	42.1	11.06	311	9	5.3	0.000	0.569
44	37.6	10.38	156	57	9.8	0.040	0.893
45	68.9	24.54	297	37	5.5	0.000	1.310

Abbreviations used in Table Z

Unit #: Treatment unit number

snags: number of snags over 10-cm per acre

cwdcov: percent cover of coarse woody debris over 6 inches diameter per acre (%)

cwdnum: number of pieces of coarse woody debris over 6 inches diameter per acre

shrubs: average shrub cover (%)

shrubdiv: average diversity of shrubs (number of shrub species)

slzones: average snag and log enhancement priority zone value (see Figure 54 and 119)

fhzones: average primary forest health issue priority zone value (see Figure 100 and 118)

Table 20. Treatment unit fire behavior characteristics – before and after treatment and change due to treatment

Unit #	Flame length - before (feet)	Flame length - after (feet)	Change in flame length (feet)	Rate of spread - before (meters/min)	Rate of spread - after (meters/min)	Change in rate of spread (meters/min)
1	1.7	0.4	1.3	1.2	0.2	1.0
2	3.8	0.5	3.3	1.5	0.2	1.3
3	2.8	0.5	2.3	2.0	0.2	1.8
4	0.9	0.3	0.6	0.3	0.1	0.2
5	1.6	0.4	1.2	0.9	0.1	0.8
6	2.7	0.4	2.3	2.8	0.2	2.6
7	2.7	0.5	2.1	1.3	0.2	1.1
8	3.4	0.5	2.9	1.6	0.2	1.4
9	2.8	0.5	2.3	1.3	0.2	1.1
10	1.8	0.4	1.4	0.9	0.1	0.8
11	4.7	0.6	4.1	3.2	0.3	2.9
12	3.2	0.5	2.7	2.4	0.2	2.2
13	6.5	0.7	5.8	2.0	0.2	1.8
14	4.3	0.4	4.0	2.0	0.1	1.9
15	3.7	0.4	3.3	1.7	0.1	1.6
16	1.4	0.3	1.1	0.7	0.1	0.6
17	1.7	0.5	1.2	0.7	0.1	0.6
18	2.9	0.4	2.5	2.4	0.2	2.3
19	1.6	0.4	1.3	0.7	0.1	0.6
20	1.6	0.4	1.2	0.7	0.1	0.6
21	1.4	0.3	1.1	0.7	0.1	0.6
22	1.4	0.4	1.0	0.6	0.2	0.4
23	2.8	0.4	2.4	2.4	0.1	2.3
24	1.5	0.3	1.2	0.6	0.1	0.5
25	1.5	0.4	1.1	0.9	0.1	0.7
26	1.6	0.4	1.3	0.7	0.1	0.5
27	1.6	0.4	1.2	0.7	0.1	0.5
28	3.9	0.4	3.5	1.6	0.1	1.5
29	3.9	0.4	3.5	1.7	0.1	1.6
30	0.9	0.4	0.6	0.3	0.1	0.2
31	2.3	0.4	2.0	1.0	0.1	0.9
32	3.4	0.9	2.5	1.6	0.4	1.2
33	2.3	0.4	1.9	1.0	0.1	0.8
34	1.4	0.4	1.1	0.6	0.1	0.5
35	1.8	0.4	1.4	1.0	0.1	0.9
36	3.3	0.5	2.8	2.7	0.3	2.4
37	3.5	0.4	3.1	1.8	0.1	1.7
38	1.9	0.4	1.5	1.0	0.1	0.9
39	2.4	0.4	2.0	1.7	0.2	1.5
40	2.5	0.4	2.1	0.8	0.1	0.7
41	3.0	0.3	2.7	1.0	0.1	0.9
42	3.3	0.4	2.9	1.5	0.1	1.4
43	2.3	0.5	1.9	1.2	0.1	1.0
44	6.2	0.6	5.6	1.8	0.2	1.6
45	2.3	0.4	1.9	0.8	0.1	0.7

Description of Individual Treatment Units by Geographic Proximity and Similarity of Conditions

Each treatment unit was designed to help achieve one or more project objective (maintaining good habitat for a great number of wildlife species; protecting aesthetics and recreational values associated with the forest; reducing the risk of catastrophic wildfire; limiting tree mortality from insects and disease to the historic range of variability; maintaining diverse; and resilient plant communities). Many treatment units help to achieve multiple objectives. These objectives, and issues related to them, have all been described in detail in earlier sections of this report. It is important that the reader remember that we are treating only a portion of the park and, thus, impacts to recreation are likely to be limited in both time and space. Also, the diversity of structure and composition across the greater landscape provides good habitat for most all wildlife species typically found in these mid-montane forests. In this section, we only focus on the effects of treatments on selected wildlife species. We have attempted to consider all the objectives of the project when designing the following treatment units, but some treatment units focus primarily on one or two objectives. In nearly all cases, we have tried to avoid treatment options or treatment unit locations where meeting one objective would compromise another objective. This sort of conflict between objectives can be avoided and would be counterproductive in meeting overall project goals.

The following is a description of treatment units organized by geographic proximity and similarity of conditions. This grouping should not be confused with the initial zone designations that we used to develop and organize the forest plan. The groupings presented below are used only to facilitate description of individual units that are in close proximity.

Group 1: Treatment Units 1, 6, 19, 20 and 25

These treatment units lie above and below the main road up the mountain, to the west of the snowmobile parking area (Figures 130 and 131). The forests in these treatment units are relatively healthy. However, the opportunity exists to reduce surface fuels so that surface fires that may occur in the lower watershed encounter a depleted fuel zone in the treatment units, which would then slow further spread into the upper part of the mountain. The treatments in this area are designed to enhance the effectiveness of the highway corridor as a fire barrier. These treatment units were identified as ideal candidates for the use of prescribed fire because of the relatively open nature of the forests, the relatively high canopy base height of the stands, and the general lack of significant ladder fuels. The basic characteristics of these treatment units are presented in Table 21.

Table 21. Basic characteristics of Treatment Units in Group 1. (see Tables 17-20)

Unit #	1st Option	2nd Options	Zone	Year	Acres	slope (%)	cbh	cbd	ba	tpa	qmd	stpa	abgr8	maxdbh	Savetrees	snags	cwdcov	cwdnum	Slzones	flzones	Flame length - before	Flame length - after	Change in flame length	Rate of spread - before	Rate of spread - after	Change in rate of spread
1	2	1	1	1	36	40	20	0.15	208	227	14	350	30	21	77	37	2	113	0.19	0.72	1.7	0.4	1.3	1.2	0.2	1.0
6	2	1	1	2	16	37	17	0.08	133	127	15	385	31	20	40	13	1	69	1.06	0.93	2.7	0.4	2.3	2.8	0.2	2.6
19	2	3,1	3	2	12	30	19	0.20	200	287	12	266	49	20	64	91	3	113	0.00	0.78	1.6	0.4	1.3	0.7	0.1	0.6
20	3	2,1	1	2	24	35	17	0.20	193	296	13	104	102	20	29	92	5	112	0.06	0.69	1.6	0.4	1.2	0.7	0.1	0.6
25	3	1	1	3	39	34	23	0.12	202	162	16	462	26	21	43	18	2	64	0.78	0.51	1.5	0.4	1.1	0.9	0.1	0.7

Prescribed fire (Options 2 or 3) was selected as the recommended treatment option for each of these units. The treatment units below or between the roads (units 1,6 and 19) can be treated with minimal pre-treatment (Option 2), with the road forming the main fire line. The units above the road (units 20 and 25) require construction of more fire line and in some cases some additional pre-treatment (Option 3). Units 19, 20 and 25 also contain the electrical transmission line that goes up the mountain within the unit boundary. Negotiation with the power company will be necessary before treatment of this area is possible. It is likely that the transmission line corridor should be excluded from the treatment area or left to the power company to treat in a fashion that is satisfactory to them and State Parks.

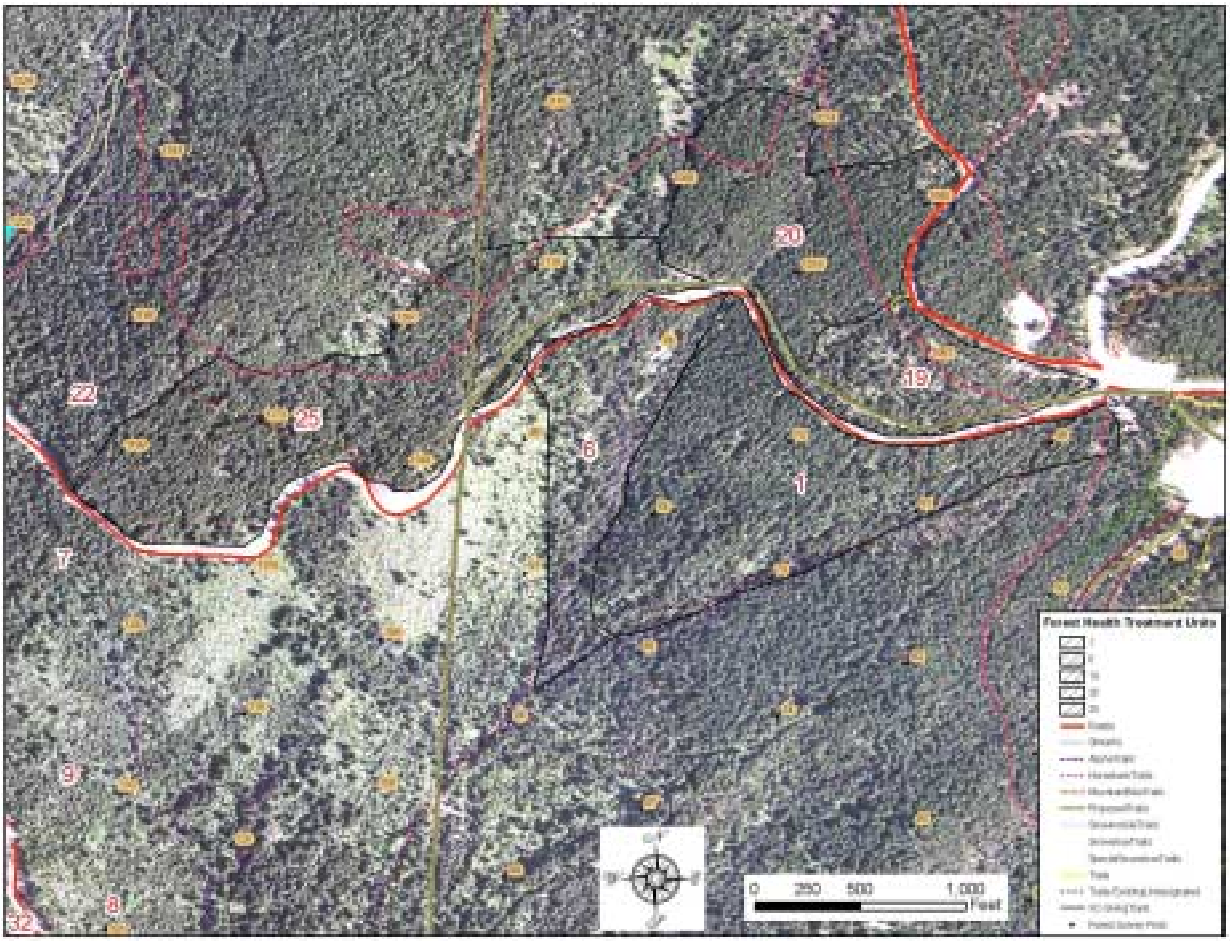

Figure 130. Aerial photograph of Treatment Units 1, 6, 19, 20 and 25. The prescribe fire would be initiated in the upper part of each Treatment Unit and would be progressively ignited down the slope.

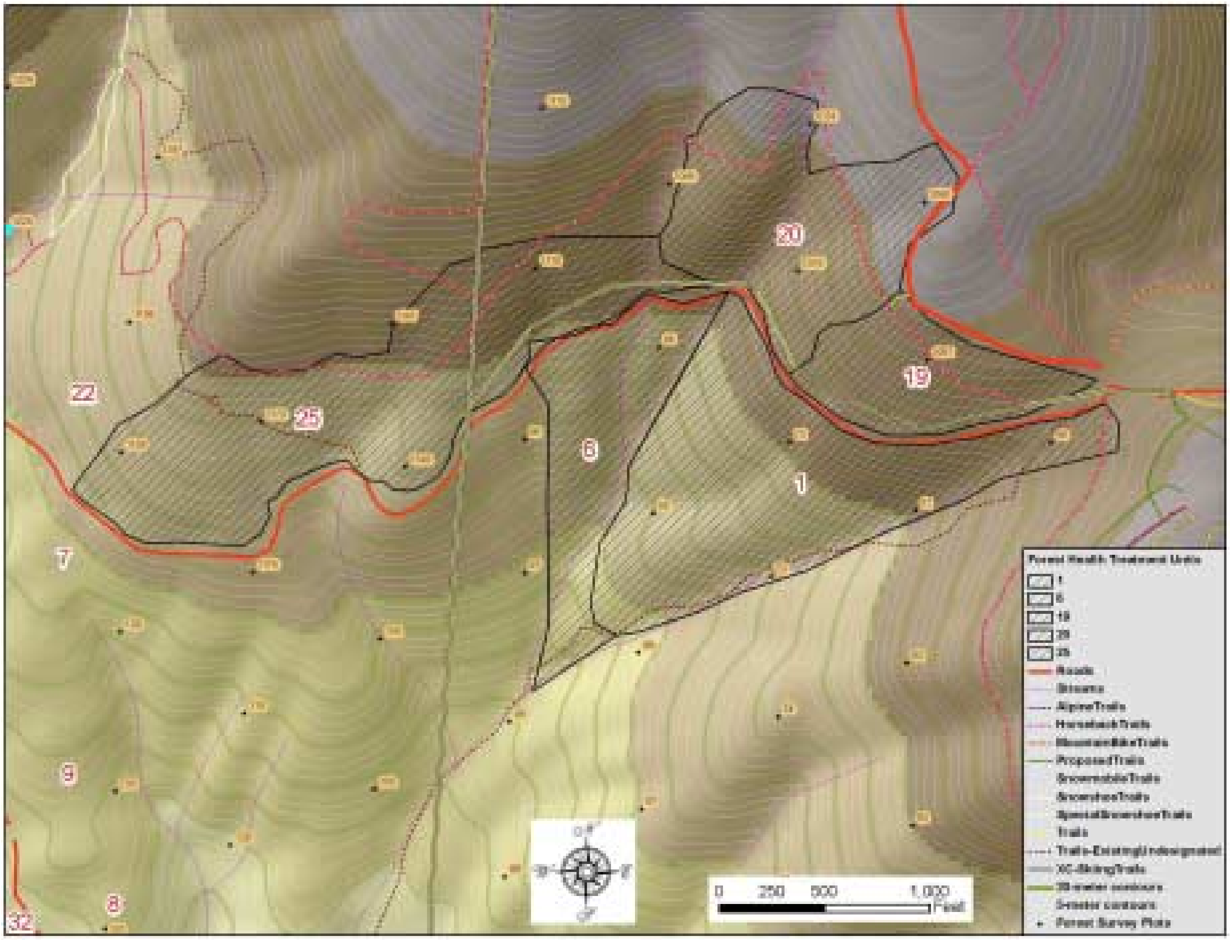

Figure 131. Topographic map of Treatment Units 1, 6 19, 20 and 25. Major contour intervals are 67 ft and minor contours are 17 ft.

These treatment units are primarily composed of mature forests in the ABGR/VAME CLUN plant association with patches of ABGR/ACGLD/CLUN, TSHE/CLUN and TSHE/XETE (see Table 3 for a description of the abbreviations used here). The forests in this group of treatment units are in relatively good forest health (moderate CWD and snags, moderate diversity of shrubs, etc.; Tables 17-20), but a reduction of surface fuels here, with the road acting as a fire break, would reduce the potential of fire spreading from the lower watershed into the upper part of the mountain. This area was identified as ideal for the use of prescribed fire. The easternmost part of Treatment Unit 1 and Treatment Unit 19 lies in the globally imperiled TSHE/XETE plant association and special care must be taken to not alter or degrade this unique plant community.

Prescribe Fire Treatment Plan

A prescribed fire would be ignited, starting in strips immediately below the road, and progressing down the slope. The prescribed fire would be ignited during a predictable west wind and the crew would start on the east side of each unit and progress to the west, thereby minimizing smoke inhalation problems. These units could be burned under a variety of weather conditions but the ideal conditions would probably occur in the late spring, when duff and coarse woody debris moisture levels are adequate to avoid significant duff and large log consumption. The prescription requires dry enough conditions for the fire to spread and consume adequate surface fuels. It should be ignited during moderate weather conditions where surface flame lengths of 0.5 to 3 feet can be maintained.

We recommend more intensive pre-treatment along the electrical transmission line corridors that cross units 19, 20 and 25, including construction of fire lines to protect the transmission line from the effects of prescribed fire. This work should be coordinated with the electrical utility company.

Treatment Effects on Sensitive Wildlife

Units 1, 6, 19, 20 and 25

Goshawks, martens, great gray owls, and pileated woodpeckers would all benefit to one degree or another from prescribed fire treatments in these units (Table 22). Lower canopy flyways would be maintained and possibly opened up by prescribed fire, benefiting goshawk foraging and great gray owl breeding and roosting. With successful snag preservation, plus snag creation as a result of fire-killed trees, marten winter foraging habitat and pileated woodpecker breeding and foraging habitat would be improved.

Lynx and marten would gain mixed results from this treatment. For lynx and marten non-winter foraging, the prescribed burn could immediately reduce shrub cover desirable for lynx and marten prey (and desirable edible shrub species for marten could be reduced as well); however, the herbaceous canopy response to fire, and potentially even the shrub response, could be good for lynx and marten prey (therefore enhancing habitat suitability). The long-term impacts are expected to be beneficial to both species' non-winter foraging habitat. Also, intentional snag recruitment due to the burn and subsequent coarse woody debris production could benefit marten non-winter foraging and perhaps marten winter foraging.

Finally, given the proximity of this area to recreation, the "cleaner" understories resulting from these treatments will contribute to longer-distance views into the forest that will likely prove desirable to many visitors.

Table 22. Effects of prescriptions for Treatment Units 1, 6, 19, 20 and 25 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Possible	Positive
	Nesting	Improbable	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Improbable	Neutral
	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Improbable	Neutral
Marten	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Improbable	Positive
Wolverine	Any	Possible	Neutral
Bald Eagle	Roosting	Possible	Neutral
Golden Eagle	Roosting	Possible	Neutral
	Foraging	Improbable	Neutral
Great Gray Owl	Breeding	Possible	Positive
	Foraging	Improbable	Neutral
	Roosting	Possible	Positive
Pileated Woodpecker	Breeding	Possible	Positive
	Foraging	Possible	Positive
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral
Western Toad	Any	Possible	Neutral

Occurrence	*Effect*
Improbable - Species most likely does not use this particular treatment area Possible - Moderate to strong possibility of species using this particular treatment area	Neutral - Treatment should have a neutral effect Positive - Treatment should have a net benefit effect on wildlife habitat suitability Negative - Treatment should have a net negative effect on wildlife habitat suitability Mixed - The positive and negative effects of treatment would be near to balancing each other out

Group 2: Treatment Units 2, 15, 34 and 35

These treatment units are located on both sides of the main road up the mountain above the park entrance (Figures 132 and 133). They are grouped together because of their geographic proximity. The basic characteristics of these treatment units are presented in Table 23.

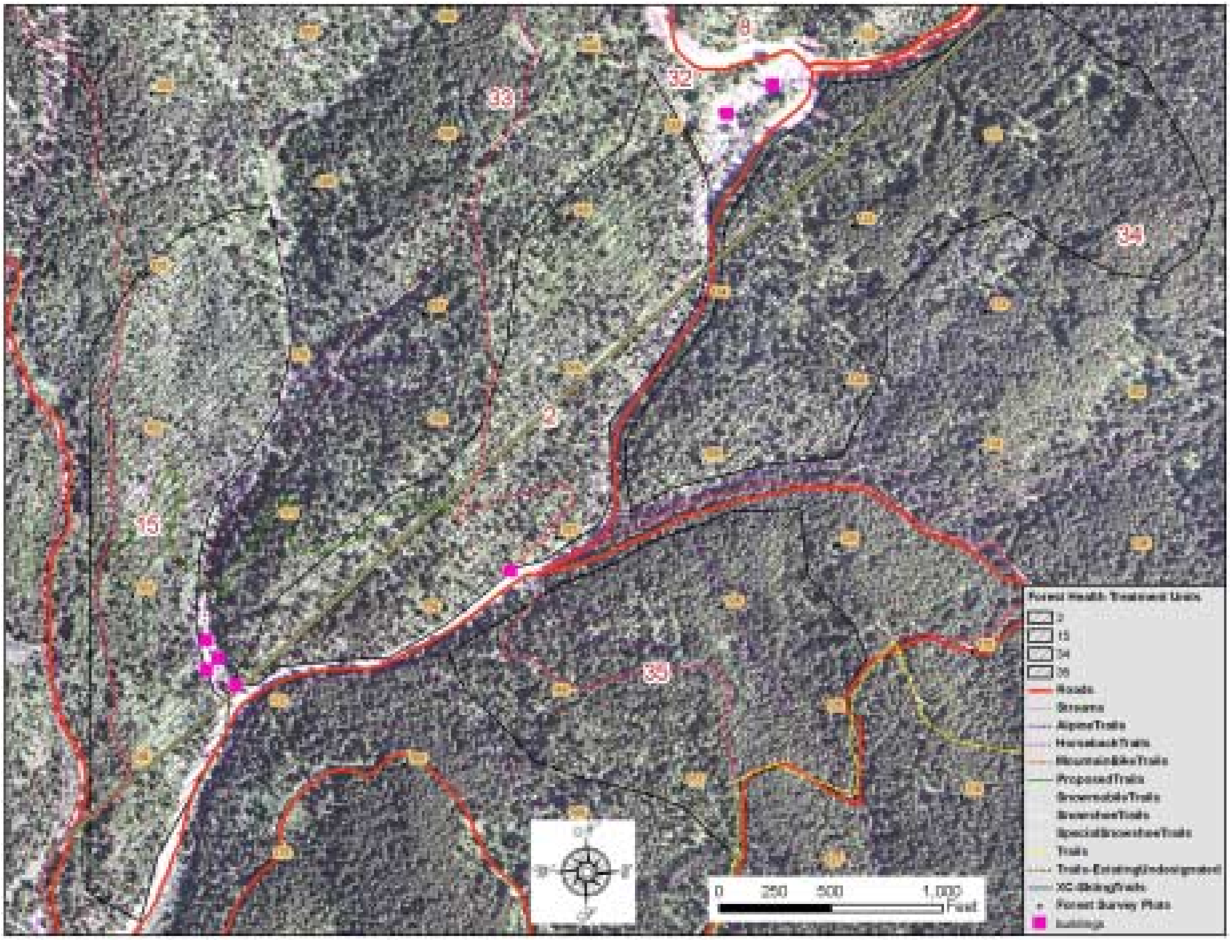

Figure 132. Aerial photograph of Treatment Units 2, 15, 34 and 35.

Table 23. Basic characteristics of Treatment Units in Group 2. (see Tables 17-20)

Unit #	1st Option	2nd Options	Zone	Year	Acres	slope (%)	cbh	cbd	ba	tpa	qmd	stpa	abgr8	maxdbh	savetrees	snags	cwdcov	cwdnum	slzones	flzones	Flame length - before	Flame length - after	Change in flame length	Rate of spread - before	Rate of spread - after	Change in rate of spread
2	3	5,1	1	2	42	40	18	0.09	160	180	13	762	61	20	30	10	2	72	1.18	1.43	3.8	0.5	3.3	1.5	0.2	1.3
15	6	5,1	1 & 4	5	41	39	16	0.11	157	288	11	728	124	20	53	36	1	56	0.99	1.58	3.7	0.4	3.3	1.7	0.1	1.6
34	6	8,1	1 & 5	4	59	29	26	0.08	168	153	14	550	31	21	61	18	3	81	0.83	1.47	1.4	0.4	1.1	0.6	0.1	0.5
35	5	3,1	1 & 5	7	39	28	26	0.10	170	180	15	568	38	20	42	34	2	92	0.49	0.88	1.8	0.4	1.4	1.0	0.1	0.9

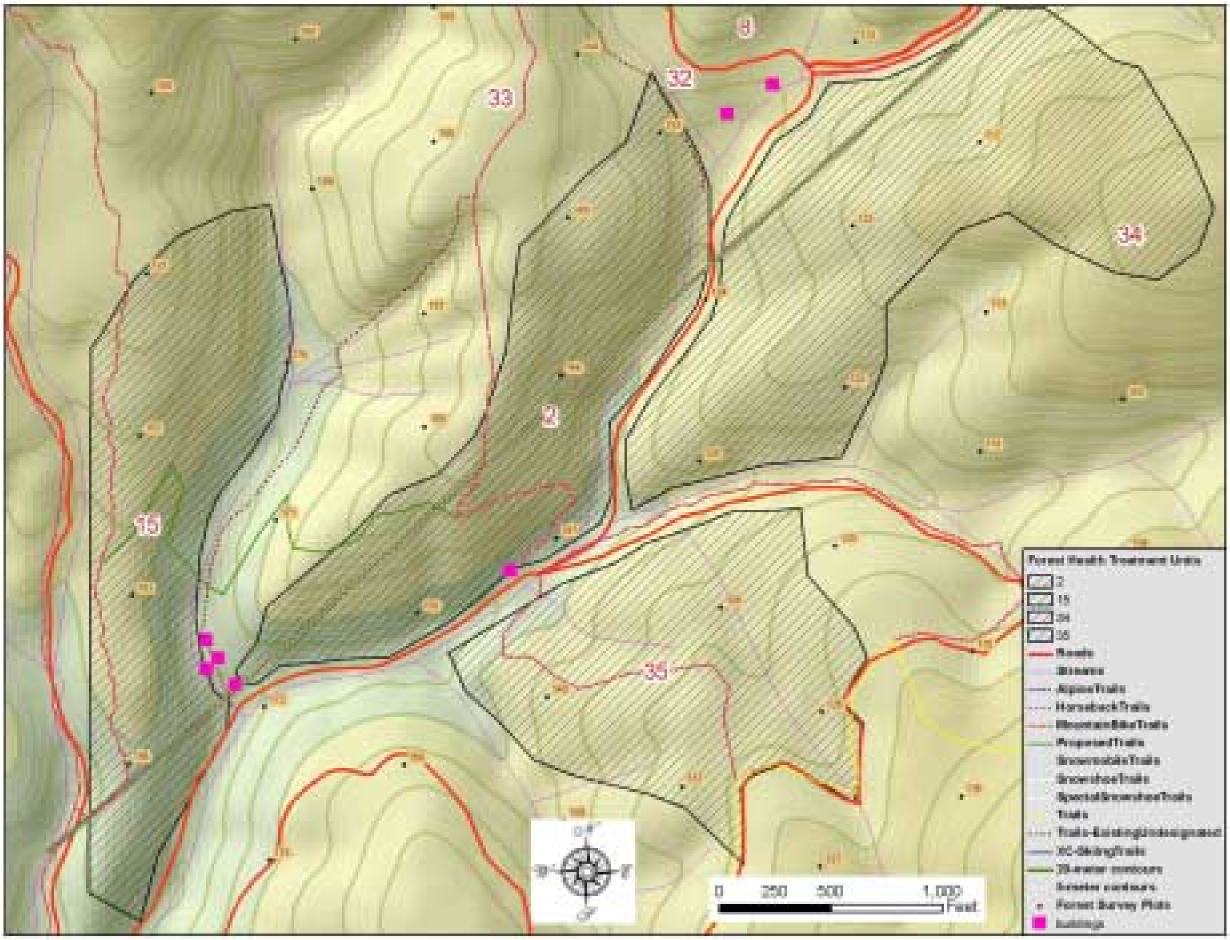

Figure 133. Topographic map of Treatment Units 2, 15, 34 and 35.

Generally, the forests in Group 2 have more severe forest health problems than in Group 1. Much of the overstory in this area was removed by logging and/or wildfire about 50-60 years ago although some shade-intolerant species like ponderosa pine and western larch persist in the canopy). Young grand fir densities often exceed 800 trees per acre. While the overstory canopy cover is low and there is a low canopy bulk density, there is a higher potential for crown fire because of the extensive ladder fuels in many of these stands.

The treatment units in this group need more pre-treatment before prescribed fire is used. The treatment units in this group are lower elevation forests than those in Group 1 and have more legacy ponderosa pine, western larch and Douglas-fir. We recommend treatment Option 3 for Unit 2, with more intensive pre-treatment and thinning along the electrical transmission line corridor. Likewise, Treatment Units 15 and 34 contain a portion of the electrical transmission line and intensive pre-treatment will be required along it.

The park headquarters is located between Treatment Units 2 and 15 and other structures are located between units 2 and 34. Extensive pre-treatment of fuels is recommended near these structures before prescribed fire is implemented. We recommend treatment Option 6 for units 15 and 34 and treatment Option 5 for Unit 35. In all cases, protection of legacy trees in this treatment group is a priority. Likewise, reduction in grand-fir abundance and reestablishment of conditions, where fire resistant ponderosa pine, Douglas-fir and western larch can reproduce and thrive, are prime objectives. Landscape-level fuel reduction to aid in protection of infrastructure and transportation corridors is a significant reason that this area receives high priority for treatment. In general, this area is lacking sufficient large snags and logs for optimal wildlife habitat. Creation of snags and logs is one of the objectives of each of the treatment options chosen for units in this group.

Treatment Effects on Sensitive Wildlife

Units 2, 15, 34, and 35

The forest and habitat conditions in these units are diverse and fragmented making it difficult to interpret the area's habitat suitability for many of our target species. Historic fire and logging have drastically reduced CWD and snag densities in some patches while young grand fir regeneration is very high in some places, effectively shading out the understory and eliminating herb and shrub components. Other areas have large legacy trees with healthy shrub and understory development. The proposed treatments of these units would probably benefit most wildlife species overall, by replacing the thick grand fir patches with understory shrubs and/or more diverse conifer regeneration (Table 24). Tree kill during the fire would add more snags and subsequent coarse woody debris to the forest, improving wildlife values. While the initial mortality on desirable understory vegetation might temporarily reduce habitat suitability for lynx and marten, the long term effects of replacing low habitat value young grand fir patches with a diversity of understory shrubs and mixed conifer regeneration will enhance the habitat value of these units from current conditions.

Table 24. Effects of prescriptions for Treatment Units 2, 15, 34, and 35 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Possible	Positive
	Nesting	Improbable	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Improbable	Neutral
	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Improbable	Neutral
Marten	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Improbable	Neutral
Wolverine	Any	Improbable	Neutral
Bald Eagle	Roosting	Possible	Neutral
Golden Eagle	Roosting	Possible	Neutral
	Foraging	Improbable	Neutral
Great Gray Owl	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
	Roosting	Improbable	Neutral
Pileated Woodpecker	Breeding	Possible	Positive
	Foraging	Possible	Positive
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral

Western Toad	Any	Possible	Positive

Group 3: Treatment Units 3, 5, 11, 12, 13, 14, 18, 31, 36

These treatment units are located above and below the Mt. Kit Carson Loop Road in the northwestern part of the project area (Figure 134 and 135). They are grouped together because of their geographic proximity. The basic characteristics of these treatment units are presented in Table 25.

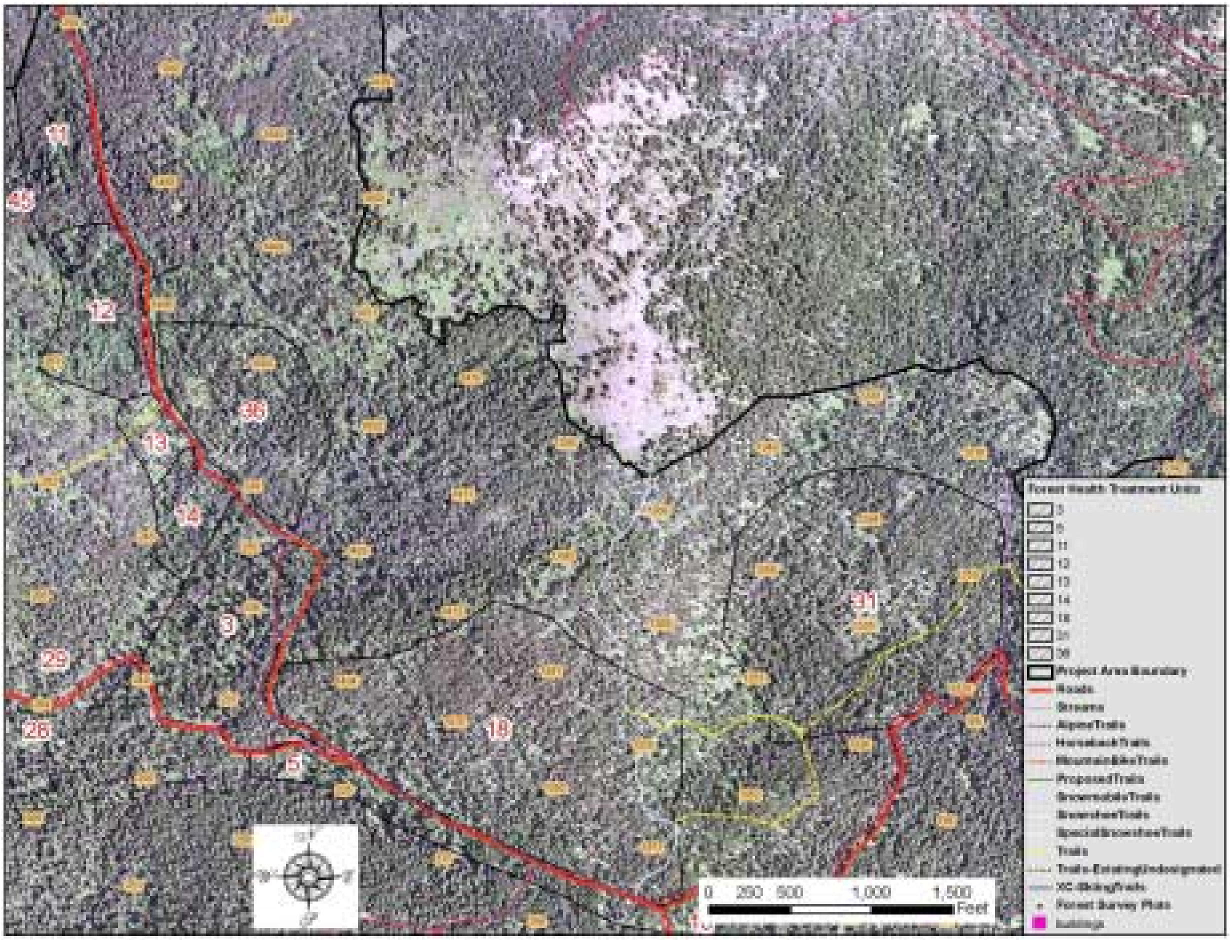

Figure 134. Aerial photograph of Treatment Units 3, 5, 11, 12, 13, 14, 18, 31, 36.

Table 25. Basic characteristics of Treatment Units in Group 3. (see Tables 17-20)

Unit #	1st Option	2nd Options	Zone	Year	Acres	slope (%)	cbh	cbd	ba	tpa	qmd	stpa	abgr8	maxdbh	savetrees	snags	cwdcov	cwdnum	slzones	flzones	Flame length - before	Flame length - after	Change in flame length	Rate of spread - before	Rate of spread - after	Change in rate of spread
3	3	5,1	2	4	24	23	25	0.06	164	119	17	781	19	24	31	48	5	179	0.00	0.38	2.8	0.5	2.3	2.0	0.2	1.8
5	3	6,1	2	2	11	27	29	0.08	178	124	17	627	16	24	22	30	11	194	0.00	0.40	1.6	0.4	1.2	0.9	0.1	0.8
11	2	1	2	2	13	47	27	0.07	155	120	15	123	0	20	38	27	6	141	0.10	0.00	4.7	0.6	4.1	3.2	0.3	2.9
12	2	1	2	2	13	33	22	0.04	80	74	11	285	0	16	24	32	5	135	0.14	0.21	3.2	0.5	2.7	2.4	0.2	2.2
13	6	8,1	2	3	3	15	31	0.05	101	156	11	896	1	16	32	78	6	210	0.00	1.00	6.5	0.7	5.8	2.0	0.2	1.8
14	6	5,1	2	3	6	23	29	0.06	135	169	14	853	8	20	71	108	6	247	0.00	1.77	4.3	0.4	4.0	2.0	0.1	1.9
18	3	2,1	2 & 6	3	63	39	30	0.07	153	102	18	967	9	23	24	36	7	145	0.03	0.87	2.9	0.4	2.5	2.4	0.2	2.3
31	3	2,1	2 & 6	4	53	39	24	0.10	148	180	14	444	60	23	37	62	8	183	0.00	0.70	2.3	0.4	2.0	1.0	0.1	0.9

36	3	2,1	2	7	20	35	24	0.04	94	101	15	572	0	20	55	97	5	184	0.00	1.11	3.3	0.5	2.8	2.7	0.3	2.4

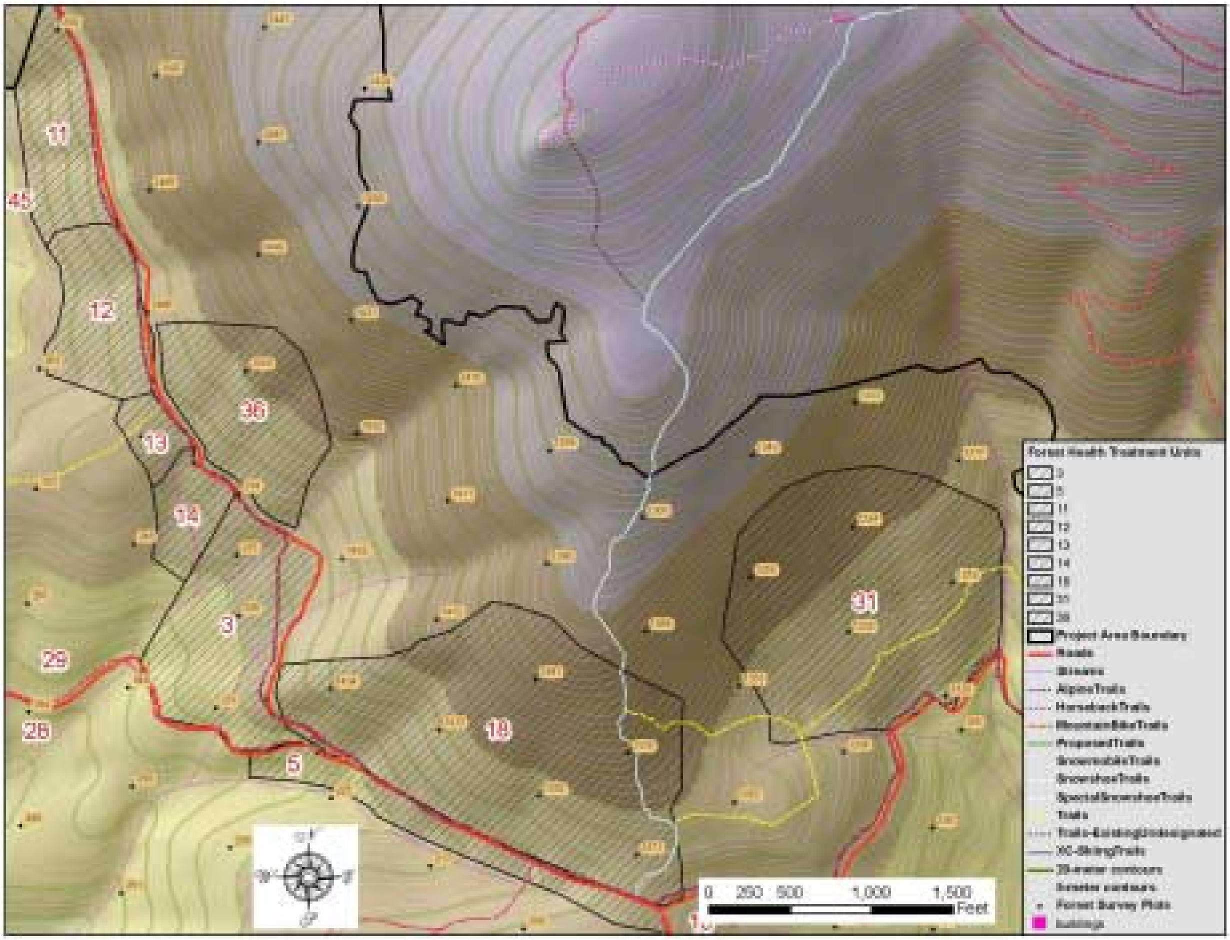

Figure 135. Topographic map of Treatment Units 3, 5, 11, 12, 13, 14, 18, 31, 36.

Treatment Unit 3 contains a mature mixed with old forest stand in the grand fir / Douglas maple / queen's cup (ABGR/ACGLD/CLUN) plant association. There are a few large western larch, Douglas-fir and grand fir in the stand. There are many young grand fir and medium size grand fir. In some places in the stand there are over 800 small grand firs per that are less than 4 inch DBH. It has many snags and large logs and provides optimal wildlife habitat for a diversity of species that thrive in old forests. Our objective in this stand is to preserve its old-growth characteristics and wildlife habitat values, while reducing the risk of wildfire damaging these values. Another objective includes dramatically reducing the density of small grand firs, which would enable the gradual transition to a forest with more fire resistant trees. We propose to treat this unit with Option 3. The treatment will help create a firebreak that would slow fires moving from the west and up the mountain. Roads bound this unit on three sides that can form the primary firebreaks.

Treatment Unit 5 is a narrow strip of forest and shrubs lying between a ravine that runs northwest from Smith Gap and the Mt. Kit Carson Loop Road. It is adjacent to Unit 3 and we propose to treat this unit with Option 3. The treatment will help create a firebreak that would slow fires moving from the west and up the mountain. The road will serve as the primary firebreak.

Treatment Units 11 and 12 are below the Mt. Kit Carson Loop Road. These units are in a mature stand in the grand fir / Douglas maple / queen's cup (ABGR/ACGLD/CLUN) plant association with a patch of old-growth in the middle of the stand. This unit is very steep. Most of these two units exceeds 30% slope and some of areas exceed 50% slope. Because of the steepness of the slope, most mechanical treatments would be unwise in this area. This area is not in bad forest health as it currently exists, but some fuel reduction via prescribed fire may be desirable to help create a reduced fuel zone along the Mt. Kit Carson Loop Road. We propose to treat these two units using Option 2, or prescribed fire with minimal pre-treatment. The road can serve as the primary fire line.

A prescribed fire would be ignited in each of these units starting in strips immediately below the road and progressing down the slope. The prescribed fire should be ignited during a predictable upslope wind. These units could be burned separately or at the same time during the spring or fall, when duff and coarse woody debris levels are adequate to avoid significant duff consumption and large log consumption. The prescription requires dry enough conditions for the fire to spread and consume adequate surface fuels. It should be ignited during moderate weather conditions where surface flame lengths of 1 to 3 feet can be maintained.

Treatment Units 13 and 14 lie further south along the Mt. Kit Carson Loop Road. They contain forests in the ABGR/ACGLD/CLUN plant association (Table 3). They both have over 800 small trees (<4 inch DBH), mostly grand fir, in the understories. Unit 13 is patchy with some openings containing mostly shrubs and herbs. Unit 14 is a more homogeneous forest. Both contain some old fire resistant "legacy" trees. Both units are in forest health priority areas (Figure 123 and Table 25). We propose treating both stands with treatment Option 6. The purpose of treatment is to dramatically reduce the density of small grand firs, enable the transition to a forest with more fire resistant trees and significantly reduce the fuel loading and help create a firebreak that would slow fires moving from the west and up the mountain. Both units could be treated at the same time, or they could be treated separately.

Treatment Units 18, 31 and 36 are above the Mt. Kit Carson Loop Road. Unit 36 is a mature/old forest in the ABGR/ACGLD/CLUN plant association (Table 3). Unit 18 contains a mosaic of grand fir associations (ABGR/VAME/CLUN, ABGR/PHMA and ABGR/ACGLD/CLUN). Unit 31 also contains a mosaic of grand fir associations (ABGR/VAME/CLUN and ABGR/PHMA), but the lower part of the unit transitions into a western hemlock association (TSHE/CLUN). A significant portion of these three units is in a forest health priority area (Figure 123 and Table 25). We proposed to treat all of these units with Option 3. Since these units are above the road, an effective fire line will need to be constructed along the tops of the units. We also recommend burning these units in the late spring, when the upper part of the mountain is still quite moist from snowmelt. This will help alleviate any risk of the prescribed fire moving beyond the treatment areas. The prescribed fire should be ignited in each of these units starting in strips immediately below the constructed fire line and progress down the slope. It should be ignited during a predictable upslope wind. These units should be burned separately, when duff and coarse woody debris levels are adequate to avoid significant duff consumption and large log consumption. The prescription requires dry enough conditions for the fire to spread and consume adequate surface fuels. It should be ignited during moderate weather conditions where surface flame lengths of 1 to 3 feet can be maintained.

Treatment Effects on Sensitive Wildlife

Units 3, 5, 18, 31, and 36

These units occur in an important wildlife migration corridor for ungulates and carnivores moving down and up in elevation between seasons in the Park. Extensive elk and deer bedding grounds were observed in or near these units. High conifer species diversity in the overstory, and high understory species diversity make this a unique forested area in the Park. We have recommended that all these units be treated with Option 3. Carefully prepared and executed prescribed fire treatments in this collection of units will retain or improve CWD levels, snag density, and will not kill excessive numbers of desirable overstory trees. The prescription for these units will help to conserve the high species diversity and optimal wildlife migration conditions found in these units. Although initial loss of shrub cover may adversely affect habitat suitability for lynx and marten non-winter foraging, the expected rapid regeneration of desirable understory species will enhance the habitat value for these two species (Table 26).

Table 26. Effects of prescription for Treatment Units 3, 5, 18, 31, and 36 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	**Possible**	**Positive**
	Nesting	**Improbable**	**Neutral**
Lynx	Dispersal	**Possible**	**Neutral**
	Breeding	**Improbable**	**Neutral**
	Non-Winter Foraging	**Possible**	**Mixed**
	Winter Foraging	**Improbable**	**Neutral**
Marten	Non-Winter Foraging	**Possible**	**Mixed**
	Winter Foraging	**Possible**	**Positive**
Wolverine	Any	**Possible**	**Neutral**
Bald Eagle	Roosting	**Possible**	**Neutral**
Golden Eagle	Roosting	**Possible**	**Neutral**
	Foraging	**Improbable**	**Neutral**
Great Gray Owl	Breeding	**Improbable**	**Neutral**
	Foraging	**Improbable**	**Neutral**
	Roosting	**Improbable**	**Neutral**
Pileated Woodpecker	Breeding	**Possible**	**Positive**
	Foraging	**Possible**	**Positive**
Black-backed Woodpecker	Breeding	**Improbable**	**Positive**
	Foraging	**Possible**	**Positive**
Townsend's Big-eared Bat	Any	**Improbable**	**Neutral**
Columbia Spotted Frog	Any	**Improbable**	**Neutral**
Western Toad	Any	**Possible**	**Neutral**

Units 11, 12, 13, and 14

Goshawks, martens, and pileated woodpeckers would all benefit to one degree or another from the treatments proposed for these units (Table 27). Lower canopy flyways would be opened up by prescribed fire, benefiting goshawk foraging. With successful snag preservation, plus potential snag creation, marten winter foraging habitat and pileated woodpecker foraging habitat should be improved.

For lynx and marten non-winter foraging a prescribed burn could immediately reduce shrub cover desirable for lynx and marten prey (and desirable edible shrub species for marten could be reduced as well). However, the herbaceous and shrub response to fire should be good for lynx and marten prey and browse in the longer term benefiting both species' non-winter foraging habitat. Also, intentional snag recruitment due to the burn and subsequent coarse woody debris production could benefit marten non-winter foraging and perhaps marten winter foraging.

Table 27. Effects of prescriptions for Treatment Units 11, 12, 13, and 14 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	**Improbable**	**Positive**
	Nesting	**Improbable**	**Neutral**
Lynx	Dispersal	**Possible**	**Neutral**
	Breeding	**Improbable**	**Neutral**
	Non-Winter Foraging	**Possible**	**Mixed**
	Winter Foraging	**Improbable**	**Neutral**
Marten	Non-Winter Foraging	**Possible**	**Mixed**
	Winter Foraging	**Improbable**	**Neutral**
Wolverine	Any	**Possible**	**Neutral**
Bald Eagle	Roosting	**Possible**	**Neutral**
Golden Eagle	Roosting	**Possible**	**Neutral**
	Foraging	**Improbable**	**Neutral**
Great Gray Owl	Breeding	**Improbable**	**Neutral**
	Foraging	**Improbable**	**Neutral**
	Roosting	**Improbable**	**Neutral**
Pileated Woodpecker	Breeding	**Possible**	**Positive**
	Foraging	**Possible**	**Positive**
Black-backed Woodpecker	Breeding	**Improbable**	**Neutral**
	Foraging	**Improbable**	**Positive**
Townsend's Big-eared Bat	Any	**Improbable**	**Neutral**
Columbia Spotted Frog	Any	**Improbable**	**Neutral**
Western Toad	Any	**Possible**	**Neutral**

Group 4: Treatment Units 4, 7, 10, 22 and 30

These treatment units are located above and below the highway up the mountain and below the Mt. Kit Carson Loop Road near the center of the study area (Figure 136 and Figure 137). They are grouped together because of their geographic proximity. The basic characteristics of these treatment units are presented in Table 28.

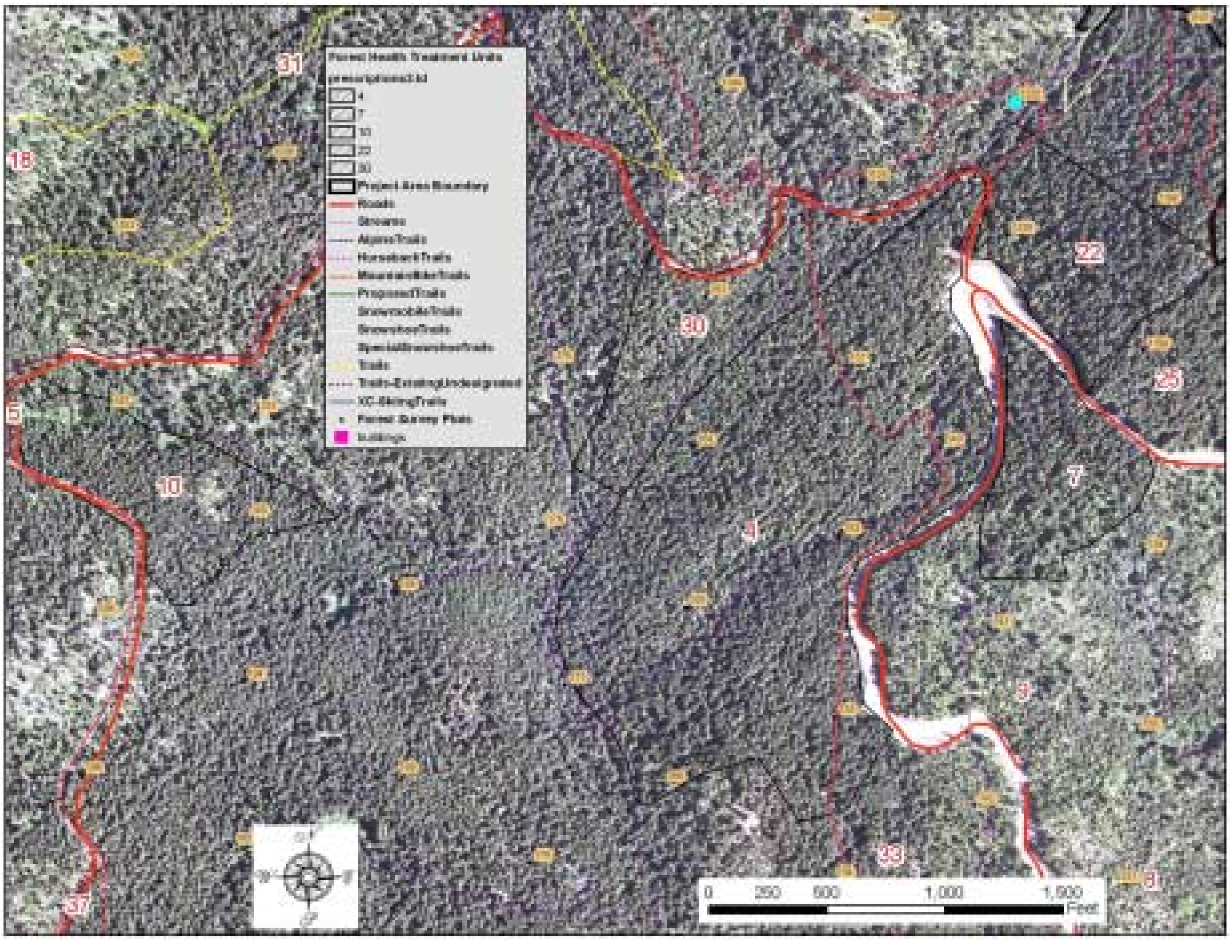

Figure 136. Aerial photograph of Treatment Units 4, 7, 10, 22 and 30.

Table 28. Basic characteristics of Treatment Units in Group 4. (see Tables 17-20)

Unit #	1st Option	2nd Options	Zone	Year	Acres	slope (%)	cbh	cbd	ba	tpa	qmd	stpa	abgr8	maxdbh	savetrees	snags	cwdcov	cwdnum	slzones	flzones	Flame length - before	Flame length - after	Change in flame length	Rate of spread - before	Rate of spread - after	Change in rate of spread
4	4	1	1	5	61	25	27	0.13	232	214	15	619	10	24	28	88	13	278	0.00	0.50	0.9	0.3	0.6	0.3	0.1	0.2
7	2	1	1	5	11	29	24	0.15	220	228	15	707	34	21	13	22	4	132	0.33	0.07	2.7	0.5	2.1	1.3	0.2	1.1
10	8	6,1	2	4	13	29	27	0.10	171	158	15	619	55	22	39	74	5	223	0.00	0.97	1.8	0.4	1.4	0.9	0.1	0.8
22	3	1	1	3	13	38	29	0.14	270	169	15	146	3	24	20	22	3	95	0.33	0.00	1.4	0.4	1.0	0.6	0.2	0.4
30	8	3,1	2	4	14	25	29	0.14	234	217	14	296	4	24	36	92	13	270	0.00	0.51	0.9	0.4	0.6	0.3	0.1	0.2

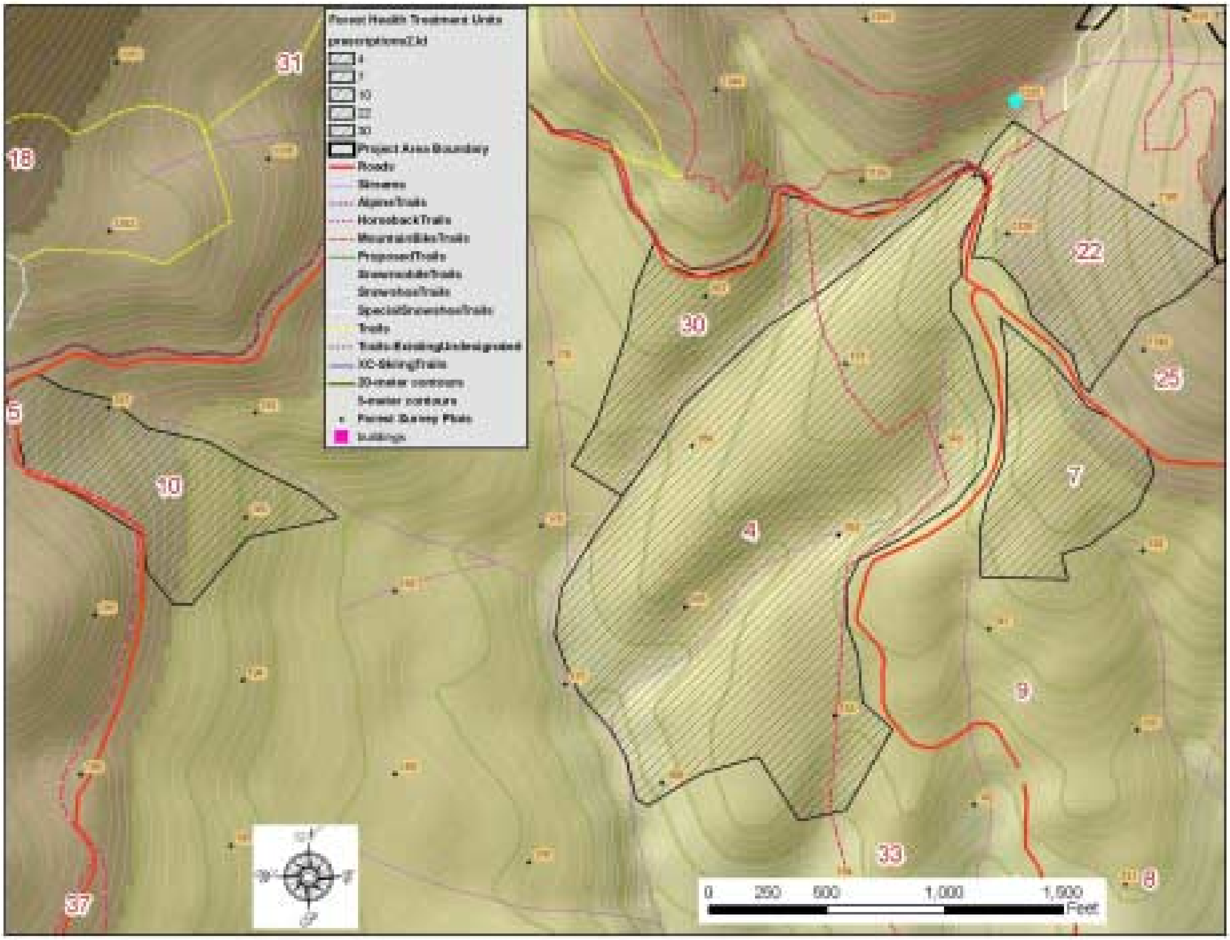

Figure 137. Topographic map of Treatment Units 4, 7, 10, 22 and 30.

Treatment Unit 4 is west of the highway, up the mountain and below the junction with the Mt. Kit Carson Loop Road. It is a young/mature forest with a mosaic of two moist, western hemlock series plant associations (TSHE/CLUN and TSHE/GYDR) with a little western redcedar (THPL/VAME) along the creek on the western edge of the unit (Table 3). The stand is a result of forest succession following clearcut logging during the last century. This stand currently has an open, sparse understory and little grand-fir encroachment. We recommend only very minor treatment of this stand using treatment Option 4. The primary objective is to reduce several larger accumulations of mixed fine and larger fuels so that they to not torch into the canopy if a surface fire moved through the area. Other than this minor treatment, natural successional processes can proceed and this stand will develop into a moist old-growth stand in another 100 years.

Treatment Unit 7 is east and below the highway up the mountain and east of the junction with the Mt. Kit Carson Loop Road. The primary objective in treating this stand is to reduce fuel loadings and help create a firebreak that would slow fires moving up the mountain. Reduction of young grand-fir is a secondary objective. While there is not a high density of young grand fir in this stand now, treatment in the next few years will prevent a dense young stand from developing. This stand can be easily treated using Option 2. Roads bound the unit on three sides, which can be used as firebreaks for the prescribed fire.

Treatment Units 10 and 30 are below the Mt. Kit Carson Loop Road and east of the junction with the highway up the mountain. Unit 10 is composed of a mature/old forest in the transition area between the TSHE/CLUN and ABGR/VAME/CLUN plant associations (Table 3). Unit 30 is composed of a mature forest in the transition area between the TSHE/CLUN, THPL/CLUN and THPL/VAME plant associations. Both these units have significant problems with grand fir encroachment and the risk this poses to fire resistant "legacy" trees. Unit 10 is located in a forest health high priority area and Unit 30 has a medium priority in terms of forest health treatment (Figure 123 and Table 28). Our objectives in these two units are to significantly reduce the density of grand fir, reduce stress on the legacy trees and create more favorable conditions for transition to a more fire resistant forest. These stands are on moderately gentle slopes and are immediately below an easily accessed road that is normally closed to public access. We propose treating these two units with Option 8. There is significant commercial volume in the two units that could be removed as part of a forest health treatment designed along those parameters. The merchantable stems can be easily removed through yarding up the relatively gentle slopes to the road. The secondary objective in treating these two stands is to reduce fuel loadings and help create a firebreak that would slow surface fires moving up the mountain. Canopy bulk density in both units is 1 kg/cubic meter or higher. Thinning these stands would reduce the canopy bulk density to a level where the risk of crown fire spreading through the stands to the upper mountain would be reduced. Both units currently contain adequate snags and logs, so the focus of the treatment should be on maintenance of these important habitat elements.

Treatment Unit 22 is above the highway up the mountain and east of the junction with the Mt. Kit Carson Loop Road. This is unit consists of a mature/old forest with a mosaic of plant associations mostly in the grand fir series (ABGR/VAME/CLUN and ABGR/ACGLD/CLUN; Table 3). In the western portion of the unit the forests transition to moister plant associations (TSHE/CLUN and THPL/CLUN). This unit is in relatively good condition with regard to forest health, but some grand fir encroachment is evident. Our objectives in treating this stand are primarily to help create a firebreak that would slow surface fires moving up the mountain. We propose to treat this unit using Option 3. A fire line would be created around the upper portion of the unit. The prescribed fire should be ignited starting in strips immediately below the constructed fire line and progress down the slope. It should be ignited during a predictable upslope wind. We recommend burning this unit in the late spring, when the upper part of the mountain is still quite moist from snowmelt. This will help alleviate any risk of the prescribed fire moving beyond the treatment area. This unit should be burned when duff and coarse woody debris levels are adequate to avoid significant duff consumption and large log consumption. The prescription requires dry enough conditions for the fire to spread and consume adequate surface fuels. Surface fuels would be augmented in some parts of the unit through thinning of some small grand firs. The prescribed fire should be ignited during moderate weather conditions where surface flame lengths of 1 to 3 feet can be maintained.

Treatment Effects on Sensitive Wildlife

Unit 4

Because the preferred treatment option (4) proposed for Unit 4 does not require significant alteration of current vegetation conditions, most wildlife species will not be affected by treatment activities (Table 29) except for the immediate disturbance of human activity and some small piles burning in localized locations for a few days.

Table 29. Effects of prescriptions for Treatment Unit 4 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Possible	Neutral
	Nesting	Possible	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Possible	Neutral
	Non-Winter Foraging	Improbable	Neutral
	Winter Foraging	Improbable	Neutral
Marten	Non-Winter Foraging	Possible	Neutral
	Winter Foraging	Possible	Neutral
Wolverine	Any	Improbable	Neutral
Bald Eagle	Roosting	Possible	Neutral
Golden Eagle	Roosting	Possible	Neutral
	Foraging	Improbable	Neutral
Great Gray Owl	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
	Roosting	Improbable	Neutral
Pileated Woodpecker	Breeding	Possible	Neutral
	Foraging	Possible	Neutral
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral
Western Toad	Any	Possible	Neutral

Units 7 and 22

Treatment Units 7 and 22 are similar and based on the use of prescribed fire. Goshawks, martens, great gray owls, and pileated woodpeckers would all benefit to one degree or another from treatment (Table 30). Lower canopy flyways would be maintained and possibly opened up by prescribed fire, benefiting goshawk foraging and great gray owl breeding and roosting. With successful snag preservation, plus snag creation as a result of fire-killed trees, marten winter foraging habitat and pileated woodpecker breeding and foraging habitat would be improved.

Marten non-winter foraging would gain mixed results from this treatment (Table 30). The prescribed burn could immediately reduce shrub cover desirable for marten prey, and desirable edible shrub species for marten could be reduced as well. However, the herbaceous canopy response to fire and potentially even the shrub response could be good for marten prey, therefore enhancing habitat suitability. The long-term impacts are expected to be beneficial to both species' non-winter foraging habitat. Also, intentional snag recruitment due to the burn and subsequent coarse woody debris production could benefit marten non-winter foraging and perhaps marten winter foraging.

Our analysis of these units and the proposed treatment indicate that the proposed treatment will have a positive or neutral effect on the other wildlife species listed in Table 30.

Table 30. Effects of prescriptions for Treatment Units 7 and 22 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Possible	Positive
	Nesting	Improbable	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Improbable	Neutral
	Non-Winter Foraging	Improbable	Neutral
	Winter Foraging	Improbable	Neutral
Marten	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Improbable	Positive
Wolverine	Any	Possible	Neutral
Bald Eagle	Roosting	Possible	Neutral
Golden Eagle	Roosting	Possible	Neutral
	Foraging	Improbable	Neutral
Great Gray Owl	Breeding	Possible	Positive
	Foraging	Improbable	Neutral
	Roosting	Possible	Positive
Pileated Woodpecker	Breeding	Possible	Positive
	Foraging	Possible	Positive
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral
Western Toad	Any	Possible	Positive

Units 10 and 30

Treatments in Units 10 and 30 include limited harvesting of overstory trees and understory thinning of young grand fir and western hemlock, followed by prescribed fire. While this may sound like an intensive treatment that could negatively impact wildlife habitats, we believe that adherence to our guidelines and restrictions on overstory thinning and tree skidding procedures will not significantly reduce wildlife habitat values and will, in effect, enhance values in these units by recruiting more critical habitat elements like coarse woody debris and snags (Table 31).

For lynx and marten non-winter foraging, a prescribed burn could immediately reduce shrub cover desirable for lynx and marten prey (and desirable edible shrub species for marten could be reduced as well). However, the herbaceous and shrub response to fire should be good for lynx and marten prey and browse in the longer term benefiting both species' non-winter foraging habitat. Also, intentional snag recruitment due to the burn and subsequent coarse woody debris production could benefit marten non-winter foraging and perhaps marten winter foraging.

Our analysis of these units and the proposed treatment indicate that the proposed treatment will have a positive or neutral effect on the other wildlife species listed in Table 31.

Table 31. Effects of prescriptions for Treatment Units 10 and 30 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Possible	Positive
	Nesting	Improbable	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Improbable	Neutral
	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Improbable	Neutral
Marten	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Improbable	Positive
Wolverine	Any	Possible	Neutral
Bald Eagle	Roosting	Possible	Neutral
Golden Eagle	Roosting	Possible	Neutral
	Foraging	Improbable	Neutral
Great Gray Owl	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
	Roosting	Improbable	Neutral
Pileated Woodpecker	Breeding	Possible	Positive
	Foraging	Possible	Positive
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral
Western Toad	Any	Possible	Positive

Group 5: Treatment Units 8, 9, 32, 33

These treatment units are northeast of the road up the mountain in an area characterized by dense young grand fir with scattered remnant larch and Douglas-fir (Figures 138 and 139). They are grouped together because of their geographic proximity. The basic characteristics of these treatment units are presented in Table 32.

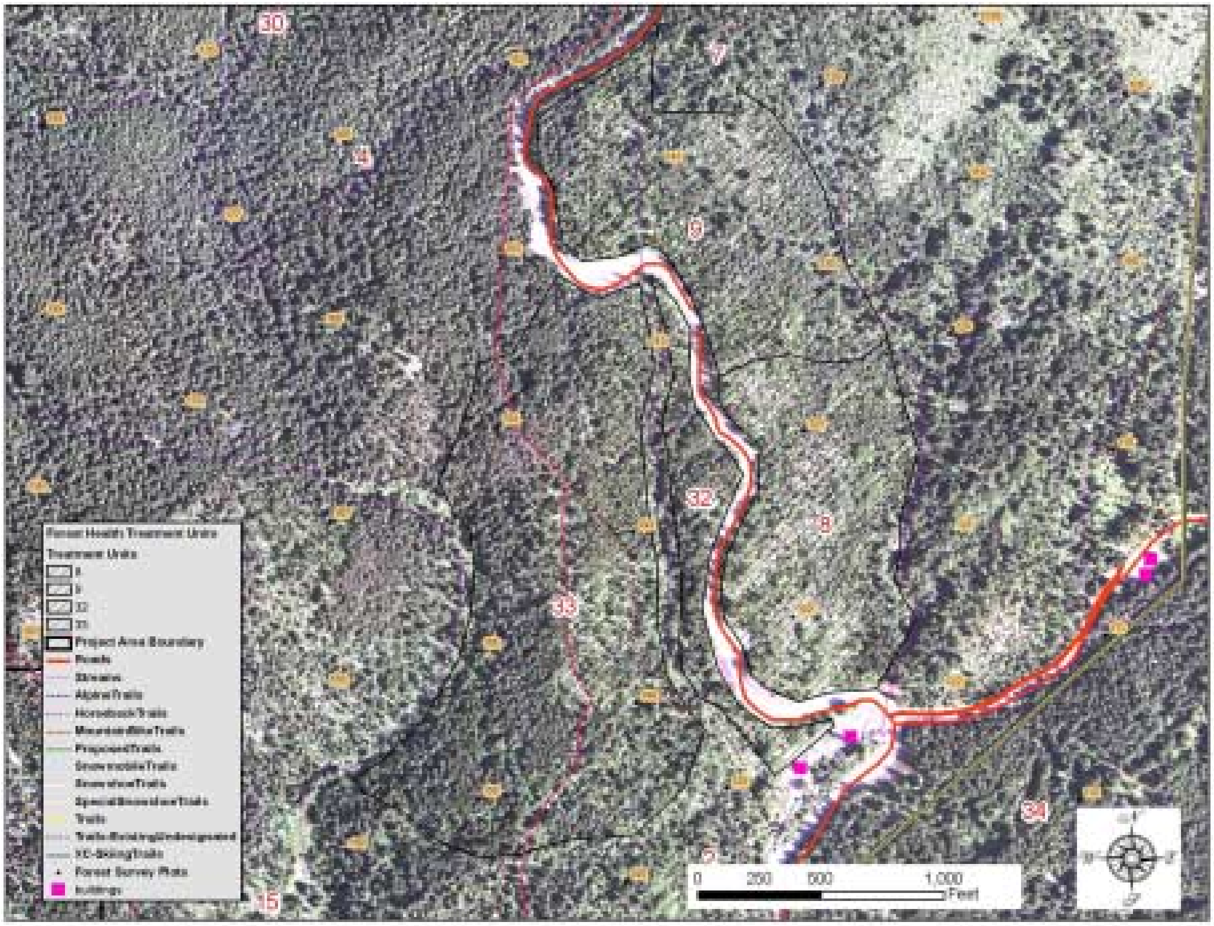

Figure 138. Aerial photograph of Treatment Units 8, 9, 32, 33.

Table 32. Basic characteristics of Treatment Units in Group 5. (see Tables 17-20)

Unit #	1st Option	2nd Options	Zone	Year	Acres	slope (%)	cbh	cbd	ba	tpa	qmd	stpa	abgr8	maxdbh	savetrees	snags	cwdcov	cwdnum	slzones	flzones	Flame length - before	Flame length - after	Change in flame length	Rate of spread - before	Rate of spread - after	Change in rate of spread
8	5	3,1	1	1	21	27	11	0.06	77	154	8	745	46	14	31	14	0	17	1.99	0.73	3.4	0.5	2.9	1.6	0.2	1.4
9	5	3,1	1	3	23	24	17	0.11	144	247	11	1040	58	18	50	53	3	85	0.82	1.31	2.8	0.5	2.3	1.3	0.2	1.1
32	3	7,1	1	1	7	22	17	0.08	131	244	9	990	46	16	88	42	1	54	0.74	1.70	3.4	0.9	2.5	1.6	0.4	1.2
33	8	6,5,1	1 & 5	4	44	32	20	0.10	170	243	11	957	34	19	82	44	3	116	0.87	1.64	2.3	0.4	1.9	1.0	0.1	0.8

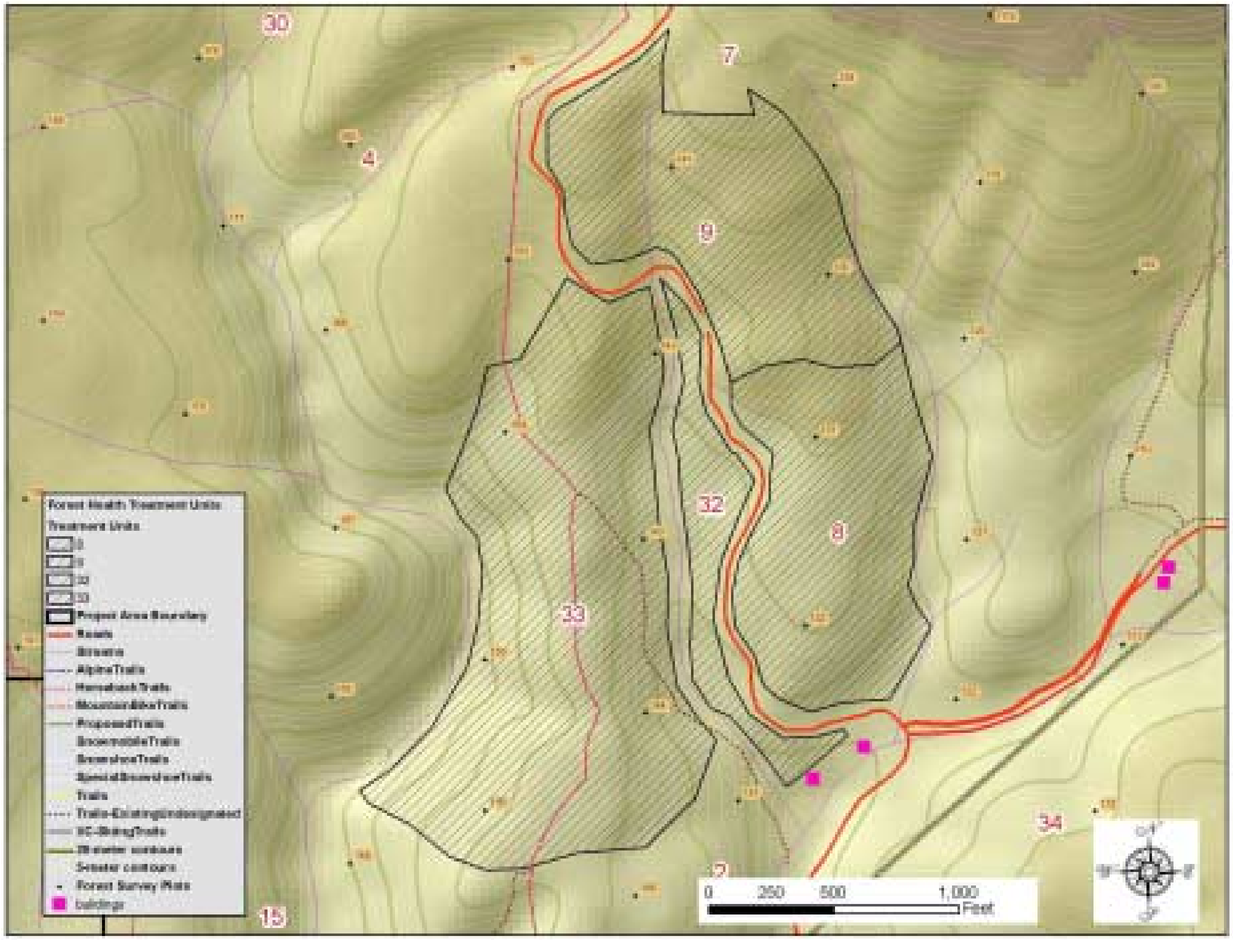

Figure 139. Topographic map of Treatment Units 8, 9, 32, 33.

Treatment Units 8 and 9 are in a stand that was both logged and burned about 50-70 years ago. The plant association of this stand is ABGR/ACGLD/CLUN (Table 3). The stand has a high canopy cover of young grand fir and moderate to low surface fuel loadings of 1-100 hour fuels. Duff depths are 0.5 inches or less. Density of young grand fir often exceeds 1,000 trees per acre. Most of the young grand fir is not yet of merchantable size, or has fairly low merchantable volume. There are scattered remnant old western larch, ponderosa pine and Douglas-fir in the stand. We consider these trees to be important legacy trees and the recommended treatment option focuses on their protection. Treatment Units 8 and 9 were identified earlier as having a medium (Unit 8) and high (Unit 9) priority for forest health treatment (Figure 123 and Table 32).

A prescribed burn could be conducted in Units 8 and 9 under the right moisture and weather conditions. The objective of the fire would be to thin the young grand fir and reduce surface fuels. However, the current surface fuel loading is fairly low in many places and may well be insufficient to carry a prescribed fire through the stand under most moisture and weather conditions. There is also risk of torching and initiation of passive and then active crown fire if the prescribed fire was conducted in dry enough conditions that surface fire would spread sufficiently through the stand due to the density of very small trees, the presence of extensive ladder fuels and the presence of large fuel accumulations. Significant pre-treatment will be necessary for the optimal use of prescribed fire.

Most of the young grand fir could be mechanically thinned from Units 8 and 9. Because the trees are quite small, there is not a high volume of merchantable wood in the stand and the thinning and subsequent slash treatments would largely be of a non-commercial nature. The volume of thinning slash would be quite high and could be quite difficult and expensive to treat in an adequate fashion. Leaving thinning slash untreated or only partially treated would increase the risk of wildfire in this stand by many orders of magnitude. Opening up the stand would also increase wildfire risk due to drier surface fuels and higher surface and mid-flame wind speeds. It is also quite likely that this treatment would result in another surge of grand fir recruitment, which in 20-40 years would result in stand conditions similar to what they are today.

Our recommended treatment for Units 8 and 9 is Option 5. Much of the stand would be left untreated during the first round of treatment. Old, fire-resistant, legacy trees would be identified in the areas and grand fir would be cut from around the base of these trees out a sufficient distance to eliminate competition. This distance would be an approximate 50-foot radius. Thinning slash would be piled and burned near the thinning perimeter. This is to reduce damage to legacy tree feeder roots and to stimulate regeneration of the fire-resistant tree species a sufficient distance from the mother tree. Our intention is that natural regeneration of western larch, Douglas-fir and ponderosa pine will be possible in the cleared areas around the trees. Subsequent to successful implementation and monitoring of this treatment and a delay of five to ten years, we recommend treating much Units 8 and 9 with prescribed fire using treatment Option 3. Some portions can be left for natural successional processes to operate (Option 1) if it proves too difficult or undesirable to treat the entire unit with prescribed fire.

Treatment Unit 32 is a narrow strip of forest below the highway and above a major stream. It is in the TSHE/CLUN plant association (Table 3). Treatment Unit 33 is a larger unit to the west of Unit 32. It is more diverse and contains forests in the TSHE/CLUN, ABGR/VAME/CLUN, ABGR/PHMA and THPL/CLUN plant associations. Both treatment units consist of forests that were determined to be in the highest forest health priority area (Figure 123). Both units contain over 900 small trees per acre under 4 inches DBH. They also contain numerous fire resistant western larch as well as some Douglas-fir and ponderosa pine. Pole-size and larger grand fir is also common in these units.

We propose treating Unit 32 with Option 3 due to its proximity to the main highway and the impact on the aesthetics of park visitors. We recommend treating Unit 33 with the most aggressive treatment, Option 8. However aesthetic concerns dictate that conservative application of Option 8 should be applied to the eastern part of the unit, which is directly visible from the main highway. Unit 33 was identified as one of the areas of the park where commercial thinning could help significantly in converting the current forest to one that is more capable of withstanding natural wildfires. The slopes are gentle enough to support cable yarding and there is an existing road/trail system through the stand that can be used for access, alleviating the need for road construction. In general, the topography of the unit is too steep for wise use of ground-based skidders or feller bunchers.

Treatment Effects on Sensitive Wildlife

Units 8 and 9

Unit 8 currently provides valuable songbird habitat in the park. This is one of the only early seral stage units in the project area. Intense grand fir regeneration is occurring in this unit, which, if left unchecked, will eventually shade out the high diversity of shrubs and deciduous trees. Snag and CWD occurrence is almost negligible in this area. The proposed treatment Option 5 should help maintain the shrub and deciduous tree components in the stand, while encouraging more diverse conifer regeneration. Thinning of the grand fir may decrease the suitability of this site for lynx winter foraging, but at the same time non-winter foraging habitat could be enhanced (Table 33). The likelihood of lynx winter foraging taking place in the unit is low given the small patch size of optimal lynx winter foraging conditions.

Unit 9 has fairly low habitat value for most of the targeted species at the current time (Table 33). The forest conditions are such that almost no snags or significant CWD occur, and the forest understory is made up of mostly small diameter grand fir with few other tree species present. Option 5 will at the very least give native shrubs and herbs an opportunity to compete for understory canopy space, potentially increasing the habitat value for lynx and marten non-winter prey and browse.

Table 33. Effects of prescriptions for Treatment Units 8 and 9 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Improbable	Neutral
	Nesting	Improbable	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Improbable	Neutral
	Non-Winter Foraging	Possible	Positive
	Winter Foraging	Possible	Negative
Marten	Non-Winter Foraging	Possible	Positive
	Winter Foraging	Improbable	Neutral
Wolverine	Any	Improbable	Neutral
Bald Eagle	Roosting	Improbable	Neutral
Golden Eagle	Roosting	Improbable	Neutral
	Foraging	Improbable	Neutral
Great Gray Owl	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
	Roosting	Improbable	Neutral
Pileated Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral
Western Toad	Any	Possible	Neutral

Unit 32
Prescribed fire in this unit will have either a neutral or positive effect to the target wildlife species we studied (Table 34). Pileated woodpecker could benefit from additional snag creation, and up slope forest habitat for western toad might improve due to thinning out of shading young grand fir (allowing herbaceous species to colonize sites close to the water).

Table 34. Effects of prescription for Treatment Unit 32 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Improbable	Neutral
	Nesting	Improbable	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Improbable	Neutral
	Non-Winter Foraging	Possible	Neutral
	Winter Foraging	Improbable	Neutral
Marten	Non-Winter Foraging	Possible	Neutral
	Winter Foraging	Improbable	Neutral
Wolverine	Any	Improbable	Neutral
Bald Eagle	Roosting	Possible	Neutral
Golden Eagle	Roosting	Possible	Neutral
	Foraging	Improbable	Neutral
Great Gray Owl	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
	Roosting	Improbable	Neutral
Pileated Woodpecker	Breeding	Possible	Positive
	Foraging	Possible	Positive
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral
Western Toad	Any	Possible	Positive

Unit 33
While the treatment options prescribed to this stand are complex, and in some areas moderate levels of disturbance may occur, the overall effect of treatments is intended to improve wildlife value for multiple species (Table 35). For marten and lynx non-winter foraging uses, the effects of the prescribed burn could have immediate negative impacts on important shrub components of the stand. However, vegetation responses to prescribed fire might create enhanced shrub and herb conditions for prey species in the longer term. Due to slope steepness, the effects of logging activities will be concentrated along road access to this unit. Areas where understory clearing of small grand fir occurs, and areas where prescribed fire reduces shrub heights and cover, may improve overall goshawk foraging opportunities. Opening up of the high density small grand fir pockets will probably benefit potential Western toad upland habitat conditions by decreasing the canopy closure on this south facing slope that is near a major creek drainage.

Table 35. Effects of prescription for Treatment Unit 33 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Improbable	Positive
	Nesting	Improbable	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Improbable	Neutral
	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Improbable	Neutral
Marten	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Improbable	Positive
Wolverine	Any	Improbable	Neutral
Bald Eagle	Roosting	Possible	Neutral
Golden Eagle	Roosting	Possible	Neutral
	Foraging	Improbable	Neutral
Great Gray Owl	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
	Roosting	Improbable	Neutral
Pileated Woodpecker	Breeding	Possible	Positive
	Foraging	Possible	Positive
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral
Western Toad	Any	Possible	Positive

Group 6: Treatment Units 16, 17, 21 23 and 24

These treatments units are located south of the main road up the mountain and below the road that goes from the Selkirk Lodge south along the ridge (Figures 140 and 141). They are grouped together because of their geographic proximity and the constraints of a high use recreational area. This is an area with high recreational use, particularly during the winter ski season. The basic characteristics of these treatment units are presented in Table 36.

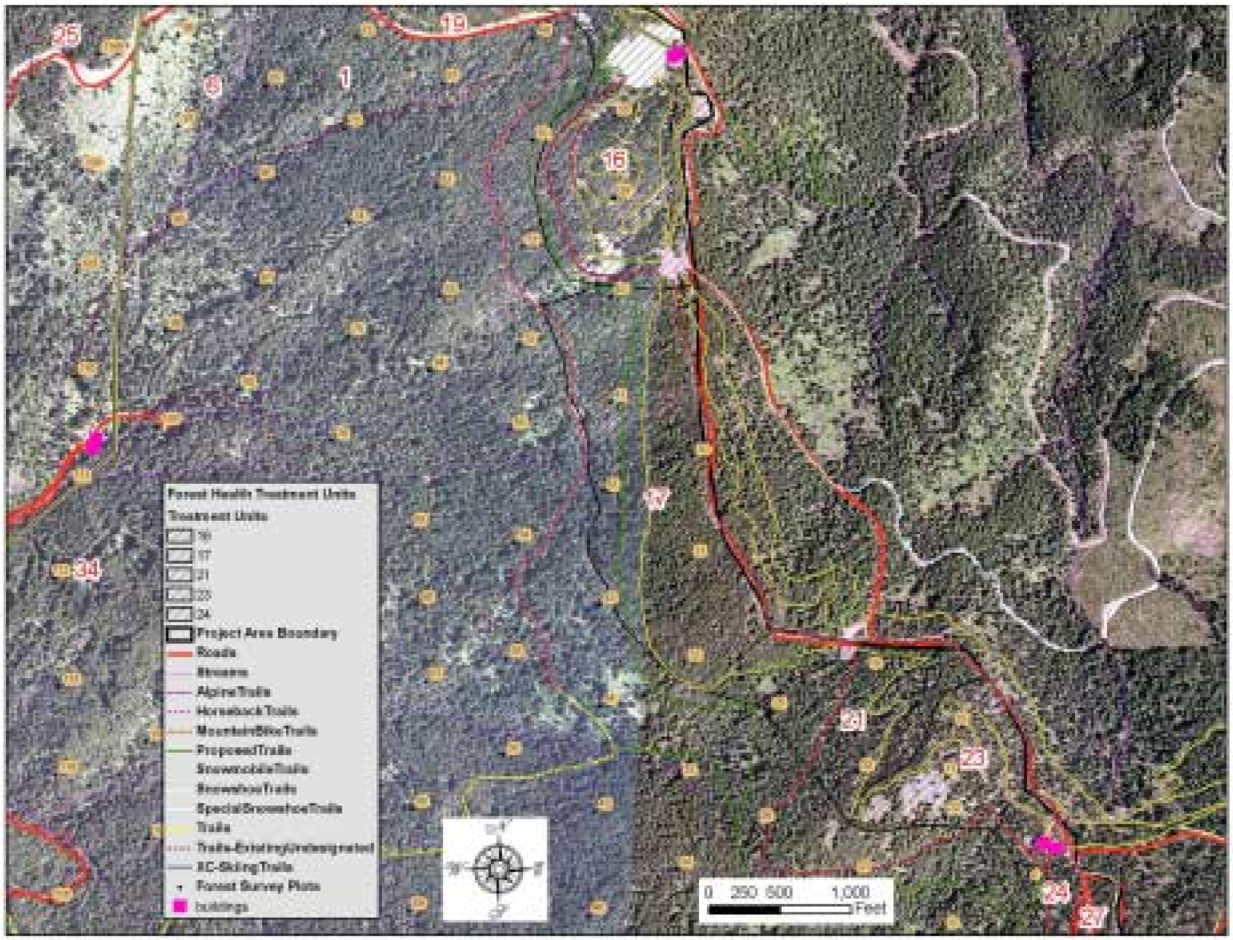

Figure 140. Aerial photograph of Treatment Units 16, 17, 21 23 and 24.

Table 36. Basic characteristics of Treatment Units in Group 6. (see Tables 17-20)

Unit #	1st Option	2nd Options	Zone	Year	Acres	slope (%)	cbh	cbd	ba	tpa	qmd	stpa	abgr8	maxdbh	savetrees	snags	cwdcov	cwdnum	slzones	flzones	Flame length - before	Flame length - after	Change in flame length	Rate of spread - before	Rate of spread - after	Change in rate of spread
16	10	3,7	3	1	42	19	21	0.12	165	204	12	308	20	19	19	153	8	166	0.00	0.00	1.4	0.3	1.1	0.7	0.1	0.6
17	2	1	3	3	63	31	24	0.11	211	189	15	360	33	22	33	86	3	143	0.00	0.31	1.7	0.5	1.2	0.7	0.1	0.6
21	2	3,1	3	5	23	24	15	0.10	150	161	15	573	36	18	10	10	5	114	0.93	0.00	1.4	0.3	1.1	0.7	0.1	0.6
23	3	2,1	3	5	23	21	15	0.07	110	115	16	787	23	17	17	18	10	177	0.65	0.21	2.8	0.4	2.4	2.4	0.1	2.3
24	3	6,1	3	5	4	23	23	0.06	130	97	16	823	15	20	26	68	24	350	0.00	0.90	1.5	0.3	1.2	0.6	0.1	0.5

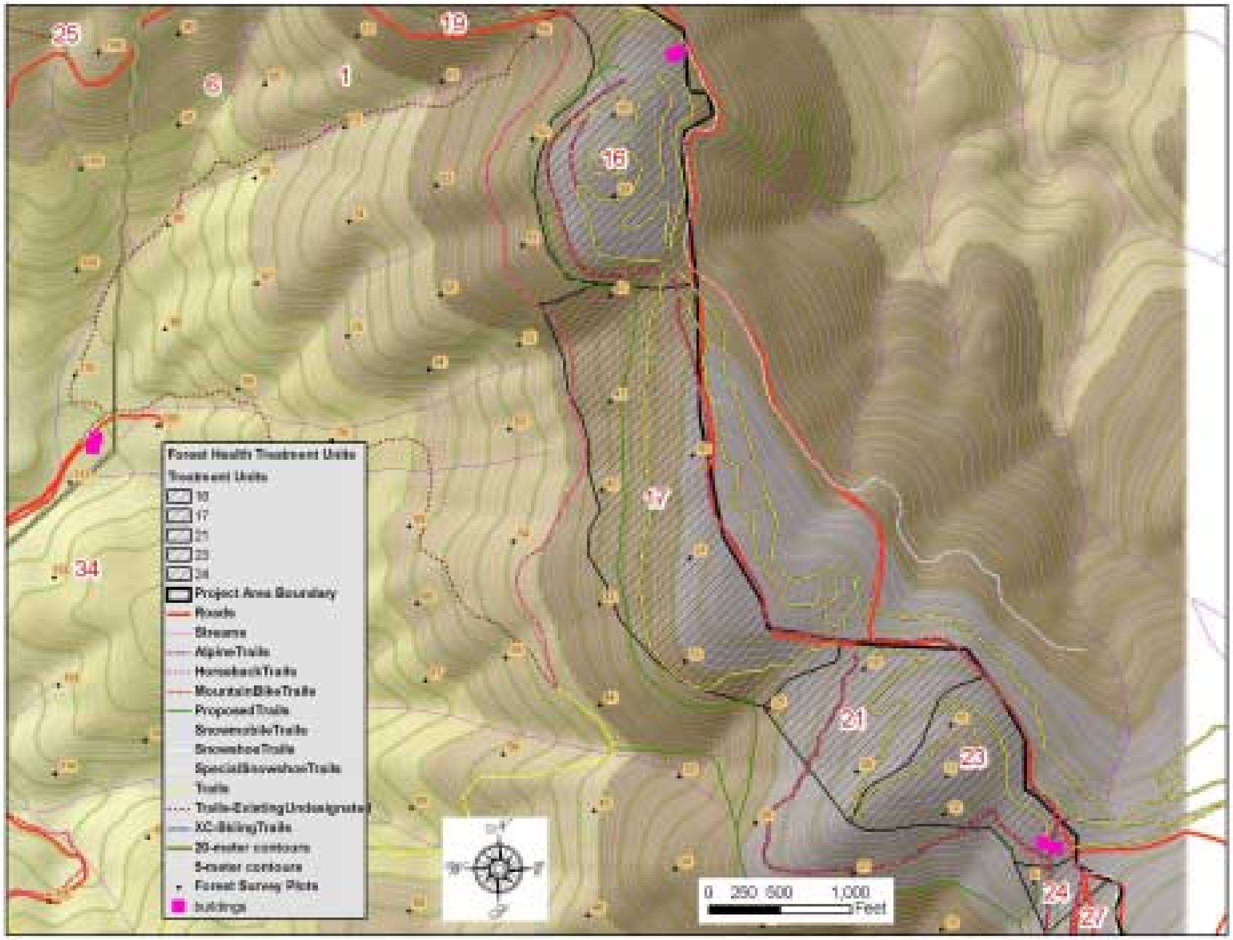

Figure 141. Topographic map of Treatment Units 16, 17, 21, 23 and 24.

Treatment Unit 16 is a heavily used recreation site, covered in part with forests in the TSHE/XETE plant association (Table 3). This site needs special care because of the intensive recreational use, the presence of the Selkirk Lodge and because the TSHE/XETE plant association is ranked as a globally imperiled plant community. The forests in this stand are mainly composed of subalpine fir and lodgepole pine, but western hemlock is successfully regenerating in the understory and is scattered in the overstory. The stand is short in stature, with nearly all trees less than 60 feet tall. The primary forest health issue we identified in this stand is very high densities of subalpine and grand fir, mostly occurring in disturbed areas, particularly along the roadsides and sides of the cross-country ski trails. In many places, these young seedlings and saplings are forming impenetrable thickets along many ski trails. We recommend treatment of Unit 16 with Option 10 to curtail further development of these dense thickets along the ski trails and other disturbed sites. This treatment focuses on the existing road and trail edges. This should be done immediately, before the dense thickets become much more difficult to mow and chip. Over the long-term, we also recommend that Unit 16 be treated with prescribed fire using Option 3 or chipping/mastication (Option 7) to reduce fuel loads across the entire unit. This will help create a fire break to both protect the Selkirk Lodge and to help slow fires burning across the park.

Treatment Units 17, 21, 23 and 24 are located further south along the ridge that runs to the southeast from the Selkirk Lodge. These units are quite similar in many respects. All of these units have cross-country ski activity on ski trails across the units, so they have considerable recreational and aesthetic considerations. They are all mature forests with quadratic mean diameters of 15 to 16 inches and average basal area of 110 to 150 square feet per acre (Table 36). All these units have scattered, fire resistant Douglas-fir and/or western larch. They also have significant numbers of small grand fir and subalpine fir in the understory, but the understory is relatively open in many places. Units 23 and 24 have nearly twice the number of small trees less than 4 inches in DBH than units 17 and 21. Unit 17 consists of a forest in the ABGR/VAME/CLUN plant association (Table 3). Unit 21 consists of a forest split between the TSHE/XETE, TSHE/MEFE and ABGR/VAME/CLUN plant associations. Unit 23 consists of a more open forest in the TSHE/XETE plant association with patches of subalpine meadow in the CARU-FEID plant association. Unit 24 is consists of a forest in the ABLA2/RHAL/XETE plant association.

We propose to treat all of these units with prescribed fire. The purpose of these treatments is to reduce fuel loads, creating a fuel-depleted zone that will slow fire spread across the park. The treatments will also reduce the density of young grand fir and subalpine fir in these units and help create a more fire resistant forest. We recommend Option 2 for Units 17 and 21 and Option 3 for Units 23 and 24. A greater level of pre-treatment (Option 3 vs. Option 2) is recommended in the units with fairly high densities of small grand fir. The margins of some cross-country ski trails and roads in these treatment units may benefit from treatment with Option 10. Units 21, 23 and 24 contain plant associations that are listed as globally imperiled (G2) or state rare and vulnerable (S3). Treatments in these units need to be very carefully implemented and monitored so that the character and long-term viability of the TSHE/XETE, TSHE/MEFE and ABLA2/RHAL/XETE plant associations are not impaired.

Treatment Effects on Sensitive Wildlife

Unit 16

It is very likely that the treatment option prescribed to this unit is currently occurring via trail maintenance operations. Based on field accounts it appears that soil disturbances of road and trail edges by machinery have created conditions that spur the concentrated germination and growth of conifer seeds sources on the disturbed sites. It is important that execution of this prescription is done with precision that prohibits further expansion of the disturbed road/trail edge zone so as to not induce more of this phenomenon. Our analysis of wildlife impacts for this Treatment Unit indicates that the treatments will have a neutral impact on sensitive wildlife species (Table 37).

Table 37. Effects of prescriptions for Treatment Unit 16 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Improbable	Neutral
	Nesting	Improbable	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Improbable	Neutral
	Non-Winter Foraging	Possible	Neutral
	Winter Foraging	Improbable	Neutral
Marten	Non-Winter Foraging	Possible	Neutral
	Winter Foraging	Improbable	Neutral
Wolverine	Any	Improbable	Neutral
Bald Eagle	Roosting	Improbable	Neutral
Golden Eagle	Roosting	Improbable	Neutral
	Foraging	Improbable	Neutral
Great Gray Owl	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
	Roosting	Improbable	Neutral
Pileated Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral
Western Toad	Any	Improbable	Neutral

Units 17, 21, 23, and 24

Goshawks, martens, great gray owls, and pileated woodpeckers would all benefit to one degree or another from the proposed treatments (Table 38). Lower canopy flyways would be opened up by prescribed fire, benefiting goshawk and great gray owl foraging. With successful snag preservation, plus potential snag creation, marten winter foraging habitat and pileated woodpecker foraging habitat would be improved.

For lynx and marten non-winter foraging the prescribed burn could immediately reduce shrub cover desirable for lynx and marten prey (and desirable edible shrub species for marten could be reduced as well). However, the herbaceous and shrub response to fire should be good for lynx and marten prey and browse in the longer term benefiting both species' non-winter foraging habitat. Also, intentional snag recruitment due to the burn and subsequent coarse woody debris production could benefit marten non-winter foraging and perhaps marten winter foraging.

Thinning of the grand fir by prescribed burning may decrease the suitability of this site for lynx winter foraging, but at the same time non-winter foraging habitat could be enhanced (Table 38). The likelihood of lynx winter foraging taking place in the unit is low given the small patch size of optimal lynx winter foraging conditions.

Table 38. Effects of prescriptions for Treatment Units 17, 21, 23, and 24 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Possible	Positive
	Nesting	Improbable	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Improbable	Neutral
	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Possible	Negative
Marten	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Possible	Positive
Wolverine	Any	Possible	Neutral
Bald Eagle	Roosting	Possible	Neutral
Golden Eagle	Roosting	Possible	Neutral
	Foraging	Possible	Neutral
Great Gray Owl	Breeding	Possible	Neutral
	Foraging	Possible	Positive
	Roosting	Possible	Neutral
Pileated Woodpecker	Breeding	Possible	Positive
	Foraging	Possible	Positive
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral
Western Toad	Any	Improbable	Neutral

Group 7: Treatment Units 26, 27, 38, 39, 40

These treatment units are located on the southern part of the study area, either below the south ridge road or along the park boundary where it abuts private timberland (Figures 142 and 143). They are grouped together because of their geographic proximity. The priority for treatment of this area in the short-term is low, but this area should be considered in a long-term forest health treatment plan. The basic characteristics of these treatment units are presented in Table 39.

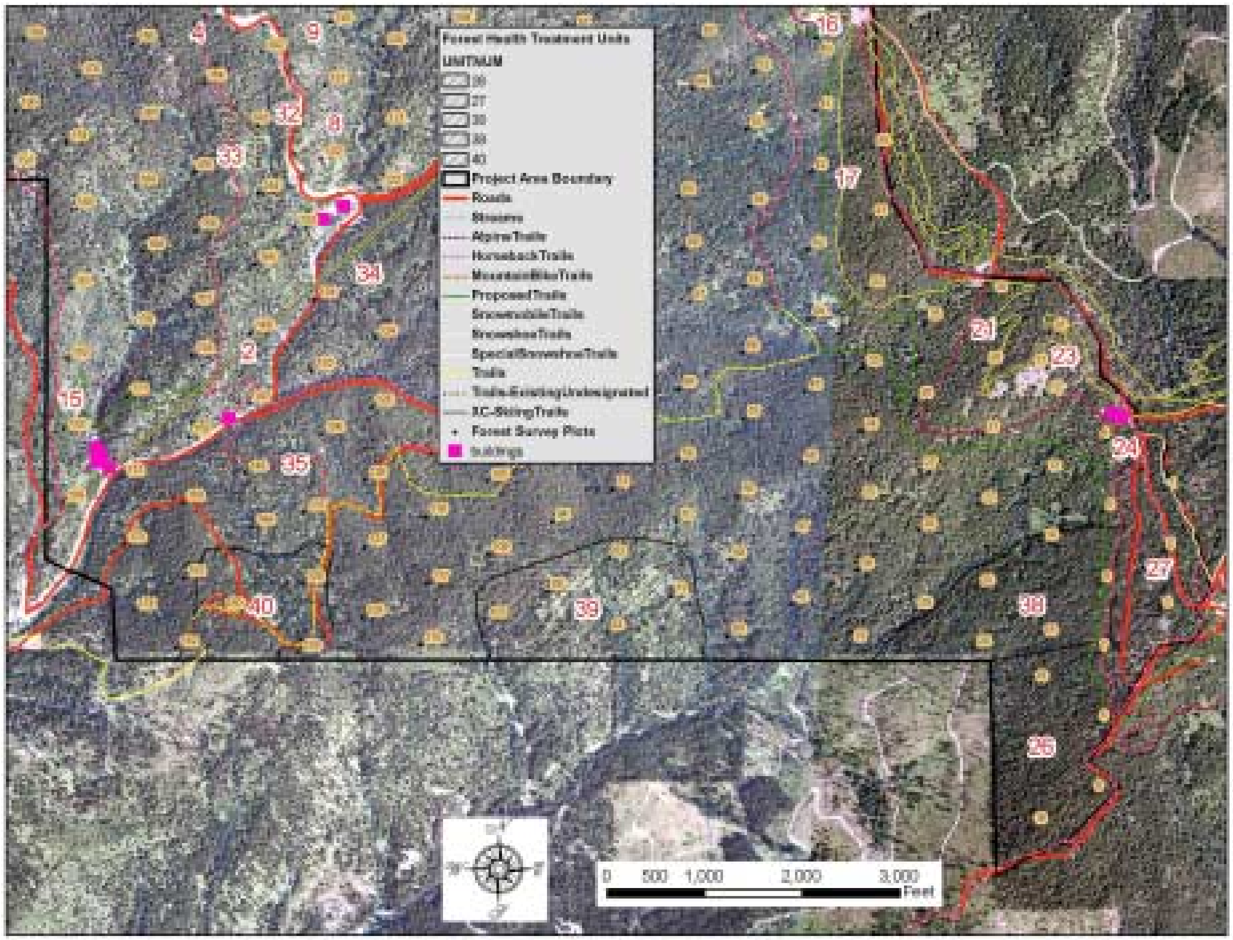

Figure 142. Aerial photograph of Treatment Units 26, 27, 38, 39, 40.

Table 39. Basic characteristics of Treatment Units in Group 7. (see Tables 17-20)

Unit #	1st Option	2nd Options	Zone	Year	Acres	slope (%)	cbh	cbd	ba	tpa	qmd	stpa	abgr8	maxdbh	savetrees	snags	cwdcov	cwdnum	slzones	flzones	Flame length - before	Flame length - after	Change in flame length	Rate of spread - before	Rate of spread - after	Change in rate of spread
26	3	2,1	3	4	56	31	19	0.10	154	168	13	436	31	22	35	51	10	200	0.00	0.90	1.6	0.4	1.3	0.7	0.1	0.5
27	6	3,1	3	4	37	28	24	0.09	133	137	14	1013	20	20	29	95	15	263	0.00	0.86	1.6	0.4	1.2	0.7	0.1	0.5
38	6	8,3,1	3 & 5	10	50	40	23	0.11	191	196	14	713	46	22	54	86	13	281	0.00	0.99	1.9	0.4	1.5	1.0	0.1	0.9
39	6	8,3,1	5	10	56	38	20	0.09	178	151	16	388	38	25	53	51	3	130	0.08	0.59	2.4	0.4	2.0	1.7	0.2	1.5
40	3	6,8,1	5	10	34	30	25	0.09	182	208	14	255	48	19	53	41	2	93	0.18	0.68	2.5	0.4	2.1	0.8	0.1	0.7

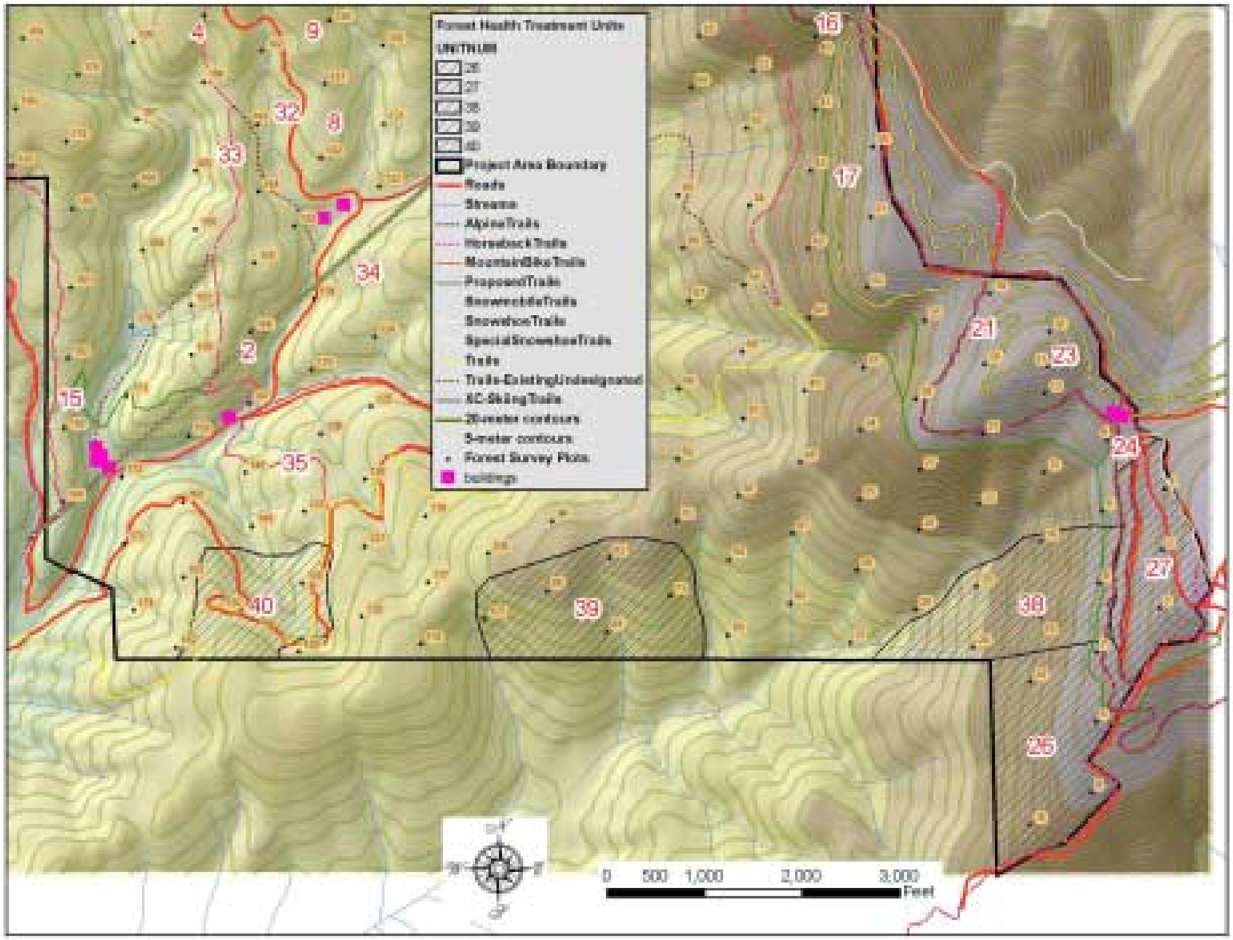

Figure 143. Topographic map of Treatment Units 26, 27, 38, 39, 40.

Treatment Units 26, 27 and 38 are located even further south along the ridge that runs to the southeast from the Selkirk Lodge. Access to the lower portion of Unit 38 would be via a road on private timberland to the south. These units are quite similar in many respects. All of these units have cross-country ski activity on ski trails and other trails also cross the units, so they merit considerable recreational and aesthetic considerations. All three units contain mature forests with quadratic mean diameters of 13 to 14 inches and average basal areas of 133 to 191 square feet per acre (Table 39). All these units have over 30 fire resistant tree species per acre. They also have significant numbers of small grand fir and subalpine fir in the understory, with at least 400 small trees under 4 inches DBH per acre. Unit 38 has over 1000 small trees less than 4 inches in DBH per acre. Unit 26 consists primarily of a forest in the ABGR/VAME/CLUN plant association (Table 3), however a small part of the unit is in the ABLA2/VAME association. Unit 27 consists of a forest split between the ABGR/VAME/CLUN and ABLA2/RHAL/XETE plant associations. Treatments in this unit need to be very carefully implemented and monitored so that the character and long-term viability of the state ranked rare and vulnerable ABLA2/RHAL/XETE plant association is not impaired. Unit 38 consists of a forest in the ABGR/VAME/CLUN plant association with a small patch of the ABGR/ACGLD/CLUN plant association. All three units were identified as containing some high priority zones for forest health treatments (Figure 123 and Table 39).

Treatment Units 39 and 40 are located along the south boundary of the park and would be accessed via roads on private timberland to the south. These units are quite similar in many respects. They are both mature forests with quadratic mean diameters of 14 and 16 inches and average basal areas of 178 and 182 square feet per acre (Table 39). Both units have over 53 fire resistant tree species per acre. They have 388 and 255 small trees under 4 inches DBH per acre. Unit 39 consists primarily of a forest in the ABGR/ACGLD/CLUN plant association (Table 3), however a parts of the unit are in the THPL/CLUN and ABGR/PHMA associations. Unit 40 consists of forests in the TSHE/CLUN, ABGR/ ACGLD /CLUN and THPL/CLUN plant associations. Both units were identified as containing some high priority areas for forest health treatments (Figure 123 and Table 39).

We propose to treat Units 26 and 40 with Option 3, prescribed fire with significant pre-treatment. The purpose of this treatment is to reduce fuel loads, creating a fuel-depleted zone that will slow fire spread across the park. The treatments will also reduce the density of young grand fir and subalpine fir in these units and help create a more fire resistant forest. We recommend Option 6 for Units 27, 38 and 39. The purpose of treatment is to dramatically reduce the density of small grand firs, enable the transition to a forest with more fire resistant trees and significantly reduce the fuel loading and help create a firebreak that would slow fires moving from the south and up the mountain. We chose Option 6 for this unit because of the high density of small trees.

Treatment Effects on Sensitive Wildlife

Units 26 and 40

Goshawks, martens, and pileated woodpeckers would all benefit to one degree or another from treatment Option 6 (Table 40). Lower canopy flyways would be opened up by non-commercial thinning and prescribed fire, facilitating goshawk foraging.

Thinning and burning of understory grand fir would have a negative impact on lynx winter foraging habitat, although our HSI model does not indicate this area as being strongly suited for lynx winter foraging. The other likely wildlife uses of these units would not be affected, or the understory thinning would enhance them. Pileated woodpecker habitat would benefit from prescribed fires by the likely increase in snag presence caused by fire derived tree mortality.

For lynx and marten non-winter foraging a prescribed burn could immediately reduce shrub cover desirable for lynx and marten prey (and desirable edible shrub species for marten could be reduced as well). However, the herbaceous and shrub response to fire should be good for lynx and marten prey and browse in the longer term benefiting both species' non-winter foraging habitat. Also, intentional snag recruitment due to the burn and subsequent coarse woody debris production could benefit marten non-winter foraging and perhaps marten winter foraging. The effects of the proposed treatment on other wildlife species are also presented in Table 40.

Table 40. Effects of prescriptions for Treatment Units 26 and 40 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	**Possible**	**Positive**
	Nesting	**Improbable**	**Neutral**
Lynx	Dispersal	**Possible**	**Neutral**
	Breeding	**Improbable**	**Neutral**
	Non-Winter Foraging	**Possible**	**Mixed**
	Winter Foraging	**Improbable**	**Negative**

Marten	Non-Winter Foraging	**Possible**	**Mixed**
	Winter Foraging	**Possible**	**Positive**
Wolverine	Any	**Possible**	**Neutral**
Bald Eagle	Roosting	**Possible**	**Neutral**
Golden Eagle	Roosting	**Possible**	**Neutral**
	Foraging	**Improbable**	**Neutral**
Great Gray Owl	Breeding	**Improbable**	**Neutral**
	Foraging	**Improbable**	**Neutral**
	Roosting	**Improbable**	**Neutral**
Pileated Woodpecker	Breeding	**Possible**	**Positive**
	Foraging	**Possible**	**Positive**
Black-backed Woodpecker	Breeding	**Improbable**	**Neutral**
	Foraging	**Improbable**	**Neutral**
Townsend's Big-eared Bat	Any	**Improbable**	**Neutral**
Columbia Spotted Frog	Any	**Improbable**	**Neutral**
Western Toad	Any	**Possible**	**Neutral**

Units 27, 38 and 39

Goshawks, martens, and pileated woodpeckers would all benefit to one degree or another from treatment Option 3. Lower canopy flyways could be opened to some degree by prescribed fire, facilitating goshawk foraging. With successful snag preservation, plus snag creation as a result of fire-killed trees, marten winter foraging habitat and pileated woodpecker breeding and foraging habitat would be improved (Table 41).

Lynx and marten would gain mixed results from treatment Option 3. For lynx and marten non-winter foraging the prescribed burn could immediately reduce shrub and small tree cover desirable for lynx and marten prey (and desirable edible shrub species for marten could be reduced as well), however the herbaceous canopy response to fire and the shrub response in the longer term would be good for lynx and marten prey, therefore enhancing habitat suitability. The long-term impacts are expected to be beneficial to both species' non-winter foraging habitat. Also intentional snag recruitment due to the burn and subsequent coarse woody debris production could benefit marten non-winter foraging and perhaps marten winter foraging. The effects of the proposed treatment on other wildlife species are also presented in Table 41.

Table 41. Effects of prescriptions for Treatment Units 27, 38 and 39 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	**Possible**	**Positive**
	Nesting	**Improbable**	**Neutral**
Lynx	Dispersal	**Possible**	**Neutral**
	Breeding	**Improbable**	**Neutral**
	Non-Winter Foraging	**Possible**	**Mixed**
	Winter Foraging	**Improbable**	**Neutral**
Marten	Non-Winter Foraging	**Possible**	**Mixed**
	Winter Foraging	**Improbable**	**Positive**
Wolverine	Any	**Possible**	**Neutral**
Bald Eagle	Roosting	**Possible**	**Neutral**
Golden Eagle	Roosting	**Possible**	**Neutral**
	Foraging	**Improbable**	**Neutral**
Great Gray Owl	Breeding	**Improbable**	**Neutral**
	Foraging	**Improbable**	**Neutral**
	Roosting	**Improbable**	**Neutral**
Pileated Woodpecker	Breeding	**Possible**	**Positive**
	Foraging	**Possible**	**Positive**
Black-backed Woodpecker	Breeding	**Improbable**	**Neutral**
	Foraging	**Improbable**	**Neutral**
Townsend's Big-eared Bat	Any	**Improbable**	**Neutral**
Columbia Spotted Frog	Any	**Improbable**	**Neutral**
Western Toad	Any	**Possible**	**Neutral**

Group 8: Treatment Units 28 and 29

These treatment units are located above and below the Mt. Spokane Day Road on the west side of the park (Figures 144 and 145). The priority for treatment of this area in the short-term is low, but this area should be considered in a long-term forest health treatment plan. They are grouped together because of their geographic proximity. The basic characteristics of these treatment units are presented in Table 42.

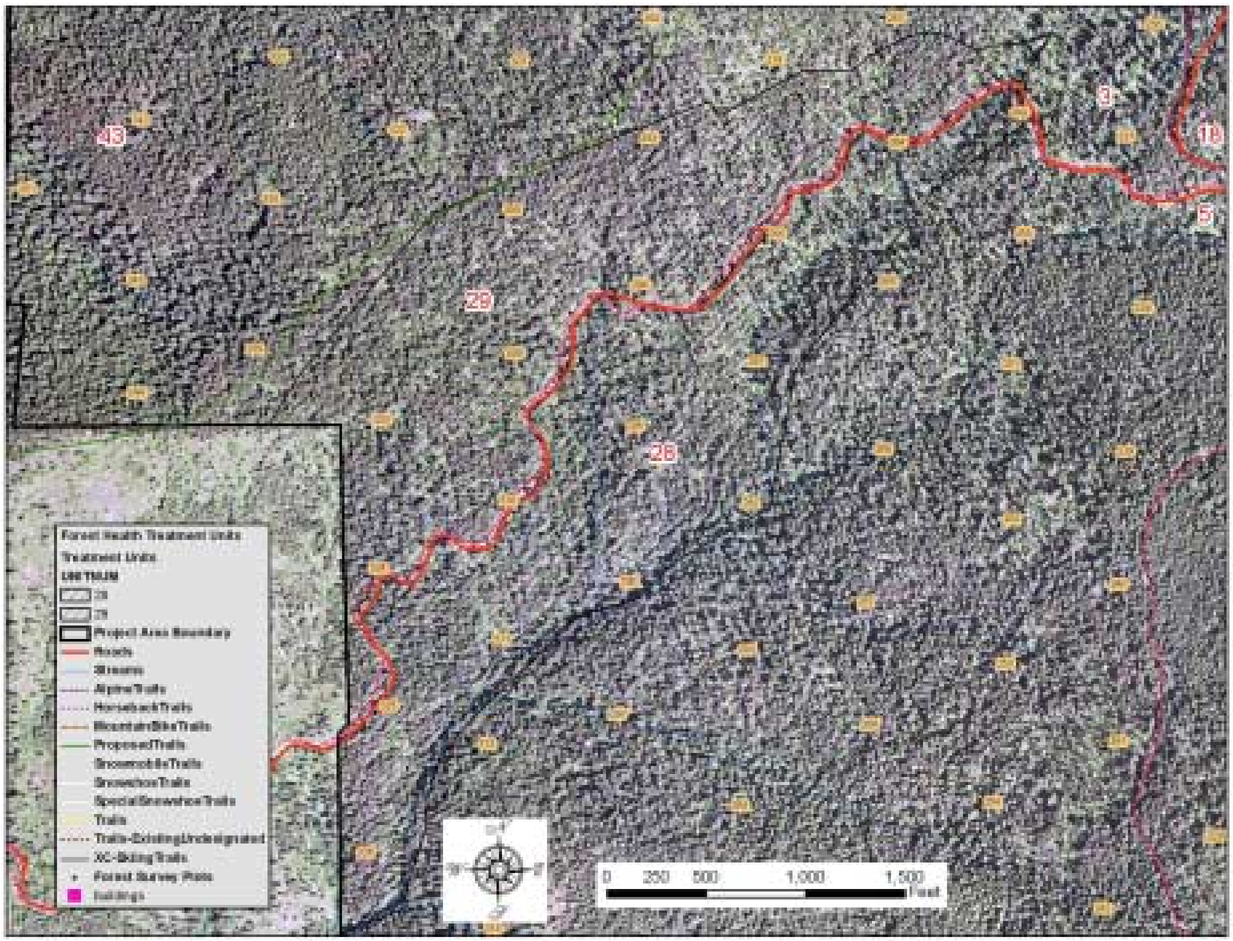

Figure 144. Aerial photograph of Treatment Units 28 and 29.

Table 42. Basic characteristics of Treatment Units in Group 8. (see Tables 17-20)

Unit #	1st Option	2nd Options	Zone	Year	Acres	slope (%)	cbh	cbd	ba	tpa	qmd	stpa	abgr8	maxdbh	savetrees	snags	cwdcov	cwdnum	slzones	flzones	Flame length - before	Flame length - after	Change in flame length	Rate of spread - before	Rate of spread - after	Change in rate of spread
28	8	6,5,1	4	3	78	29	24	0.07	135	129	17	755	37	21	35	72	6	146	0.10	0.97	3.9	0.4	3.5	1.6	0.1	1.5
29	5	8,3,1	4	3	80	27	25	0.09	155	156	16	862	46	22	43	66	6	154	0.00	1.09	3.9	0.4	3.5	1.7	0.1	1.6

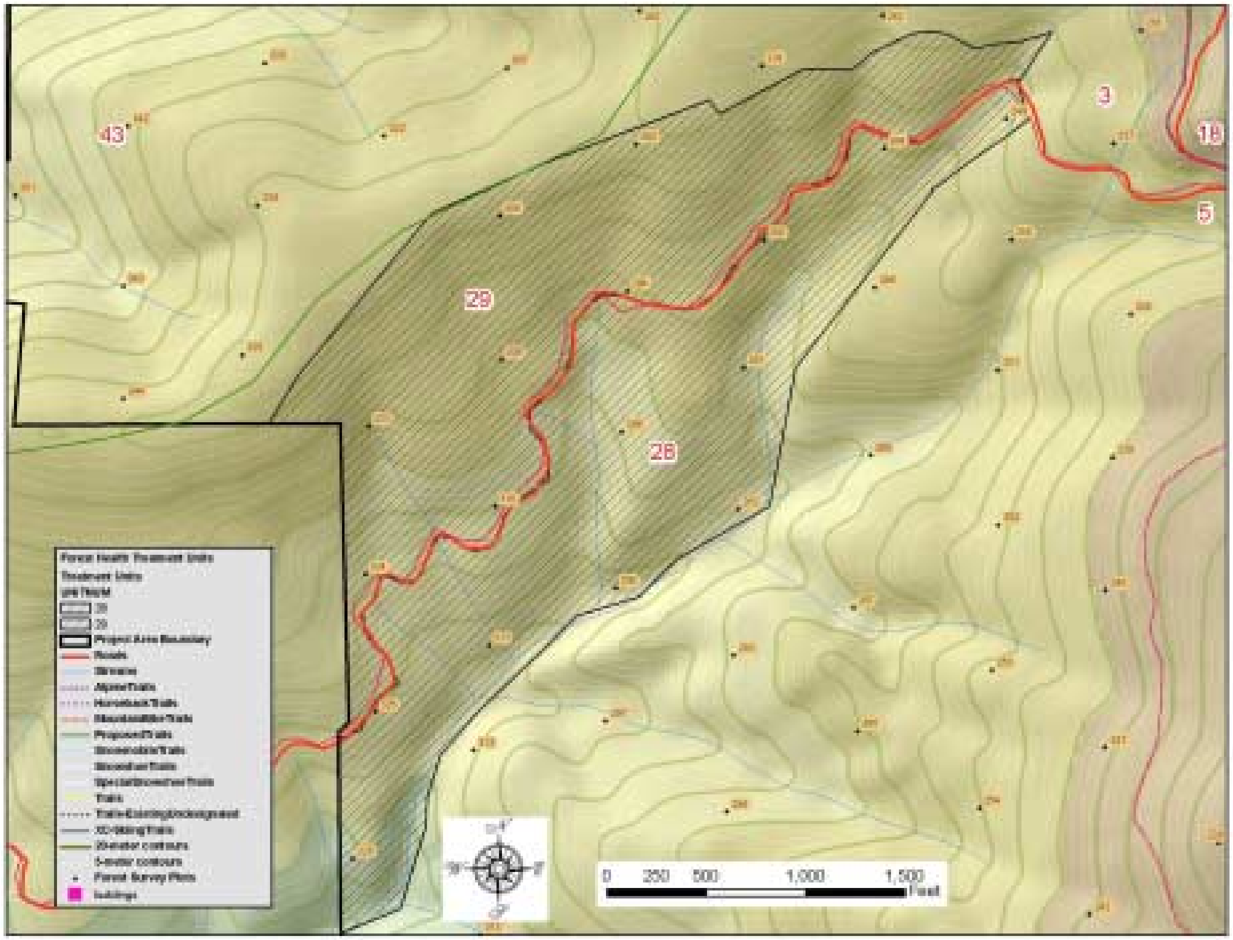

Figure 145. Topographic map of Treatment Units 28 and 29.

Treatment Unit 28 is below the Mt. Spokane Day Road and Unit 29 is above the Day Road. Both units contain forests in the ABGR/PHMA and ABGR/ACGLD/CLUN plant associations (Table 3). Both stands contain over 30 fire resistant trees (ponderosa pine, Douglas-fir or western larch) per acre (Table 42). In fact, this area contains some of the best old-growth ponderosa pine remaining at Mt. Spokane State Park. These two units also contain over 700 small trees less than 4 inches in DBH per acre and over 35 young grand firs between 4 and 8 inches DBH per acre. The have relatively high quadratic mean diameters and at least 8 trees per acre over 21 inches in diameter. Both units were identified as being in high priority zones for forest health treatments (Figure 123 and Table 42).

We recommend treatment of both stands to reduce the prevalence of young grand fir and to allow for the establishment of more fire resistant species. Our ultimate goal for this area is to encourage the development of a forest that is relatively fire resistant and can be easily maintained in that condition by the regular use of prescribed fire. Treatment of these two units will also help create a secondary firebreak that will slow fires burning across the park. Option 8 was chosen for treatment of Unit 28, because it can accomplish these objectives and because this unit appears to be an appropriate site for commercial thinning. This unit lies below the road and uphill yarding can be easily accomplished. Option 5 was chosen for Unit 29, which lies above the road. Downhill yarding would be required for any merchantable trees that are cut in this unit and because of the steepness of the unit and the greater potential for soil impacts from downhill yarding, we decided that it would be better to use a less aggressive approach to treatment of this unit. Option 8 is listed as an alternative treatment option for this unit.

Wildlife habitat values are already currently high in both of these units. Treatments should focus on maintaining these habitat values and avoid activities that would lead to habitat deterioration.

Treatment Effects on Sensitive Wildlife

Unit 28

Treatment Option 8 is prescribed for this unit and in some areas of the unit moderate levels of disturbance may occur. The overall effect of treatments is intended to improve wildlife value for multiple species. For marten and lynx non-winter foraging uses, the effects of the prescribed burn could have immediate negative impacts on important shrub components of the stand. However, vegetative response to prescribed fire might create enhanced shrub and herb conditions for prey species in the longer term. Due to slope steepness, the effects of burning and logging activities will be concentrated along the edge of the unit that intersects the Day Road. This means that most of the polygon will not be affected by the more intense vegetation manipulation activities. Areas where understory clearing of small grand fir occurs, and areas where prescribed fire reduces shrub heights and cover, may improve overall goshawk foraging opportunities. Opening up of the high density small grand fir pockets will probably benefit potential Western toad upland habitat conditions by decreasing the canopy closure on this south facing slope that is near a major creek drainage. The effects of the proposed treatment for Unit 28 on wildlife species are presented in Table 43.

Table 43. Effects of prescription for Treatment Unit 28 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Improbable	Positive
	Nesting	Improbable	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Improbable	Neutral
	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Improbable	Neutral
Marten	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Improbable	Neutral
Wolverine	Any	Possible	Neutral
Bald Eagle	Roosting	Possible	Neutral
Golden Eagle	Roosting	Possible	Neutral
	Foraging	Improbable	Neutral
Great Gray Owl	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
	Roosting	Improbable	Neutral
Pileated Woodpecker	Breeding	Possible	Neutral
	Foraging	Possible	Neutral
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral
Western Toad	Any	Possible	Positive

Unit 29

Impacts of the proposed treatment on vegetation would occur in pockets of high-density small grand fir. Clearing out these pockets will help improve goshawk forage habitat and Western toad upland habitat on a sunny south-facing slope. Thinning will also give native shrubs and herbs an opportunity to compete for understory canopy space, potentially increasing the habitat value for lynx and marten non-winter prey and browse. The effects of the proposed treatment for Unit 29 on wildlife species are presented in Table 44.

Table 44. Effects of prescription for Treatment Unit 29 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Improbable	Positive
	Nesting	Improbable	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Improbable	Neutral
	Non-Winter Foraging	Possible	Positive
	Winter Foraging	Improbable	Neutral
Marten	Non-Winter Foraging	Possible	Positive
	Winter Foraging	Improbable	Neutral
Wolverine	Any	Possible	Neutral
Bald Eagle	Roosting	Possible	Neutral
Golden Eagle	Roosting	Possible	Neutral
	Foraging	Improbable	Neutral
Great Gray Owl	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
	Roosting	Improbable	Neutral
Pileated Woodpecker	Breeding	Possible	Neutral
	Foraging	Possible	Neutral
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral
Western Toad	Any	Possible	Positive

Group 9: Treatment Units 37, 41 and 42

These treatment units are located in the southwestern part of the project area and are accessed off the spur road that runs south from Smith Gap or from adjacent private timberlands (Figures 146 and 147). The priority for treatment of this area in the short-term is low, but this area should be considered in a long-term forest health treatment plan. They are grouped together because of their geographic proximity. The basic characteristics of these treatment units are presented in Table 45.

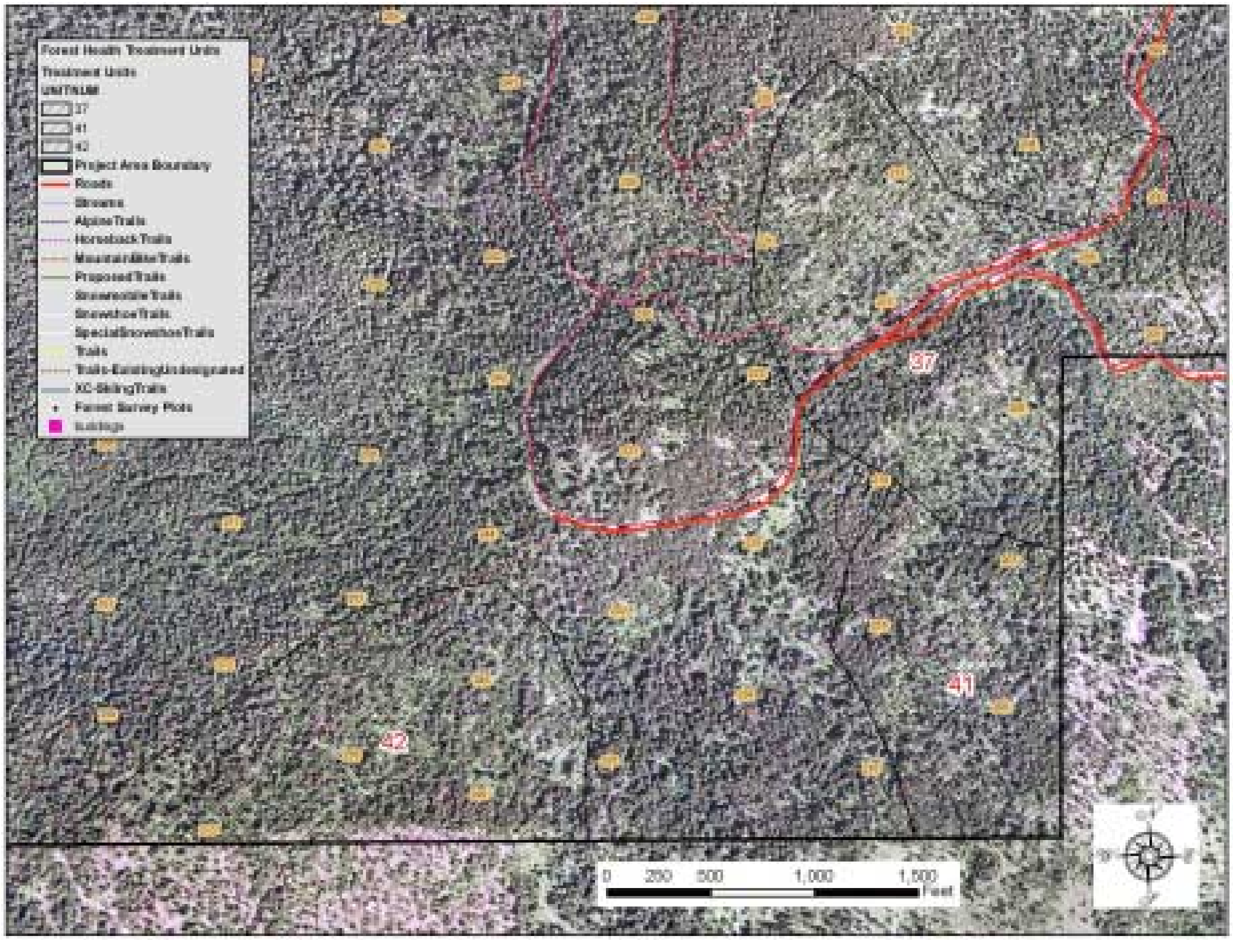

Figure 146. Aerial photograph of Treatment Units 37, 41 and 42.

Table 45. Basic characteristics of Treatment Units in Group 9. (see Tables 17-20)

Unit #	1st Option	2nd Options	Zone	Year	Acres	slope (%)	cbh	cbd	ba	tpa	qmd	stpa	abgr8	maxdbh	savetrees	snags	cwdcov	cwdnum	slzones	flzones	Flame length - before	Flame length - after	Change in flame length	Rate of spread - before	Rate of spread - after	Change in rate of spread
37	8	5,6,1	4	6	67	31	21	0.08	141	158	13	513	28	19	75	101	5	185	0.00	1.36	3.5	0.4	3.1	1.8	0.1	1.7
41	6	8,5,1	5 & 4	10	33	32	20	0.07	137	147	13	330	23	20	54	56	7	181	0.00	0.89	3.0	0.3	2.7	1.0	0.1	0.9
42	5	3,1	5 & 4	10	48	29	21	0.08	130	146	13	348	19	20	44	45	6	177	0.01	0.45	3.3	0.4	2.9	1.5	0.1	1.4

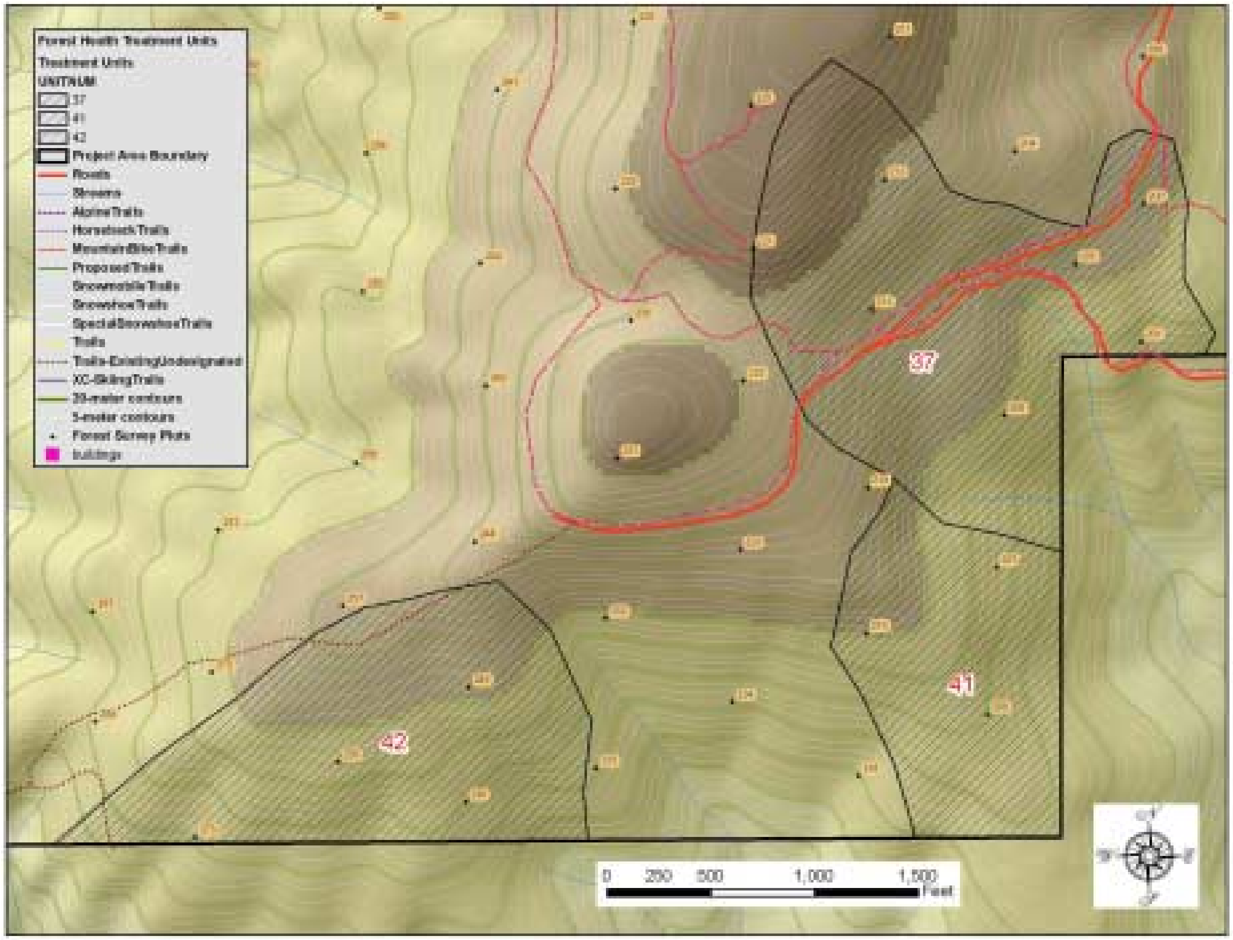

Figure 147. Topographic map of Treatment Units 37, 41 and 42.

Treatment Unit 37 extends both below and above the side road that runs southwest from Smith Gap. It borders private lands at the park boundary. It contains a diverse forest primarily in the grand fir series (ABGR/PHMA, ABGR/VAME/CLUN, ABGR/ACGLD/CLUN plant associations; Table 3), but some western hemlock series forests exist on the edges of the stand (TSHE/CLUN plant association). This stand contains 75 fire resistant legacy trees per acre and a high density (> 500) of small trees less than 4 inches in DBH. It was identified as a high priority area for forest health treatment in the project area (Figure 123 and Table 45).

Treatment Unit 37 has enough understory and midstory trees that need to be thinned for it to be considered a good candidate for Option 8, which involves commercial harvest. This treatment option will accomplish the objectives we have for this unit, which is to protect the legacy fire resistant trees from further encroachment and competition from young grand firs and to reestablish a more fire-resistant forest. Treatment of this stand will also create a firebreak, which will slow the spread of wildfires that start on private lands south of the park from up the slope and through the park. Part of this unit is above the road and yarding of merchantable tree boles may not be desirable if it cannot be accomplished without significant ground disturbance. Likewise, some areas of this unit are relatively steep and yarding restrictions should be imposed on these areas. We recommend that this unit be yarded when the ground is frozen and snow is on the ground to minimize soil disturbance. Parts of this unit that are not treated using Option 8 should be treated with one of the alternate treatment options (Table 17).

Treatment Unit 41 is located about 500 feet below the side road that runs southwest from Smith Gap. It borders private lands at the park boundary. We recommend treatment Option 6 for this unit. This treatment should protect the legacy fire resistant trees from further encroachment and competition from young grand firs and reestablish a more fire-resistant forest. Treatment of this stand will also create a firebreak, which will slow the spread of wildfires that start on private lands south of the park from up the slope and through the park.

Treatment Unit 42 is also located about 500 feet below the side road that runs southwest from Smith Gap. It is near the end of that road and also borders private lands at the park boundary. We recommend treatment Option 5 for this unit. This treatment option should protect the legacy fire resistant trees from further encroachment and competition from young grand firs and help to reestablish a more fire-resistant forest. Treatment of this stand will also create a firebreak, which will slow the spread of wildfires that start on private lands south of the park from up the slope and through the park.

Treatment Effects on Sensitive Wildlife

Unit 37

Treatments in this unit include limited harvesting of overstory trees, and understory thinning of young grand fir and western hemlock, followed by prescribed fire. While this may sound like an intensive treatment that could negatively impact wildlife habitats, we believe that adherence to our guidelines and restrictions on overstory thinning and tree skidding procedures will not significantly reduce wildlife habitat values because most habitat elements in the stand will be maintained. Additionally, habitat values will in be enhanced via recruitment of large coarse woody debris and snags. The effects of the proposed treatment for Unit 37 on wildlife species are presented in Table 46.

For lynx and marten non-winter foraging a prescribed burn could immediately reduce shrub cover desirable for lynx and marten prey (and desirable edible shrub species for marten could be reduced as well). However, the herbaceous and shrub response to fire should be good for lynx and marten prey and browse in the longer term benefiting both species' non-winter foraging habitat. Also, intentional snag recruitment due to the burn and subsequent coarse woody debris production could benefit marten non-winter foraging and perhaps marten winter foraging and pileated woodpecker uses.

Table 46. Effects of prescription for Treatment Unit 37 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Improbable	Positive
	Nesting	Improbable	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Improbable	Neutral
	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Improbable	Neutral
Marten	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Improbable	Neutral
Wolverine	Any	Possible	Neutral
Bald Eagle	Roosting	Possible	Neutral
Golden Eagle	Roosting	Possible	Neutral
	Foraging	Improbable	Neutral
Great Gray Owl	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
	Roosting	Improbable	Neutral
Pileated Woodpecker	Breeding	Possible	Positive
	Foraging	Possible	Positive
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral
Western Toad	Any	Possible	Neutral

Unit 41

Goshawks, martens, and pileated woodpeckers would all benefit to one degree or another from the prescribed treatment (Table 47). Lower canopy flyways would be maintained and possibly opened up by prescribed fire, benefiting goshawk foraging. With successful snag preservation, plus snag creation as a result of fire-killed trees, marten winter foraging habitat and pileated woodpecker breeding and foraging habitat would be improved.

Lynx and marten would gain mixed results from this treatment (Table 47). For lynx and marten non-winter foraging, the prescribed burn could immediately reduce shrub cover desirable for lynx and marten prey (and desirable edible shrub species for marten could be reduced as well). However, the herbaceous canopy response to fire and potentially even the shrub response could be good for lynx and marten prey, therefore enhancing habitat suitability. The long-term impacts are expected to be beneficial to both species' non-winter foraging habitat. Also, intentional snag recruitment due to the burn and subsequent coarse woody debris production could benefit marten non-winter foraging and perhaps marten winter foraging. The effects of the proposed treatment for Unit 37 on other wildlife species are presented in Table 47.

Table 47. Effects of prescription for Treatment Unit 41 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Possible	Positive
	Nesting	Improbable	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Improbable	Neutral
	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Improbable	Neutral
Marten	Non-Winter Foraging	Possible	Mixed
	Winter Foraging	Improbable	Neutral
Wolverine	Any	Possible	Neutral
Bald Eagle	Roosting	Possible	Neutral
Golden Eagle	Roosting	Possible	Neutral
	Foraging	Improbable	Neutral
Great Gray Owl	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
	Roosting	Improbable	Neutral
Pileated Woodpecker	Breeding	Possible	Positive
	Foraging	Possible	Positive
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral
Western Toad	Any	Possible	Neutral

Unit 42
Impacts on vegetation would occur in pockets of high-density small grand fir. Clearing out these pockets will help improve goshawk forage habitat. Thinning will also give native shrubs and herbs an opportunity to compete for understory canopy space, potentially increasing the habitat value for lynx and marten non-winter prey and browse. The effects of the proposed treatment for Unit 42 on wildlife species are presented in Table 48.

Table 48. Effects of prescription for Treatment Unit 42 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Improbable	Positive
	Nesting	Improbable	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Improbable	Neutral
	Non-Winter Foraging	Possible	Positive
	Winter Foraging	Improbable	Neutral
Marten	Non-Winter Foraging	Possible	Positive
	Winter Foraging	Improbable	Neutral
Wolverine	Any	Possible	Neutral
Bald Eagle	Roosting	Possible	Neutral
Golden Eagle	Roosting	Possible	Neutral
	Foraging	Improbable	Neutral
Great Gray Owl	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
	Roosting	Improbable	Neutral
Pileated Woodpecker	Breeding	Possible	Neutral
	Foraging	Possible	Neutral
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral
Western Toad	Any	Possible	Neutral

Group 10: Treatment Units 43, 44 and 45

These treatment units are located on the west side of the park and are accessed from private timberland (Figures 148 and 149). The priority for treatment of this area in the short-term is low, but this area should be considered in a long-term forest health treatment plan. They are grouped together because of their geographic proximity. The basic characteristics of these treatment units are presented in Table 49.

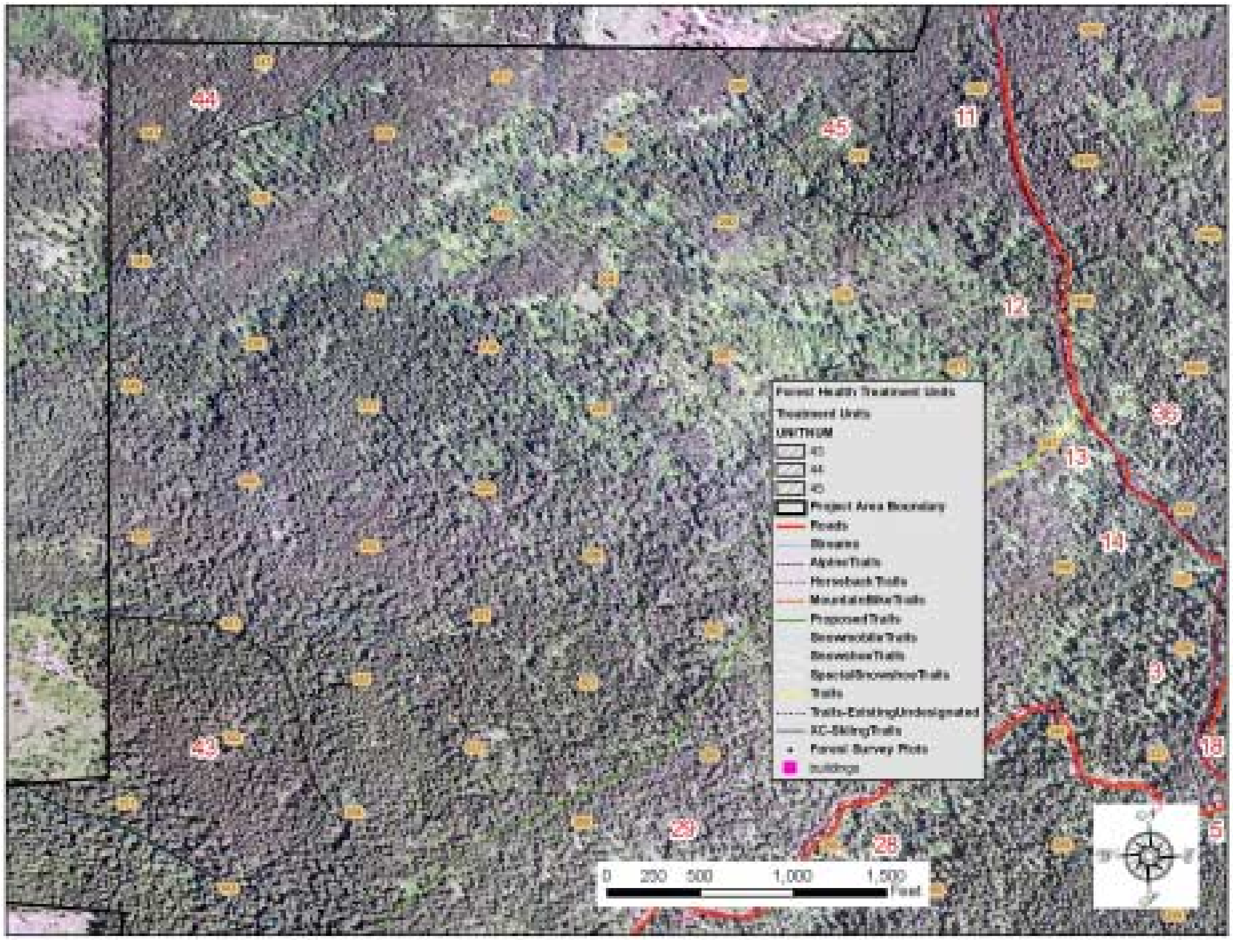

Figure 148. Aerial photograph of Treatment Units 43, 44 and 45.

Table 49. Basic characteristics of Treatment Units in Group 10. (see Tables 17-20)

Unit #	1st Option	2nd Options	Zone	Year	Acres	slope (%)	cbh	cbd	ba	tpa	qmd	stpa	abgr8	maxdbh	savetrees	snags	cwdcov	cwdnum	slzones	flzones	Flame length - before	Flame length - after	Change in flame length	Rate of spread - before	Rate of spread - after	Change in rate of spread
43	8	6,5,1	5	10	31	39	28	0.10	195	124	17	1020	16	26	29	42	11	311	0.00	0.57	2.3	0.5	1.9	1.2	0.1	1.0
44	8	6,5,1	5	10	17	21	36	0.09	193	218	14	526	15	23	36	38	10	156	0.04	0.89	6.2	0.6	5.6	1.8	0.2	1.6
45	5	3,1	5 & 2	10	14	32	32	0.06	174	120	16	583	5	19	26	69	25	297	0.00	1.31	2.3	0.4	1.9	0.8	0.1	0.7

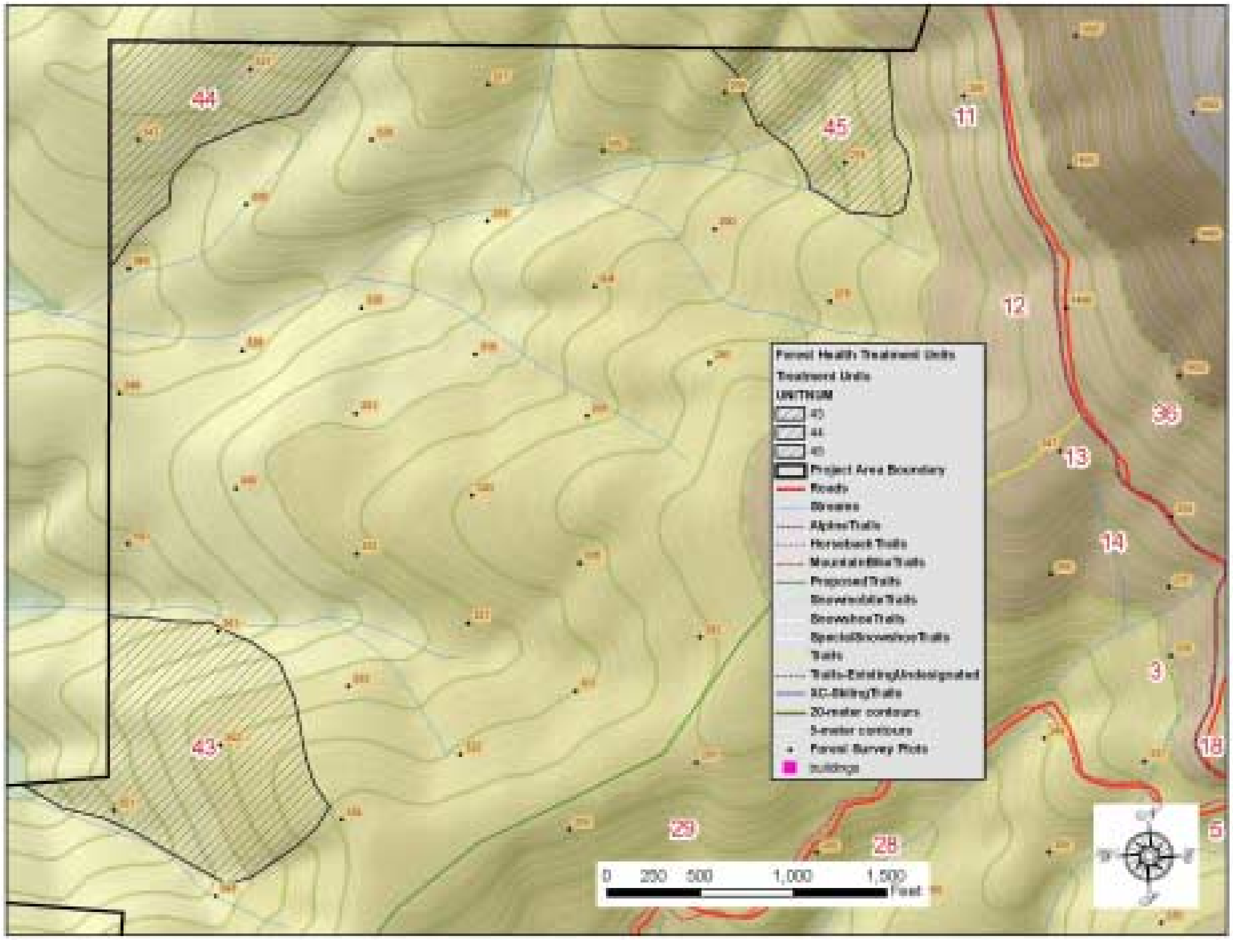

Figure 149. Topographic map of Treatment Units 43, 44 and 45.

Treatment Units 43 and 44 both border private lands along the western park boundary. Unit 43 contains a mature/old forest with two plant associations (ABGR/ACGLD/CLUN and TSHE/CLUN; Table 3). Unit 44 contains a mature/old forest in the ABGR/PHMA plant association. Unit 45 contains a mature/old forest with a mosaic of plant associations (ABGR/PHMA, ABGR/ACGLD/CLUN, and THPL/CLUN). All of these units contain over 25 fire resistant legacy trees per acre and a high density (> 500) of small trees less than 4 inches in DBH. Each unit contains significant acreage in one of the priority areas identified for forest health treatment (Figure 123 and Table 49).

Treatment Units 43 and 44 have an abundance of understory and midstory trees that need to be thinned so that it is a good candidate for Option 8, which involves commercial harvest. Existing road access to both of these units is available, but would have to be negotiated through private lands to the west. Treatment Option 8 will accomplish the objectives we have for these units, which is to protect the legacy fire resistant trees from further encroachment and competition from young grand firs and to reestablish a more fire-resistant forest. Treatment of this stand will also create firebreak, which will slow the spread of wildfires that start on private lands west of the park from moving up the slope and through the park. Some areas of this unit are relatively steep and yarding restrictions should be imposed on these areas to avoid excessive ground disturbance. We recommend that this unit be yarded when the ground is frozen and snow is on the ground to minimize soil disturbance. Parts of this unit that are not treated using Option 8 should be treated with one of the alternate treatment options (Table 17).

The top part of Treatment Unit 45 is accessible through existing road access, but this would have to be negotiated through private lands to the northwest. Other parts of the unit are not readily accessible through existing roads and we do not recommend building new roads on this relatively steep terrain. We have recommended Treatment Option 5 for this unit for an initial treatment followed at some later date with Option 3. Combined, these treatments will protect the legacy fire resistant trees from further encroachment and competition from young grand firs and reestablish a more fire-resistant forest. Treatment of this stand will also create a firebreak, which will slow the spread of wildfires that start on private lands north of the project area from moving through the park.

Treatment Effects on Sensitive Wildlife

Units 43 and 44

Treatments in these units include limited harvesting of midstory and overstory trees, and understory thinning of young grand fir and western hemlock, followed by prescribed fire. While this may sound like an intensive treatment that could negatively impact wildlife habitats, we believe that adherence to our guidelines and restrictions on overstory thinning and tree skidding procedures will not significantly reduce wildlife habitat values and will in effect enhance values in this unit. The effects of the proposed treatment for Units 43 and 44 on wildlife species are presented in Table 50.

For lynx and marten non-winter foraging a prescribed burn could immediately reduce shrub cover desirable for lynx and marten prey (and desirable edible shrub species for marten could be reduced as well). However, the herbaceous and shrub response to fire should be good for lynx and marten prey and browse in the longer term benefiting both species' non-winter foraging habitat. Also, intentional snag recruitment due to the burn and subsequent coarse woody debris production could benefit marten non-winter foraging and perhaps marten winter foraging.

Thinning of the grand fir here may decrease the suitability of these sites for lynx winter foraging, but at the same time non-winter foraging habitat could be enhanced. The likelihood of lynx winter foraging taking place in these units is low given the small patch size of optimal lynx winter foraging conditions.

Table 50. Effects of prescriptions for Treatment Units 43 and 44 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	**Possible**	**Positive**
	Nesting	**Improbable**	**Neutral**
Lynx	Dispersal	**Possible**	**Neutral**
	Breeding	**Improbable**	**Neutral**
	Non-Winter Foraging	**Possible**	**Mixed**
	Winter Foraging	**Possible**	**Negative**
Marten	Non-Winter Foraging	**Possible**	**Mixed**
	Winter Foraging	**Improbable**	**Neutral**
Wolverine	Any	**Possible**	**Neutral**
Bald Eagle	Roosting	**Possible**	**Neutral**
Golden Eagle	Roosting	**Possible**	**Neutral**
	Foraging	**Improbable**	**Neutral**
Great Gray Owl	Breeding	**Improbable**	**Neutral**
	Foraging	**Improbable**	**Neutral**
	Roosting	**Improbable**	**Neutral**
Pileated Woodpecker	Breeding	**Possible**	**Positive**
	Foraging	**Possible**	**Positive**
Black-backed Woodpecker	Breeding	**Improbable**	**Neutral**
	Foraging	**Improbable**	**Neutral**
Townsend's Big-eared Bat	Any	**Improbable**	**Neutral**
Columbia Spotted Frog	Any	**Improbable**	**Neutral**
Western Toad	Any	**Possible**	**Neutral**

Unit 45
Impacts on vegetation would occur in pockets of high-density small grand fir. Clearing out these pockets will help improve goshawk forage habitat. Thinning will also give native shrubs and herbs an opportunity to compete for understory canopy space, potentially increasing the habitat value for lynx and marten non-winter prey and browse. The effects of the proposed treatment for Unit 45 on wildlife species are presented in Table 51.

Table 51. Effects of prescription for Treatment Unit 45 on sensitive wildlife species.

Species	Use	Occurrence	Effect
Goshawk	Foraging	Improbable	Positive
	Nesting	Improbable	Neutral
Lynx	Dispersal	Possible	Neutral
	Breeding	Improbable	Neutral
	Non-Winter Foraging	Possible	Positive
	Winter Foraging	Improbable	Neutral
Marten	Non-Winter Foraging	Possible	Positive
	Winter Foraging	Possible	Neutral
Wolverine	Any	Possible	Neutral
Bald Eagle	Roosting	Possible	Neutral
Golden Eagle	Roosting	Possible	Neutral
	Foraging	Improbable	Neutral
Great Gray Owl	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
	Roosting	Improbable	Neutral
Pileated Woodpecker	Breeding	Possible	Neutral
	Foraging	Possible	Neutral
Black-backed Woodpecker	Breeding	Improbable	Neutral
	Foraging	Improbable	Neutral
Townsend's Big-eared Bat	Any	Improbable	Neutral
Columbia Spotted Frog	Any	Improbable	Neutral
Western Toad	Any	Possible	Neutral

Reflections and Recommendations pertaining to Forest Health Planning

Wildlife Habitat Assessments

Data collected in the forest condition assessment plots did not include information on some habitat elements for wildlife species of concern. In future studies of this nature, we recommend that all important habitat elements for wildlife species of concern be identified *in advance* and that field data collection methods incorporate them. In a separate document, we provide guidance on how to modify the scope of work of a future contract to include collection of data on important wildlife habitat elements (Morrison et al. 2007).

Mt. Spokane State Park has become an island of relatively intact coniferous forest habitat in a sea of private timberlands and increasing residential development. The project area is just one part of that island. Nearly all the wildlife species that we analyzed for this project are wide ranging species and maintenance of viable populations of these species cannot be accomplished in the project area or even in the State Park as a whole. We recommend expanding the habitat suitability analysis that we have started to the entire park, and if possible to the larger landscape in which the park is situated. If viable wildlife populations in the project area are to be maintained in the long-run, a comprehensive wildlife management plan with this objective should be developed in conjunction with Washington Department of Fish and Wildlife, other state and federal agencies, tribes, and private landowners in the region. The work we have started can serve as a jumping off point. An analysis of a small area will have only limited usefulness in the long-term if not expanded to an area large enough to be relevant to the maintenance of viable populations of wildlife species of conservation concern.

We have taken considerable care to develop a forest health treatment plan for the project area that puts an emphasis on maintenance and enhancement of habitat for sensitive wildlife species. The treatments we propose are intentionally conservative in their approach. This is in large part due to our findings related to the current high quality of wildlife habitat in the project area and our concern that treatments should enhance, or at least maintain, this habitat. We hope that during implementation of the forest plan, maintenance of the high quality wildlife habitat, which currently exists in this area, continues to receive the same level of emphasis.

Fire Behavior

Data from the forest condition assessment plots was used to determine fuel loads for the fire behavior software programs. Because the plot data was designed from standard silvicultural surveys, important fuel characteristics had to be calculated *ad hoc* prior to running the fire behavior programs. During the follow-up visit to Mt. Spokane, we sampled a number of plots for these fuel characteristics, particularly depth of duff and litter. In future studies that potentially involve fire hazard reduction, it will be important to include more quantitative measurements of fuels data using fuel inventory methods such as those in Brown (1974).

We used the FCCS software to develop fuelbeds and explore the effects of treatments on fuel conditions in potential treatment areas. We also explored its use in modeling fire behavior, but found that other programs such as Behave, Nexus and FlamMap produced results in which we had a greater degree of confidence. Until the FCCS software is developed further, tested in real world situations and the fire behavior algorithms published, we recommend using software based on the Rothermel (1972) fire spread model for determination of fire behavior. Although the Rothermel model does not incorporate the fine level of detail as FCCS, it has a longer history of use, the fire behavior algorithms are published, and the assumptions are generally understood by the fire and fuels analysis community. FCCS is useful in its current form for development of fuelbeds and evaluating the details of fuel conditions in a stand. It may also be useful in evaluating the relative (not absolute) effects of changes in fuel loading and fire behavior resulting from fuel treatments. FCCS has considerable potential and we welcome its further development and integration with other fire behavior modeling software.

The classification of plots into fuel models was sometimes problematic due to the lack of a quantitative key in Scott and Burgan (2005). We resorted to developing our own key that would work for the project area at Mt. Spokane. The Scott and Burgan fuel models are an improvement over the 13 standard fuel models (Anderson 1972), but considerable more work needs to be done in this realm before a widely applicable set of fuel models is available that adequately describes the wide range in fuel conditions encountered in the real world. FCCS could develop into such a system. At the very least, someone needs to develop a robust dichotomous key to the Scott and Burgan fuel models. The current key provided with the fuel models has many deficiencies.

In addition, there were no baseline fuel studies from this area with which to compare. In comparing our fuel models with the LANDFIRE project (Rollins and Frame 2006), we found that their fuel models were incompatible, leading to the conclusion that Mt. Spokane is a good area for further research on fuels and fire behavior. Future fuel inventories that lack baseline data should allocate project time for evaluating whether the available fuel models are appropriate, and if not, consideration should be given to alternatives such as developing custom fuel models. Several individuals could probably accomplish the research necessary to fill some of these basic data gaps as a two-year project.

While we used data from the LANDFIRE project in order to model fires that start outside the project area and then burn into the park, we do not recommend its use except in similar situations. While we did not conduct a formal accuracy assessment of the LANDFIRE data that covered the project area, we noted that it deviated significantly from the data that we collected at 406 forest survey plots. We would rate the overall accuracy of many of the LANDFIRE forest condition data layers as very low. The LANDFIRE canopy cover data layer is adequate, but LANDFIRE information on fire behavior fuel model, canopy bulk density, canopy height and canopy base height proved to be incorrect in most places we examined.

After considerable amount of weather modeling, it became clear that the climate of Mt. Spokane and the area to the north is a unique ecosystem characterized by high precipitation at relatively low elevations. We observed frequent days of wet weather, and seldom saw dry fuels. This area is correctly labeled an inland temperate rain forest. Our project would have benefited from better weather data for Mt. Spokane. If possible, future studies in the Mt. Spokane area should be based on weather data determined on Mt. Spokane, rather than by extrapolating from remote sites. A RAWS could be located on Mt. Spokane that would be useful for park rangers and ecologists.

Lastly, development of a state-of-the-art fire management plan for Mt. Spokane State Park should be a high priority. This plan should contain a fire suppression strategy for rapidly containing any fire ignitions that do occur in the park. Park personnel familiarity with this plan and readiness during the fire season is perhaps the most important step that Washington State Parks can take to protect the forests at Mt. Spokane from catastrophic losses during extreme fire events. We recommend further development and use of FARSITE landscape-level fire modeling system that we have discussed in this report. Implementation of a FARSITE fire model and response system would give State Park staff a huge advantage in wildfire response and attack when fires do start in the project area. Expansion of the spatial datasets used in FARSITE to the entire park would be necessary. We do not recommend reliance on the LANDFIRE data for other areas of the park, as these data layers are not accurate. FARSITE is not a difficult program to learn and park staff could be trained in its use for evaluating fire behavior, rapid response and attack options during fire events.

Forest Health Assessment

Most of our forest survey work was conducted in the late autumn, when it was quite difficult to identify herbs, grasses and other vascular plants. As a result, we were not able to assess the project area as thoroughly as we would have wished to for non-native invasive plants or rare native plants. More information about these species would be beneficial in designing optimal forest management strategies.

We did note that some non-native invasive plants are present in the project area and steps should be taken to limit their spread. Effective controls against further spread and infestations by these exotic species would be: prohibit further road and trail creation; maintain natural vegetation cover where it exists; maintain relatively high levels forest canopy cover (to shade out invasive plants); and prevent off-trail/road soil disturbances.

The presence of forest stands in the project area representing two globally imperiled plant associations is worth noting again. Stands that contain the western hemlock/bear grass (*Tsuga heterophylla/Xerophyllum tenax*) and the western hemlock/rusty menziesia (*Tsuga heterophylla / Menziesia ferruginea*) plant associations (both with global rarity rankings of G2) should receive special management attention. These forest stands represent exceedingly rare habitat conditions and must be managed carefully to ensure their protection. About 80 acres within the study area were characterized by one or the other plant association. Likewise, the subalpine fir / cascade azalea / beargrass (*Abies lasiocarpa / Rhododendron albiflorum / Xerophyllum tenax*) plant association, found in about 20 acres of the project area, also warrants special management attention. It is not rare globally, but it does have a S3 state ranking, which means that it is considered to be rare and vulnerable to extirpation in Washington State. All three rare plant associations were found near the edge of the project area and likely extend into other areas of Mt. Spokane State Park. Further survey work should be done to determine the extent of these imperiled and vulnerable plant associations. Information about their distribution throughout the park should be incorporated into the overall management plan for the park.

We were only able to obtain a limited amount of information about the past forest management history of the park. The information we did obtain, led us to conclude that much of the project had experienced extensive logging in the last century. More information about the timing and extent of past logging, slash disposal and other forest management activities would be helpful in analyzing the current forest health condition and assessing how these forests respond to disturbance.

Forest Health Plan and Prescriptions

Our assessment of the forest condition of the project area indicated that overall forest health was relatively good. Some of the concerns about forest health that prevail throughout the eastern portion of the Columbia Basin may be less relevant at Mt. Spokane because of the more mesic conditions that resemble forested landscapes west of the Cascade Range. Therefore, it is our belief that there is no "forest health emergency" at Mt. Spokane that requires immediate and desperate actions. Rather, a slow, steady and thoughtful approach to treating the forest health issues that are specific to the park is recommended. It is much more important to proceed carefully with a long-term action plan than to rush into aggressive actions that may cause more harm than good. In developing our forest plan, we have tried to balance the need for immediate action with the need to take a conservative approach that recognizes that many areas in the park are in good health now and need nothing more than continued good stewardship. Good forest management at Mt. Spokane presents an opportunity to maintain and slowly reestablish, where necessary, forests that are more resistant to wildfires, insects and disease. The park is a unique landscape and there will be a learning curve in developing the optimal management plan for the area. It is essential for Washington Parks to utilize highly qualified and experienced crew managers to oversee implementation of the treatments outlined in this plan so that the learning curve is not too steep. We recommend an adaptive management approach that includes regular monitoring of treatment implementation and its effects. In fact, the eventual success of this forest health plan relies largely on careful implementation, monitoring and maintenance.

Long-term Maintenance and Monitoring

Before Washington State Parks embarks on implementation of the treatments outlined in this forest plan, a commitment needs to be made to long-term maintenance and monitoring. A monitoring plan needs to be developed to carefully monitor treatment units before, immediately after and in successive years to better learn what works and how to fine-tune treatments in the future. A maintenance plan also needs to be developed to ensure that the benefits derived from treatment are not lost due to neglect. Both long-term monitoring and the regular maintenance of treated areas are both essential to achieving the specific objectives of this forest plan.

The overall goal of a maintenance and monitoring plan is to further the development of more fire-resistant, wildlife-rich, aesthetically pleasing, healthy forests that can in many areas be easily maintained by regular use of prescribed fire with little need for pre-treatment. To accomplish this goal, long-term maintenance, monitoring and adaptive management are essential. There are no "silver bullets" or "one-shot" solutions to forest health issues. Persistence over the decades is more important than urgent and aggressive action. But this is not an excuse for procrastination. Forest health issues that we have identified will become more difficult to treat as time progresses. We envision that if this approach is adopted, eventually it will be possible to use prescribed fire alone to maintain vibrant, diverse and resilient forest in the project area with minimal cost and effort.

Data Products Produced

As required by our project contract we produced a point data layer showing: 1) snag density and species; 2) CWD density and % cover; 3) shrub density and species; and 4) understory density and species for each plot. These attributes are contained in a project geodatabase, which holds GIS data on additional stand polygon and inventory plot data as well. We produced a plot base report, which is referred to in this report as Appendix M. This is a separate 406 page Adobe Acrobat (PDF) document that contains a summary of all the data collected at each plot. We also produced an organized directory containing all the digital plot photographs taken at each plot. This is available on a DVD.

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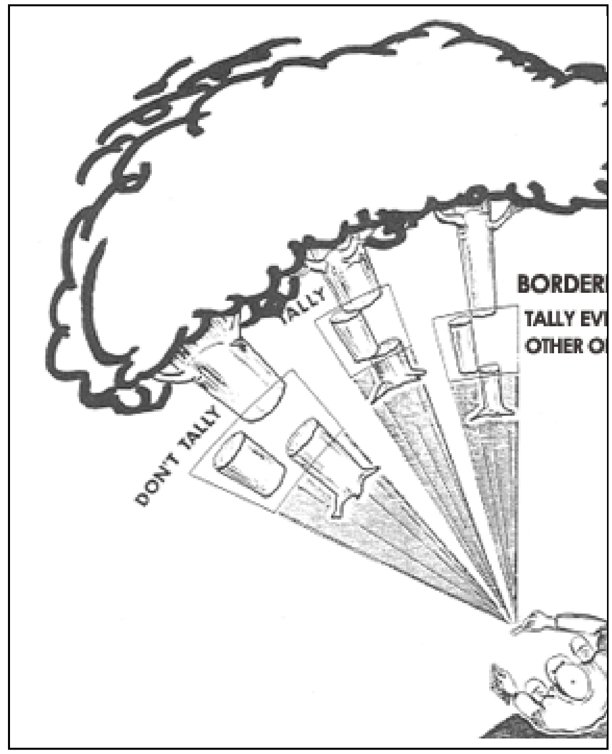
Appendix A - Forest Survey Instructions

Determining Basal Area Factor

The prism must always be held directly above the "plot center" stick for accuracy.



IN= the offset portion of the tree's stem appears to connect with the main stem
OUT=the offset portion does not connect

For borderline trees, tally every other tree (see diagram)

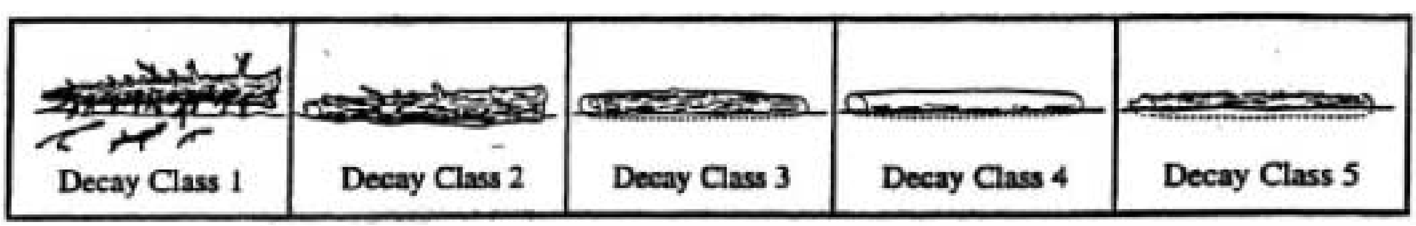
If the slope is more than 15%, correct the point sampling by tilting the prism by the approximate slope angle before viewing. (Alternatively, multiply the BAF of the prism by the secant of the angle to each tree.)

Determining Tree Dominance

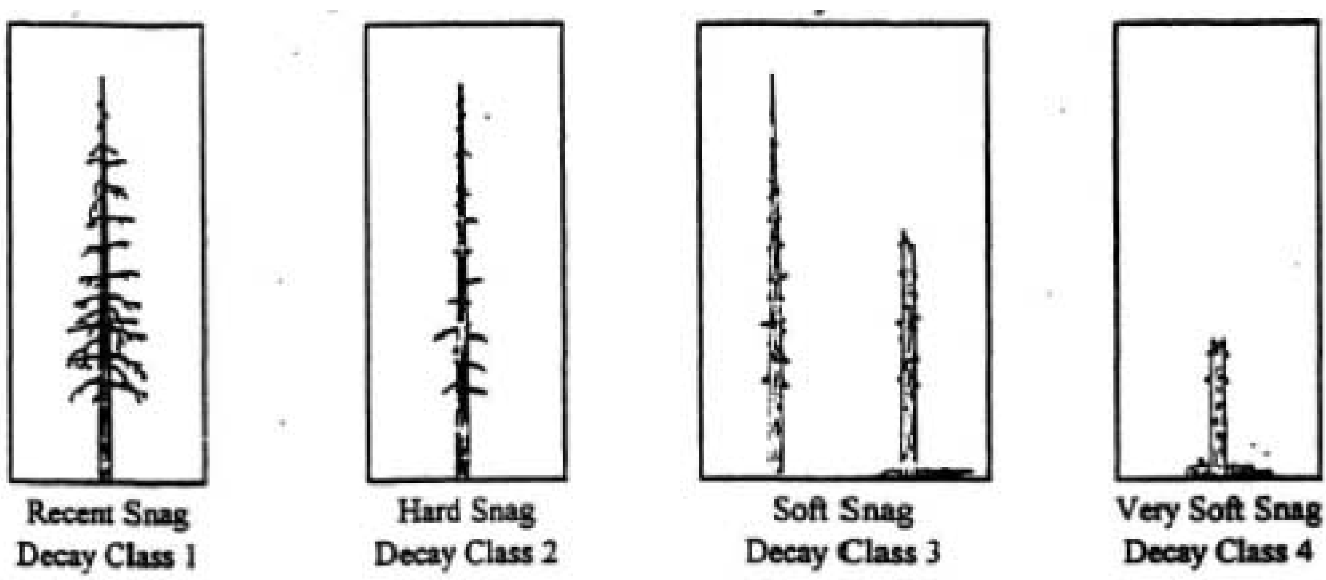
1. **D-Dominant.** Trees with crowns extending above the general level of the crown canopy and receiving full light from above and partly from the sides. These trees are taller than the average trees in the stand and their crowns are well developed, but they could be somewhat crowded on the sides. Also, trees whose crowns have received full light from above and from all sides during early development and most of their life. Their crown form or shape appears to be free of influence from neighboring trees.
2. **CD-Co- dominant.** Trees with crowns at the general level of the crown canopy. Crowns receive full light from above but little direct sunlight penetrates to their sides. Usually they have medium- sized crowns and are somewhat crowded from the sides. In stagnated stands, co- dominant trees have small- sized crowns and are crowded on the sides.
3. **I-Intermediate.** Trees that are shorter than dominants and co- dominants, but their crowns extend into the canopy of dominant and co- dominant trees. They receive little direct light from above and none from the sides. As a result, intermediates usually have small crowns and are very crowded from the sides.
4. **S-Subdominant.** Trees with crowns entirely below the general level of the crown canopy that receive no direct sunlight either from above or the sides.

From: http://fhm.fs.fed.us/posters/posters03/kraft_crown.pdf#search=%22%22Kraft%20Crown%22%20Classification%20system%22

Determining Decay Class of Snags and Coarse Woody Debris



CWD	Decay Class Code				
Characteristic	**1**	**2**	**3**	**4**	**5**
Bark	Intact	Intact	Trace	Absent	Absent
Twigs < 1.2 in	Present	Absent	Absent	Absent	Absent
Texture	Intact	Intact to softening	Hard, large pieces	Small, soft blocky pieces	Soft and powdery
Shape	Round	Round	Round	Round to Oval	Oval
Color of wood	Original color	Original color	Original to faded color	Light brown to reddish brown	Red brown to dark brown
Portion on ground	Log elev. on support points	Log elev. on support points sagging slightly	Log sagging near ground	All of log on ground	All of log on ground
Invading roots	None	None	In sapwood	In heartwood	In heartwood



Snags	Decay Class Code			
Characteristic	**1**	**2**	**3**	**4**
Bark	Intact	Intact	Trace	Absent
Twigs and branches < 1.2 in. dia.	Present	Absent	Absent	Absent
Texture	Intact	Intact to softening	Hard, large pieces	Small, soft blocky pieces
Shape	Round	Round	Round	Round to oval
Color of wood	Original color	Original color	Original to faded color	Light brown to reddish brown

from: http://www.dnr.state.md.us/education/envirothon/forestry/measurements.html

Polygon Form Instructions

VEGETATION COVER includes all vascular plants, mosses, lichens and foliose lichens (crustose lichens excluded they are considered rock); this never exceeds 100%. Space between leaves/branches is included in “cover”.

Code	**Cover (%)**	Cover mid-pt
0	0	0
1	<1	0.5
2	1-5	3
3	5-25	15
4	25-60	43
5	60-90	75
6	>90	95

TREES, SHRUBS, GRAMINOIDS, FORBS, EXOTICS cover includes the space between leaves/branches. Each Life form category canopy cover must be 0-100%. Therefore, the sum of all life forms (layers) can exceed 100%. List most abundant species in each life form category; when trees are cored, note DBH, species, length of core, number of rings counted.

SOIL SURFACE estimate to nearest **%** the following, the sum of the categories adds to 100%
Rock outcrop = exposed bedrock including detached boulders over 1m across
Gravel/cobble = large fragments between sand and boulder
Bare ground = exposed mineral soil
Mosses/lichens = nonvascular plant cover on soil
Litter = includes logs, branches, and basal area of plants
Describe in comments if there is wide variation in any category; note % standing water if it is persistent or characteristic of site.

LAND USE - put 0 (zero) if not applicable to site.
Logging

1 = unlogged, no evidence of past logging or occasional cut stumps not part of systematic harvest of trees, no or very little impact on stand composition

2 = selectively logged: frequent cut stumps but origin of dominant or co-dominant cohort appears to be natural disturbance

3 = heavy logging disturbance with natural regeneration: many cut stumps that predate the dominant or co-dominant cohort with no tree planting

4 = tree plantation: dominant cohort appears to be planted after clearcutting

Stand Age
1 = very young 0-40 yr 4 = old-growth 200+ yr
2 = young 40-90 yr 5 = young with scattered old trees (2-10 old trees per acre)
3 = mature 90-200 yr 6 = mature with scattered old trees

FIRE HISTORY

PLANT ASSOCIATION (PA) = list all PAs encountered in polygon survey, in comments list source of name if not on provided key. NOTE: Contractor is required to consult with the WNHP to obtain the most current classification and condition ranking information available.

Condition Rank of PA in key or estimate (see Appendix B for details)
% of Stand = your estimate
Pattern = how PA is distributed in stand
1 = matrix (most of polygon)
2 = large patches
3 = small patches
4 = clumped, clustered, contiguous
5 = scattered, more or less evenly repeating
6 = linear
7 = other

EXOTIC = primary species observed; secondary species observed (please pay special attention to noxious weeds). Also note the relative abundance of exotics in each polygon, using the 1-6 cover codes noted above.

Appendix B – Ecological Condition Ranking System

Ecological Condition Ranks

When assessing conservation priorities and management decisions, it can be useful to rank natural communities into levels of ecological condition. For example, an unfragmented area with high native species diversity, absence of non-native species and little soil erosion often has greater conservation value than another area in the same habitat type that is fragmented, infested with weeds or has erosion problems. Likewise, areas with a lower ecological condition rank may be targets for restoration activities.

The flowing ecological condition ranks were applied to vegetation polygons that were surveyed in this project:

Condition Rank 1. This condition class represents areas that have been altered to the point where the ecological condition often deviates dramatically from baseline conditions found in areas where stressors are much less prevalent. Areas characterized by Condition Class 1 often have high amounts of bare ground and/or non-native plant cover. The structure is often significantly altered from baseline conditions. Often one or more of the structural layers (trees, shrubs, herbs, grasses, mosses & lichens, biotic crust) may be significantly altered or even missing from the community. The composition of native vegetation is skewed toward species that can survive despite regular disturbance. Species diversity of native plants is usually low and native grass species are usually absent or in very low abundance (for a given community type). Evidence of accelerated erosion and soil compaction may be present. Hydrologic alteration may also be present. Significant direct evidence of various stress factors is usually abundant. Rare plant and animal species generally do not occur in this condition class.

Condition Rank 2. This condition class represents areas that show a fairly broad range of stress ranging from high to moderately low impact from a variety of stressors. Areas characterized by Condition Class 2 usually have moderate levels of non-native plant cover. The structure of the natural community present in Condition Class 2 areas is often relatively intact when compared to baseline conditions. Usually all structural layers are present, but form and stature may be altered from baseline conditions. Soil surface conditions are often intermediate between those in Condition Class 1 and Condition Class 3. Species diversity of native plants is often moderate for that community. Non-native species are usually present, but not as common or abundant as in Condition Class 1. Native grass species are often present, but usually in low abundance for that community type. Diversity of native grass species is relatively low when compared to baseline conditions. Evidence of accelerated erosion and soil compaction may be present in isolated areas, but is not dramatic or widespread. Hydrologic alteration is absent. Direct signs of stressors may be present, but not widespread or abundant. Rare plant and animal species may be found in this condition class, but are not common. Rare species that are found in this condition class are relatively tolerant of the stressors that are present.

Condition Rank 3. This condition class represents areas that show the least stress in the project area and are the closest to representing baseline conditions. Areas characterized by Condition Class 3 have little evidence of non-native plant invasion. The composition and structure of native vegetation in this condition class correspond to the natural ranges of variation characteristic to this habitat type. Old-growth conditions may exist. Species diversity of native plants is often high relative to the community under consideration. Native grass species are usually present and often fairly abundant for the community type. Species diversity of native grass species is also often high. Soil compaction, accelerated erosion and hydrologic alteration are absent. Direct signs of stressors are usually absent. Certain rare species may only exist within this condition class and rare species are generally more common than in the lower condition classes.

Appendix C – Plant Names and Codes

The table cross-references the plants referred to in this document by common name, scientific name, alpha code and family.

Common Name	Scientific Name	CODE	Family
bitter cherry	Prunus emarginata (Dougl. ex Hook.) D. Dietr.	PREM	Rosaceae
black cottonwood	Populus trichocarpa Torr. & Gray ex Hook. =	POTR15	Salicaceae
blue wildrye	Elymus glaucus Buckl.	ELGL	Poaceae
bluejoint	Calamagrostis canadensis (Michx.) Beauv.	CACA	Poaceae
bracken fern	Pteridium aquilinum (L.) Kuhn	PTAQ	Dennstaedtiaceae
bride's bonnet	Clintonia uniflora (Menzies ex J.A. & J.H. Schultes) Kunth	CLUN2	Liliaceae
British Columbia wildginger	Asarum caudatum Lindl.	ASCA2	Aristolochiaceae
Canada goldenrod	Solidago canadensis L.	SOCA	Asteraceae
Canada thistle	Cirsium arvense (L.) Scop.	CIAR4	Asteraceae
Carolina bugbane	Trautvetteria caroliniensis (Walt.) Vail	TRCA	Ranunculaceae
Columbia brome	Bromus vulgaris (Hook.) Shear	BRVU	Poaceae
common beargrass	Xerophyllum tenax (Pursh) Nutt.	XETE	Liliaceae
common cowparsnip	Heracleum lanatum Michx. = Heracleum maximum Bartr.	HELA4	Apiaceae
common ladyfern	Athyrium filix-femina (L.) Roth	ATFI	Dryopteridaceae
common mullein	Verbascum thapsus L.	VETH	Scrophulariaceae
common snowberry	Symphoricarpos albus (L.) Blake	SYAL	Caprifoliaceae
common St. Johnswort	Hypericum perforatum L.	HYPE	Clusiaceae
coralroot	Corallorhiza sp. Gagnebin	CORAL5	Orchidaceae
creeping barberry	Mahonia repens (Lindl.) G. Don	MARE11	Berberidaceae
Dalmatian toadflax	Linaria dalmatica (L.) P. Mill.	LIDA	Scrophulariaceae
darkwoods violet	Viola orbiculata Geyer ex Holz.	VIOR	Violaceae
Douglas-fir	Pseudotsuga menziesii (Mirbel) Franco	PSME	Pinaceae
dwarf rose	Rosa gymnocarpa Nutt.	ROGY	Rosaceae
Engelmann spruce	Picea engelmannii Parry ex Engelm.	PIEN	Pinaceae
feathery false lily of the valley	Maianthemum racemosum (L.) Link	MARA7	Liliaceae
fragrant bedstraw	Galium triflorum Michx.	GATR3	Rubiaceae
Geyer's sedge	Carex geyeri Boott	CAGE2	Cyperaceae
grand fir	Abies grandis (Dougl. ex D. Don) Lindl.	ABGR	Pinaceae
gray alder	Alnus incana (L.) Moench	ALIN2	Betulaceae
Greene's mountain ash	Sorbus scopulina Greene	SOSC2	Rosaceae
hairy catsear	Hypochaeris radicata L.	HYRA3	Asteraceae
hollyleaved barberry	Mahonia aquifolium (Pursh) Nutt.	MAAQ2	Berberidaceae
Idaho fescue	Festuca idahoensis Elmer	FEID	Poaceae
Idaho goldthread	Coptis occidentalis (Nutt.) Torr. & Gray	COOC	Ranunculaceae
Indian's dream	Aspidotis densa (Brack.) Lellinger	ASDE6	Pteridaceae
largeleaf sandwort	Moehringia macrophylla (Hook.) Fenzl	MOMA3	Caryophyllaceae
lodgepole pine	Pinus contorta Dougl. ex Loud.	PICO	Pinaceae
Lupine	Lupinus Spp.	Lupinus	Fabaceae
mallow ninebark	Physocarpus malvaceus (Greene) Kuntze	PHMA5	Rosaceae
oceanspray	Holodiscus discolor (Pursh) Maxim.	HODI	Rosaceae
orange honeysuckle	Lonicera ciliosa (Pursh) Poir. ex DC.	LOCI3	Caprifoliaceae
Oregon drops of gold	Disporum hookeri (Torr.) Nichols. var. oreganum (S. Wats.) Q. Jones	DIHO	Liliaceae

Pacific trillium	Trillium ovatum Pursh	TROV2	Liliaceae
pathfinder	Adenocaulon bicolor Hook.	ADBI	Asteraceae
pinegrass	Calamagrostis rubescens Buckl.	CARU	Poaceae
pioneer violet	Viola glabella Nutt.	VIGL	Violaceae
Piper's anemone	Anemone piperi Britt. ex Rydb.	ANPI	Ranunculaceae
pipsissewa	Chimaphila umbellata (L.) W. Bart.	CHUM	Pyrolaceae
ponderosa pine	Pinus ponderosa P.& C. Lawson	PIPO	Pinaceae
prickly currant	Ribes lacustre (Pers.) Poir.	RILA	Grossulariaceae
quaking aspen	Populus tremuloides Michx.	POTR5	Salicaceae
red baneberry	Actaea rubra (Ait.) Willd.	ACRU2	Ranunculaceae
redosier dogwood	Cornus stolonifera Michx.	COST4	Cornaceae
Rocky Mountain maple	Acer glabrum Torr.	ACGL	Aceraceae
rusty menziesia	Menziesia ferruginea Sm.	MEFE	Ericaceae
Saskatoon serviceberry	Amelanchier alnifolia (Nutt.) Nutt. ex M. Roemer	AMAL2	Rosaceae
Scouler's St. Johnswort	Hypericum formosum Kunth = Hypericum scouleri Hook.	HYFO	Clusiaceae
Scouler's willow	Salix scouleriana Barratt ex Hook.	SASC	Salicaceae
sidebells wintergreen	Pyrola secunda L. = Orthilia secunda (L.) House	PYSE	Pyrolaceae
slide alder	Alnus sinuata (Regel) Rydb.	ALSI3	Betulaceae
small enchanter's nightshade	Circaea alpina L.	CIAL	Onagraceae
spotted knapweed	Centaurea maculosa auct. non Lam. [misapplied] >>Centaurea stoebe ssp. micranthos	CEMA4	Asteraceae
starry false lily of the valley	Maianthemum stellatum (L.) Link	MAST4	Liliaceae
starry false lily of the valley	Smilacina stellata (L.) Desf. = Maianthemum stellatum (L.) Link	SMST	Liliaceae
subalpine fir	Abies lasiocarpa (Hook.) Nutt.	ABLA	Pinaceae
thimbleberry	Rubus parviflorus Nutt.	RUPA	Rosaceae
thinleaf huckleberry	Vaccinium membranaceum Dougl. ex Torr.	VAME	Ericaceae
threeleaf foamflower	Tiarella trifoliata L.	TITR	Saxifragaceae
twinflower	Linnaea borealis L.	LIBO3	Ericaceae
Utah honeysuckle	Lonicera utahensis S. Wats.	LOUT2	Caprifoliaceae
wall-lettuce	Lactuca muralis (L.) Fresen. = Mycelis muralis (L.) Dumort.	LAMU	Asteraceae
water birch	Betula occidentalis Hook.	BEOC2	Betulaceae
western hemlock	Tsuga heterophylla (Raf.) Sarg.	TSHE	Pinaceae
western larch	Larix occidentalis Nutt.	LAOC	Pinaceae
western meadow-rue	Thalictrum occidentale Gray	THOC	Ranunculaceae
western oakfern	Gymnocarpium dryopteris (L.) Newman	GYDR	Dryopteridaceae
western pearly everlasting	Anaphalis margaritacea (L.) Benth.	ANMA	Asteraceae
western red cedar	Thuja plicata Donn ex D. Don	THPL	Cupressaceae
western white pine	Pinus monticola Dougl. ex D. Don	PIMO3	Pinaceae
white hawkweed	Hieracium albiflorum Hook.	HIAL2	Asteraceae
white spirea	Spiraea betulifolia Pallas	SPBE2	Rosaceae
willow	Salix L.	Salix	Salicaceae
woodland strawberry	Fragaria vesca L.	FRVE	Rosaceae
yellow hawkweek	Hieracium sp. L.	HIERA	Asteraceae

Appendix D - Wildlife Habitat Models

This appendix provides further information about how the suitability index values were calculated based on our field derived data and/or GIS and remote sensing analysis. This appendix mainly provides a set of graphs and tables that detail the conversions of field derived statistics on individual habitat elements into the suitability index values incorporated in the HSI models. Each graph represents one habitat element plotting suitability index along the y-axis and the input parameter along the x-axis. The parameters were developed through literature review and/or adopted from previous HSI models.

Goshawk Habitat Suitability Model - Foraging

Modeled habitat elements based on field data:

Table 1 provides an accounting of the different field derived habitat element variables we incorporated in creating the goshawk foraging model.

Table D1. Habitat elements used to create the goshawk foraging HSI model.

Foraging Model	
Notes:	**HSI Equations:**
Grading variables:	
Large diameter trees present	See stand diameter index
Tall trees present	See stand height index
Canopy closure	See canopy closure index
Openness of lower canopy flyways1	See shrub cover index
Openness of lower canopy flyways2	See variable radius plot (VRP) small trees index
Openness of lower canopy flyways3	See fixed radius plot (FRP) small trees index
Distance from development	See development distance index

Figures 1 – 7 further describe how the model predicts foraging habitat suitability based on input parameters developed through literature review or adopted from previous HSI models.

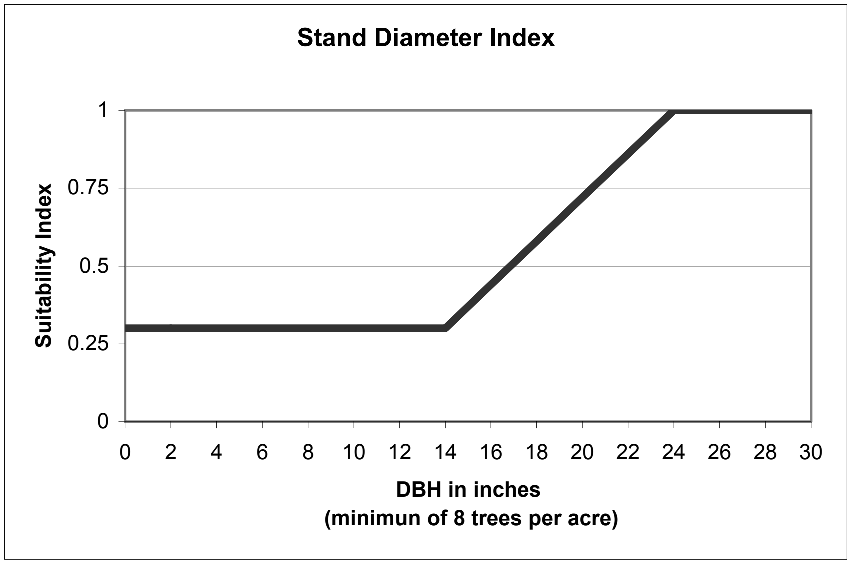


Figure D1. Stand diameter index input/output parameters.

Figure D2. Stand height index input/output parameters.

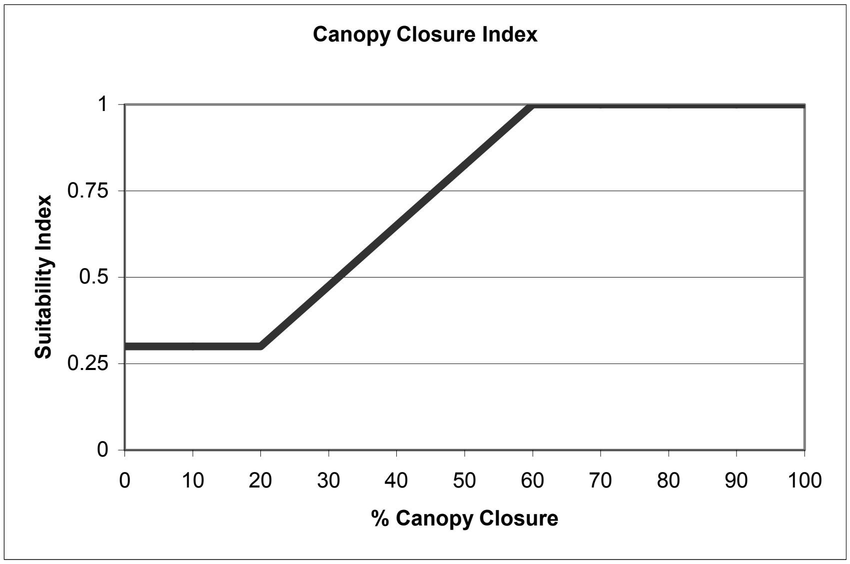


Figure D3. Canopy closure input/output parameters.

The input variables for calculating canopy closure are complex (Figure 3). For this equation we adjusted the original canopy cover field data variables due to the fact that many of our field densiometer readings were affected by tall shrubs. To eliminate large shrubs from being counted in the canopy closure variable, we calculated the total shrub cover for each plot for shrubs greater than 7 feet tall. This shrub cover value was multiplied by one-third and then subtracted from the original canopy cover value obtained from the densiometer readings to produce our canopy closure variables.

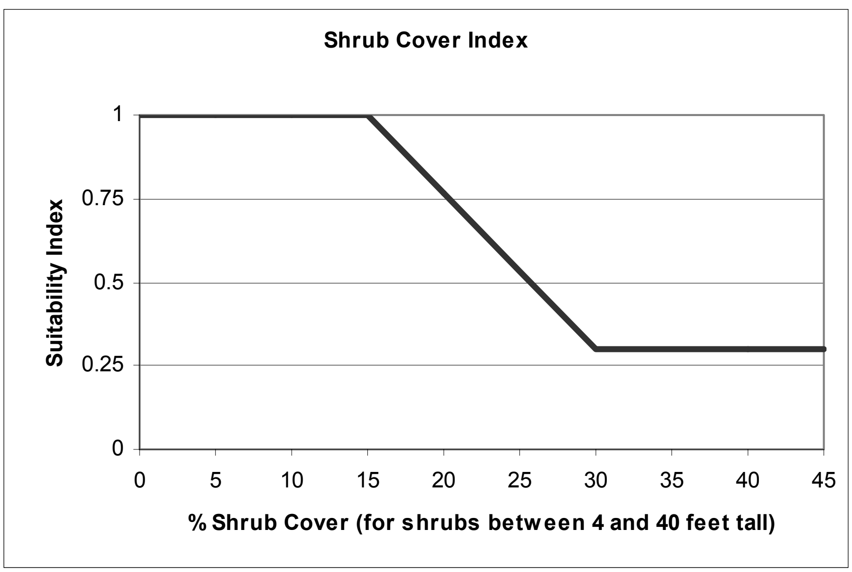


Figure D4. Shrub cover index input/output parameters.

As with the canopy closure variables, the shrub index input variables were also derived via a complex process that required adjusting our original field data (Figure 4). The shrub index was designed to look at the presence of large shrubs in the lower forest canopy. However, because of the growth form characteristics of some shrubs such as *Acer glabrum* and *Alnus incana*, we eliminated shrubs over 40 feet tall from this index because these types of shrubs tended to function more as trees in the forest overstory and did not dramatically affect flight path possibilities in the lower forest canopy. We also did not include small shrubs less 4 feet tall because they do not tend to negatively affect lower-canopy fly-ways.

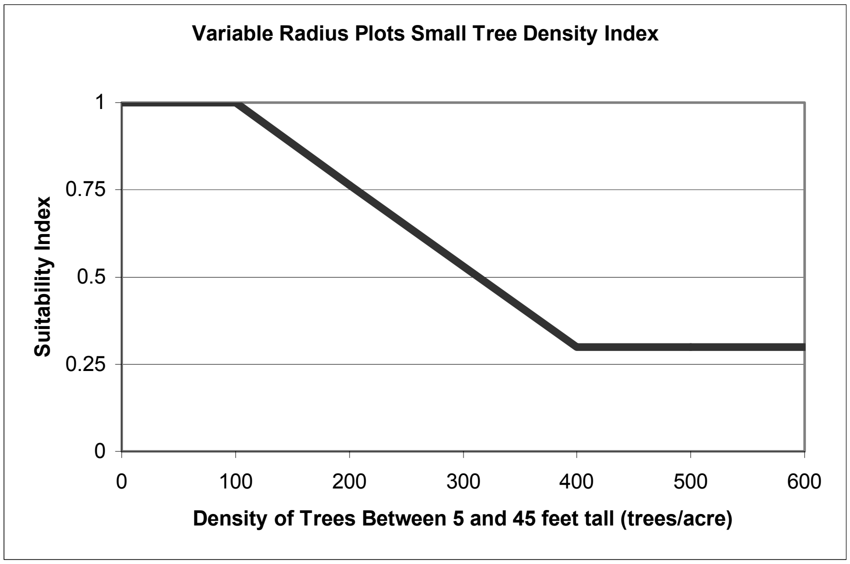


Figure D5. Variable radius plots small tree density index input/output parameters.

We only calculated the density of trees per acre between 5 and 45 feet tall for the variable radius plot small tree index (Figure 5). We assumed these trees primarily affected possible flight paths in the lower forest canopy.

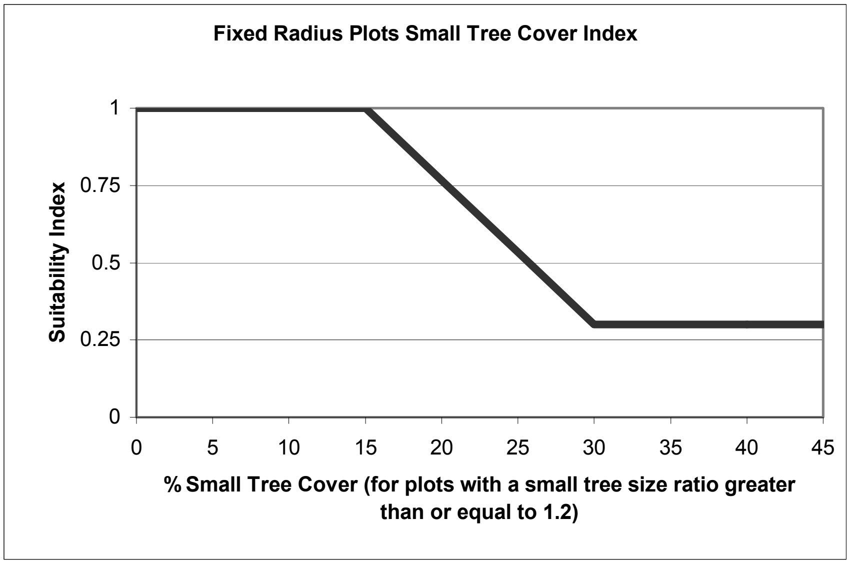


Figure D6. Fixed radius plots small tree cover index input/output parameters.

We created an estimated "Cover Per Tree" variable for the fixed radius plot small tree data because we needed to separate out and eliminate very small trees (trees < 4 ft tall) from our analysis (Figure 6). The "Cover Per Tree" variable was derived by dividing the total small tree cover by the density of small trees (and multiplying this by 100 to make the values easier to read by eliminating large decimals). A review of the continuum of the Cover Per Tree variables indicated that plots with a value of 1.2 or more tended to have trees over 4 feet tall, so we did not include fixed radius plot small tree measurements when this value was less than 1.2.

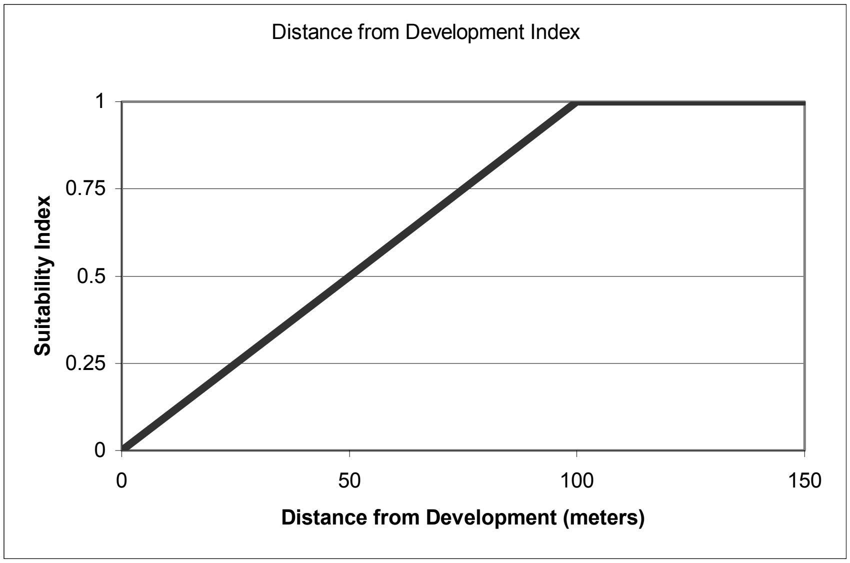


Figure D7. Development distance input/output parameters.

Development in this case refers to the park's main road and major parking areas, building lots, and permanent structures within the project area (Figure 7). This element was derived via GIS analysis.

Goshawk Habitat Suitability Model – Nesting

Modeled habitat elements based on field data:

Table 2 provides an accounting of the different field derived habitat element variables we incorporated in creating the goshawk nesting model.

Table D2. Habitat elements used to create the goshawk nesting HSI model.

Nesting Model	
Grading variables:	**HSI Equations:**
Large diameter trees present	See stand diameter index
Tall trees present	See stand height index
Canopy closure	See canopy closure index
Openness of lower canopy flyways1	See shrub cover index
Openness of lower canopy flyways2	See fixed radius plot (FRP) small trees index
Openness of lower canopy flyways3	See variable radius plot (VRP) small trees index
Snags present	see snag density index
Slope steepness	see slope index table
Forest edge	see forest edge index table

Figures 8 - 16 further describe how the model predicts nesting habitat suitability based on input parameters developed through literature review or adopted from previous HSI models.

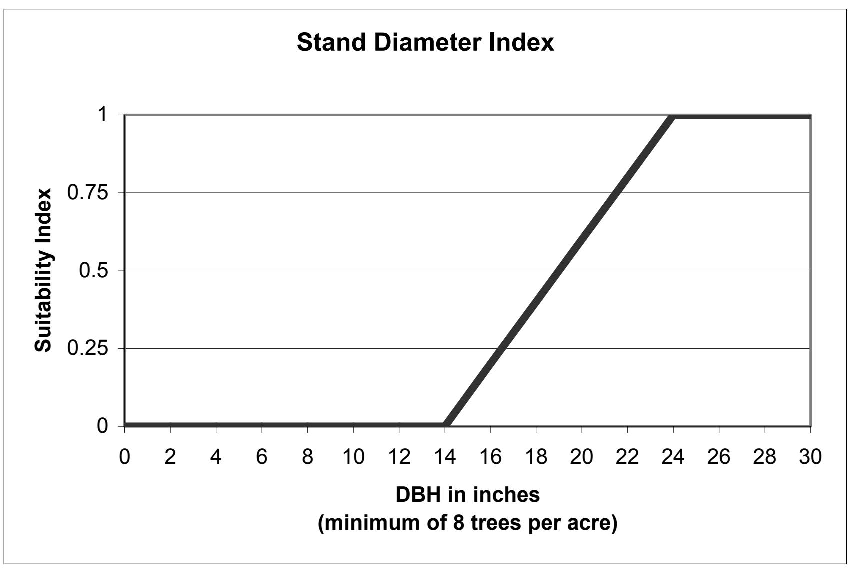


Figure D8. Stand diameter index input/output parameters.

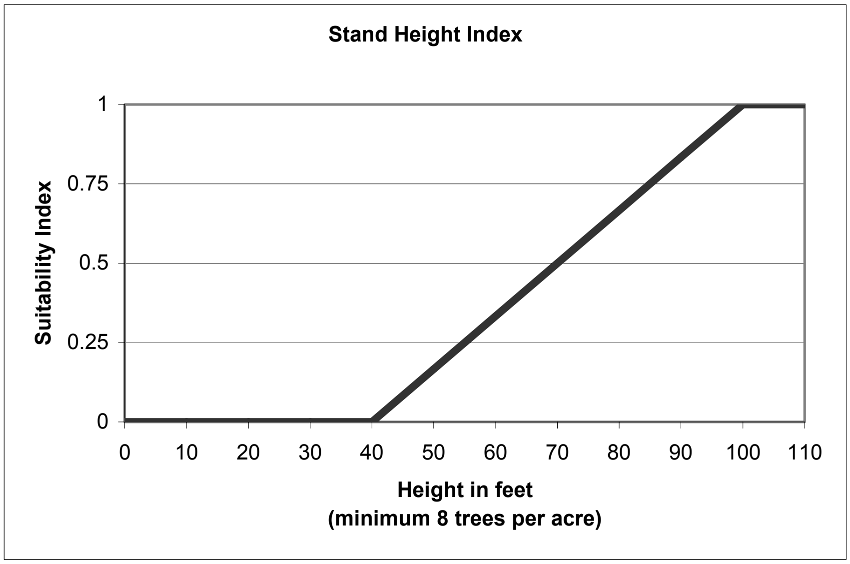


Figure D9. Stand height index input/output parameters.

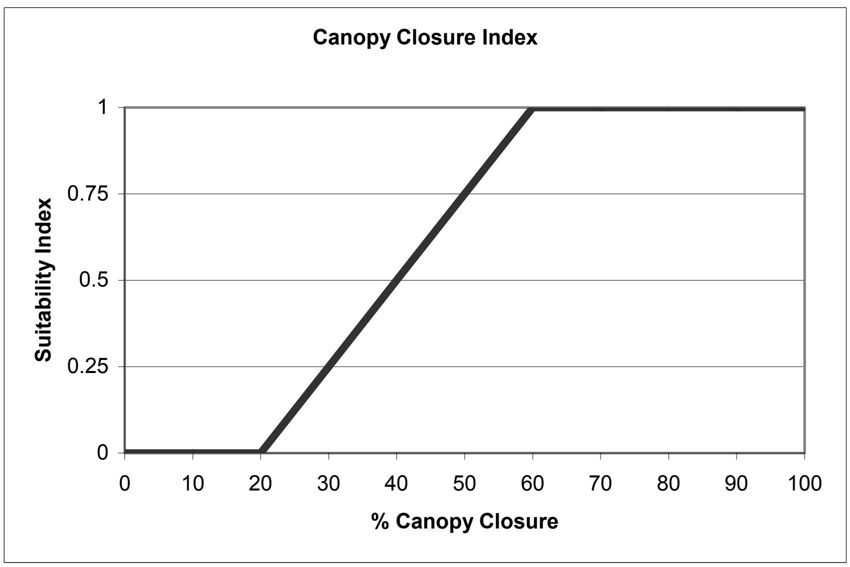


Figure D10. Canopy closure input/output parameters.

We followed the same data preparation procedures detailed for the canopy closure index under the goshawk foraging model (Figure 10).

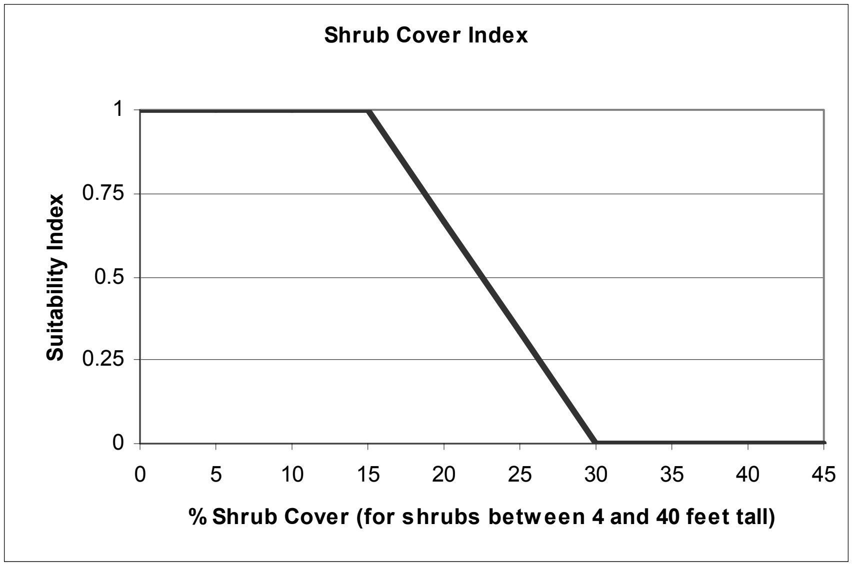


Figure D11. Shrub cover index input/output parameters.

We followed the same data preparation procedures detailed for the shrub cover index under the goshawk foraging model (Figure 11).

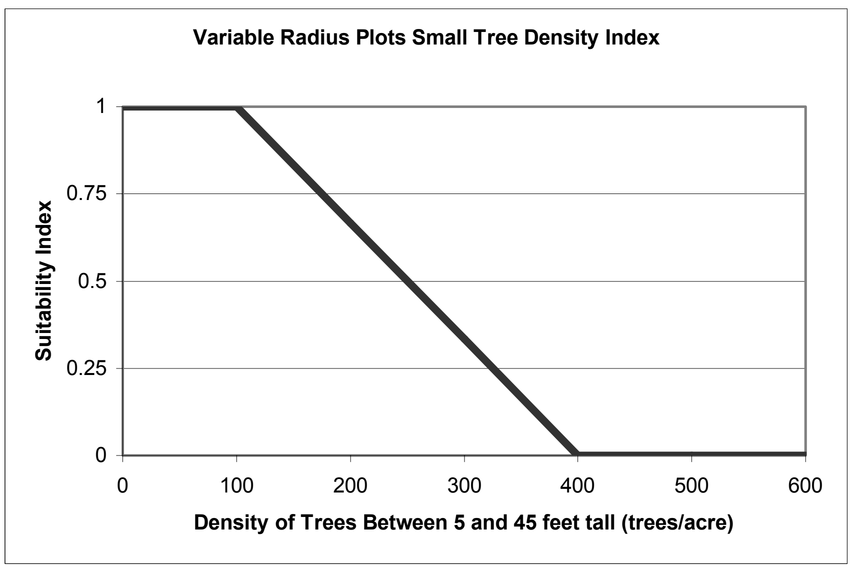


Figure D12. Variable radius plots small tree density index input/output parameters.

We followed the same data preparation procedures detailed for the VRP small tree index under the goshawk foraging model (Figure 12).

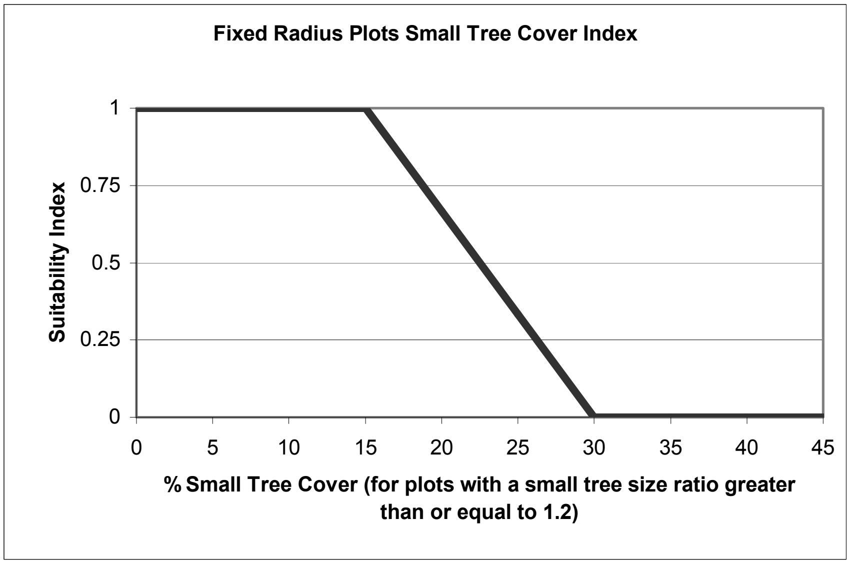


Figure D13. Fixed radius plots small tree cover index input/output parameters.

We followed the same data preparation procedures detailed for the FRP small tree index under the goshawk foraging model (Figure 13).

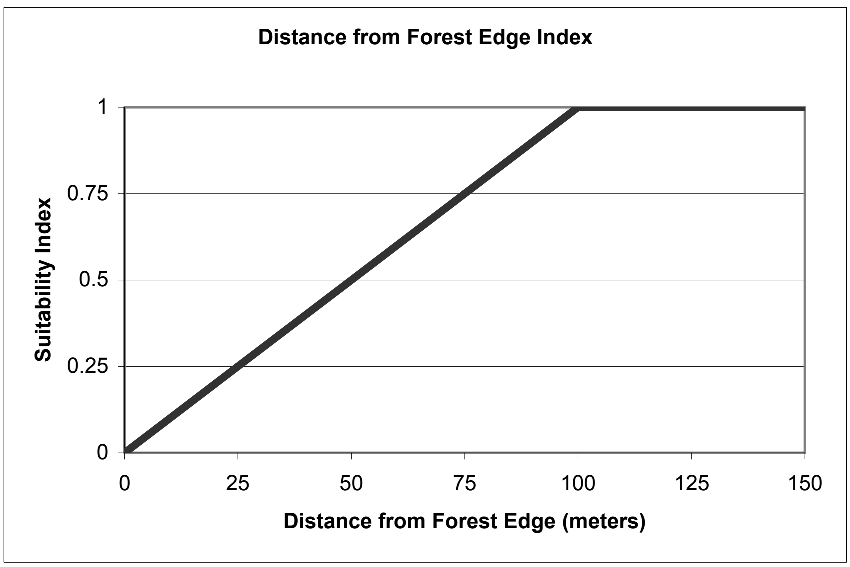


Figure D14. Distance from forest edge input/output parameters.

Forest edge in this case refers to areas where continuous forest cover (excluding young regenerating stands) is interrupted by large patches of non-forest nearly devoid of overstory trees (Figure 14). Such areas may include developed sites, clear-cuts, and/or shrublands.

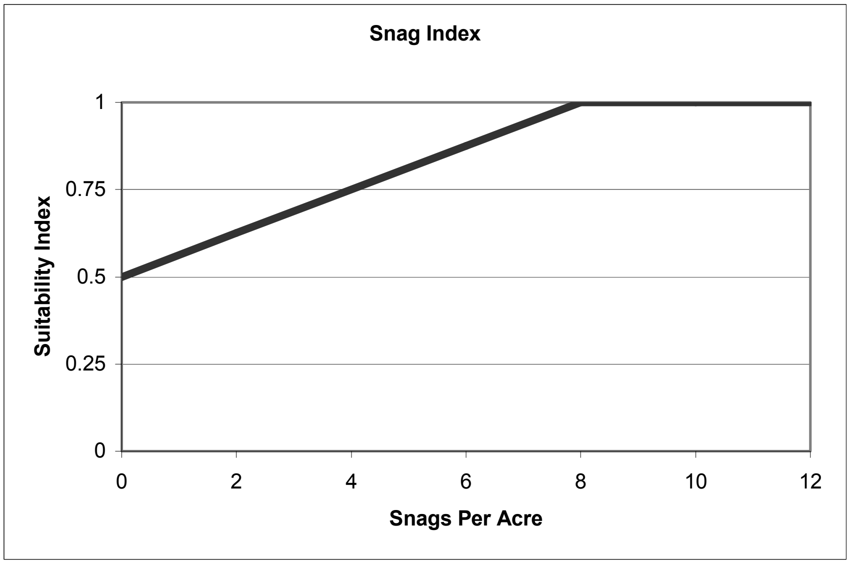


Figure D15. Snags index input/output parameters.

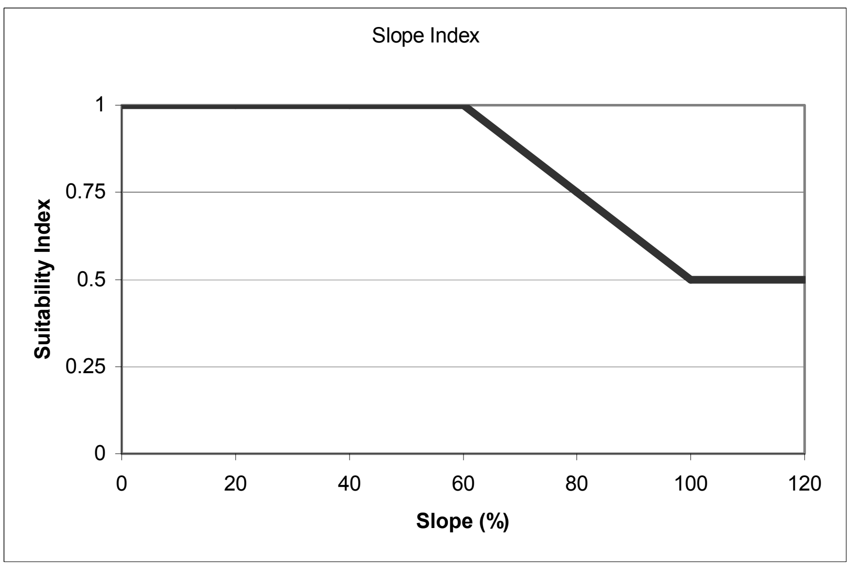


Figure D16. Slope index input/output parameters.

Lynx Habitat Suitability Models – Dispersal

Modeled habitat elements based on field data:

Table 3 provides an accounting of the different remote sensing-derived habitat element variables we incorporated into the lynx dispersal model.

Table D3. Habitat elements used to create the lynx dispersal HSI model.

Dispersal Model	
Notes:	**HSI Equations:**
Large openings	Non-cover bearing openings greater than 100 meters in width = 0, all else 1
Topographic Feature	All ridgelines, saddles, and riparian valley bottoms = 1, all else .7
Developed Area (including main park road)	Developed areas = 0.25, all else 1

The input values for these habitat elements were derived by GIS and remote sensing analysis. Each habitat element was modeled into a raster dataset covering the extent of the project area. The parameters defined in Table 3 were developed based on review of current literature concerning lynx dispersal.

Lynx Habitat Suitability Models – Breeding

Modeled habitat elements based on field data:

Table 4 provides an accounting of the different field derived habitat element variables we incorporated into the lynx breeding model.

Table D4. Habitat elements used to create the lynx breeding HSI model.

Breeding Model	
Notes:	**HSI Equations:**
Aspect	(Northness > 0) = 1, all others 0.5
Grading variables:	
Old/mature forest	See stand diameter index
Coarse woody debris	See CWD index
Canopy closure	See canopy closure index

Figure 17 - 19 further describe how the model predicts breeding habitat suitability based on input parameters developed through literature review or adopted from previous HSI models.

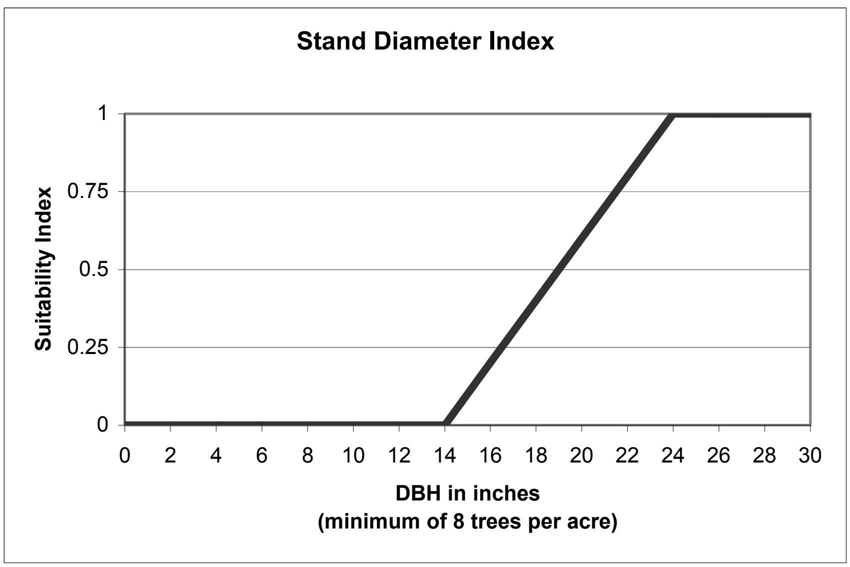


Figure D17. Stand diameter index input/output parameters.

The density of occurrence of large diameter trees is being used in the model as an indicator of older mature forests (Figure 17).

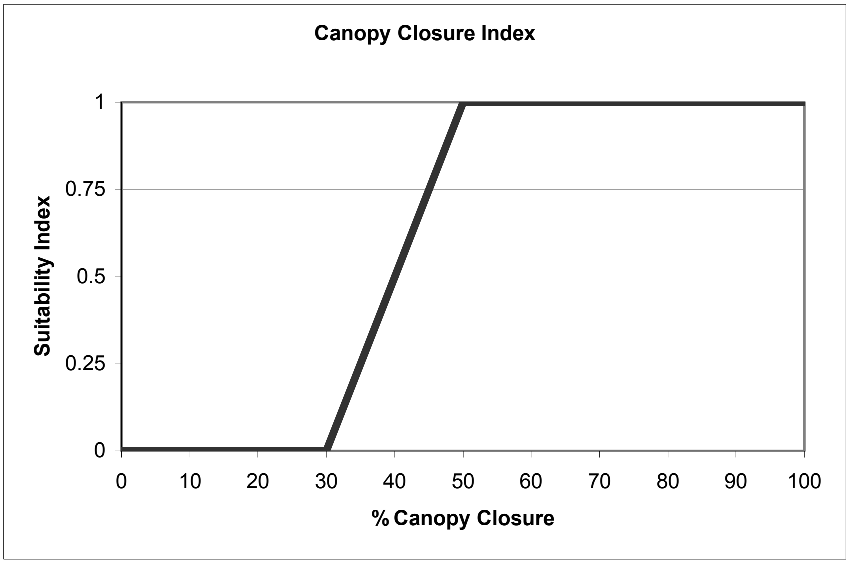


Figure D18. Canopy closure input/output parameters.

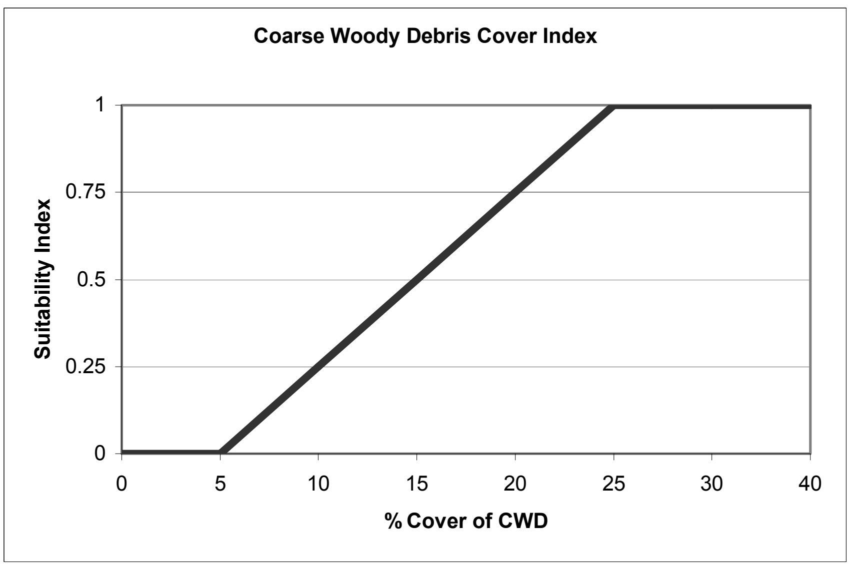


Figure D19. Coarse woody debris input/output parameters.

Lynx Habitat Suitability Models – Non-Winter Foraging

Modeled habitat elements based on field data:

Table 5 provides an accounting of the different field derived habitat element variables we incorporated into the lynx non-winter foraging model.

Table D5. Habitat elements used to create the lynx non-winter foraging HSI model.

Non-Winter Foraging Model	
Notes:	**HSI Equations:**
Prey browse cover	See prey browse index
Prey hiding cover	See prey hiding index

Figures 20 and 21 further describe how the model predicts non-winter foraging habitat suitability based on input parameters developed through literature review or adopted from previous HSI models.

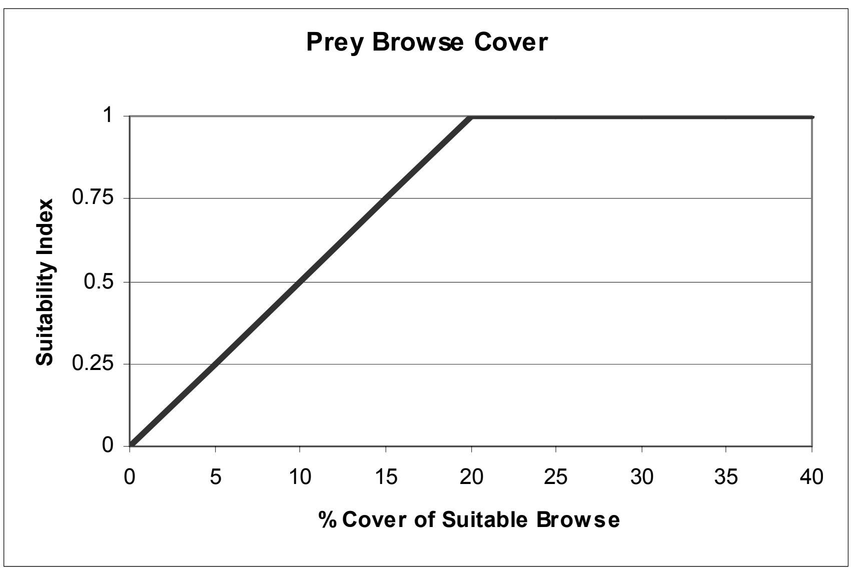


Figure D20. Prey browse cover index input/output parameters.

To calculate the prey browse cover index we summed up all herb and shrub cover estimates for each plot to get total herb/shrub percent cover (Figure 20). However, we removed shrubs over 20 ft tall from the summation, and *Alnus sinuata* and *Acer glabrum* because these shrubs did not contribute to prey browse potential on a site.

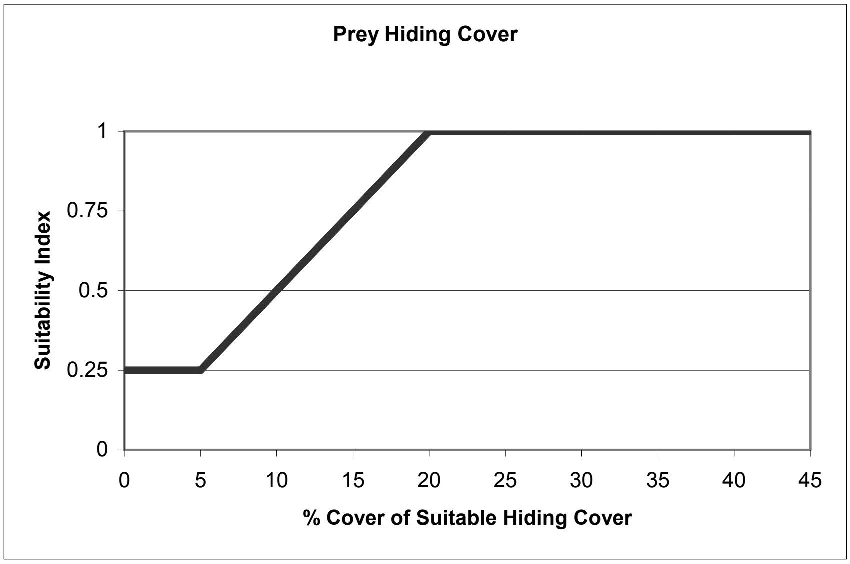


Figure D21. Prey hiding cover index input/output parameters.

The prey hiding cover index was calculated by adding the cover of small trees per plot with the cover of suitable herbs and shrubs (Figure 21). Understory plants less than 1.5 feet were not included in this index, and we removed shrubs over 20 ft tall from the summation because they did not contribute to hiding cover potential on a site.

Lynx Habitat Suitability Models – Winter Foraging

Modeled habitat elements based on field data:

Table 6 provides an accounting of the different field derived habitat element variables we incorporated into the lynx winter foraging model.

Table D6. Habitat elements used to create the marten winter foraging HSI model.

Winter Foraging Model	
Notes:	**HSI Equations:**
Grading variables:	
Slope steepness	See slope index table
Small tree density	See small tree index

Figure 22 and 23 further describe how the model predicts winter foraging habitat suitability based on input parameters developed through literature review or adopted from previous HSI models.

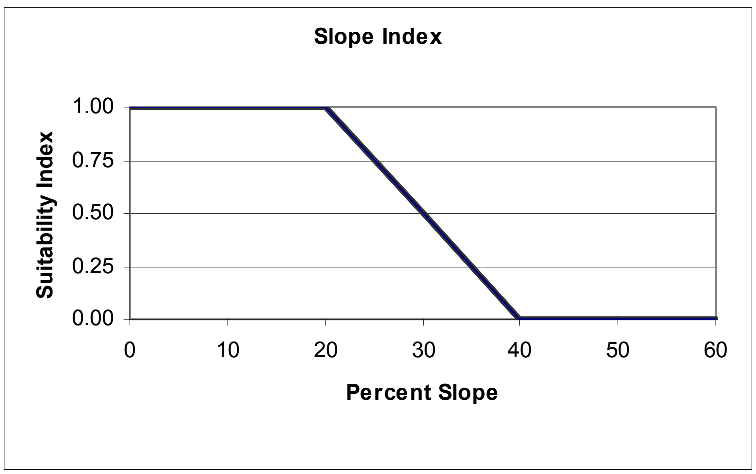


Figure D22. Slope index input/output parameters.

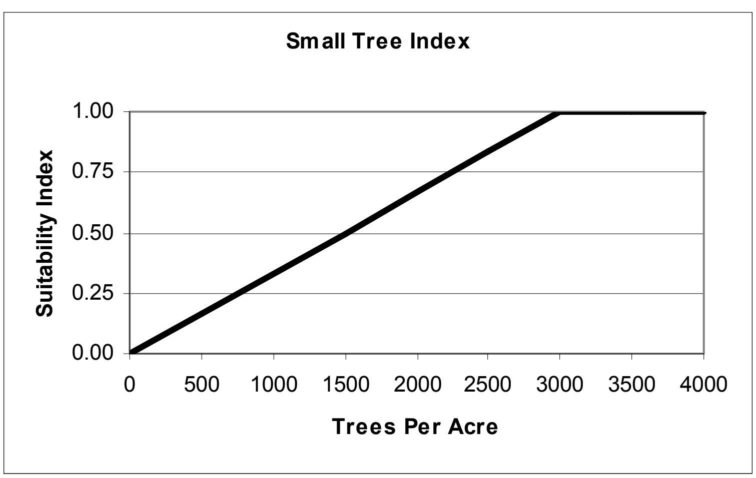


Figure D23. Small tree index input/output parameters.

To calculate this index (Figure 23), we summed all the live tree stems per acre data between the variable radius plots and the fixed radius plots, excluding variable radius stems under 4 inches DBH (these were already counted in the fixed radius plots).

Marten Habitat Suitability Models – Non-Winter Foraging

Modeled habitat elements based on field data:

Table 7 provides an accounting of the different field derived habitat element variables we incorporated into the marten non-winter foraging model.

Table D7. Habitat elements used to create the marten non-winter foraging HSI model.

Non-Winter Foraging Model	
Notes:	**HSI Equations:**
Grading variables:	
Shrub cover	See shrub cover index
Coarse woody debris	See CWD index
Snags	See snags index

No large clearings or recently burned areas exist within the project study area, so marten avoidance of these landscape features is being ignored in this model. Because of this, we consider all parts of the project area moderately suitable for marten non-winter foraging, hence the default HSI variable assignment of 0.5. The model predicts habitat enhancement from default moderate conditions by looking at the presence of understory characteristics such as shrub cover, coarse woody debris, and snags. Figure 24 – 26 describe how the model predicts enhancement of habitat suitability based on input parameters developed through literature review or adopted from previous HSI models.

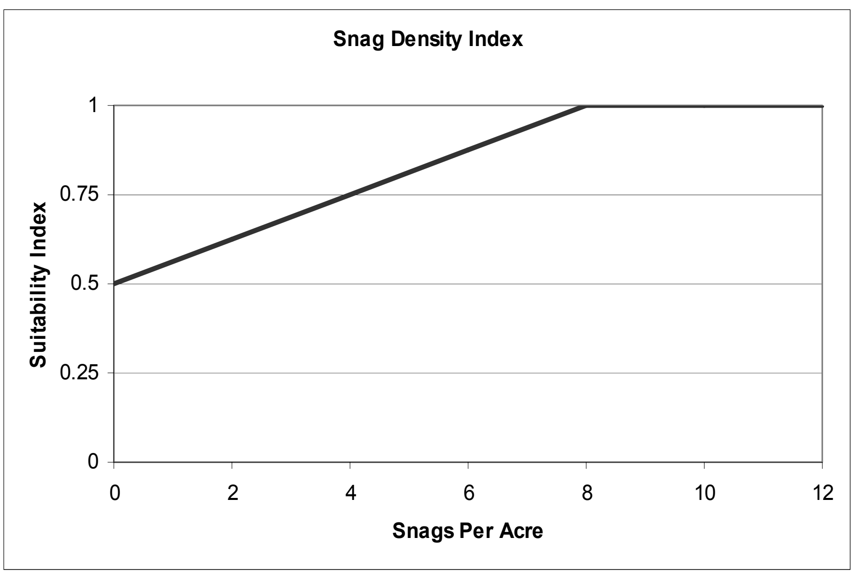


Figure D24. Snag density input/output parameters.

This index looks at the presence of snags in terms of snag density (Figure 24). Snags with 12 inches DBH or less were not included in the index.

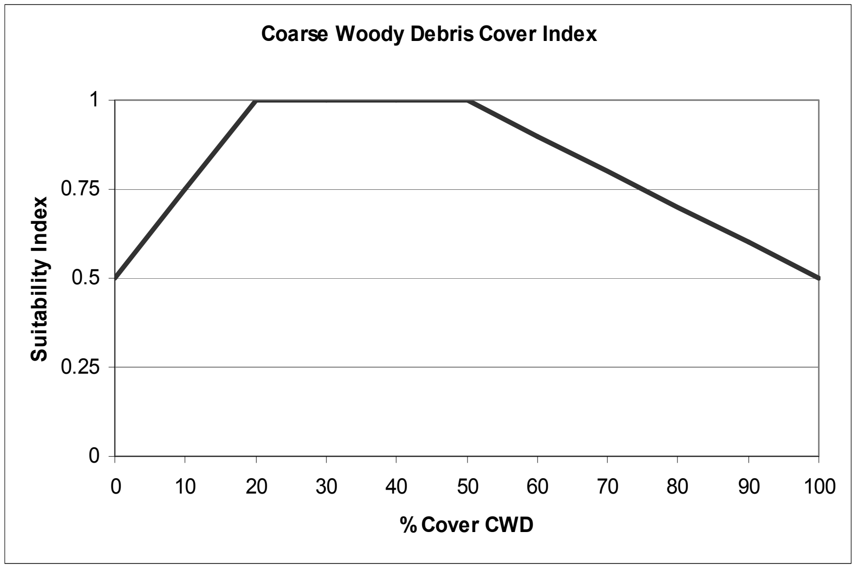


Figure D25. Coarse woody debris input/output parameters.

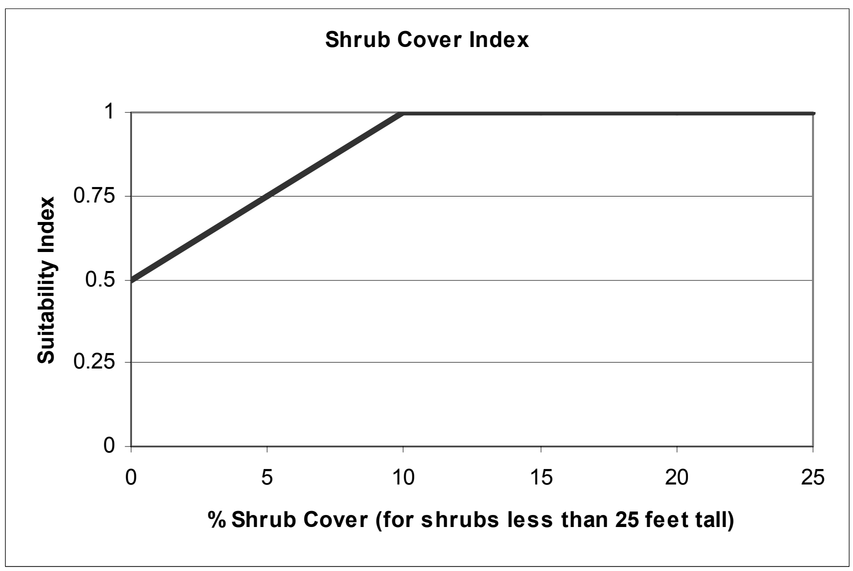


Figure D26. Shrub cover index input/output parameters.

The shrub cover index was designed to look at the presence of shrubs in the forest understory (Figure 26). Shrubs are assumed to increase habitat value for marten by directly providing possible food sources such as berries and fruits, while also contributing to microhabitat complexity, which may help to increase the availability of marten prey. Shrubs also provide cover to active marten. Large shrubs acting more like trees, such as *Acer glabrum* or *Alnus incana* over 25 feet tall, were not counted as shrub cover in this index. Also, extremely small shrubs such as *Linnaea borealis* or *Spiraea betulifolia* were not counted in the model. Bear grass (*Xerophyllum tenax*) was counted in this index when it occurred at 5% or more as groundcover because it can provide adequate cover for prey and active marten.

Marten Habitat Suitability Models – Winter Foraging

Modeled habitat elements based on field data:

Table 8 provides an accounting of the different field derived habitat element variables we incorporated into the marten winter foraging model.

Table D8. Habitat elements used to create the marten winter foraging HSI model.

Winter Foraging Model	
Notes:	**HSI Equations:**
Grading variables:	
Coarse woody debris	See CWD index
Snags	See snags index
Forest maturity	See big tree index

Unlike the non-winter foraging model, we are assuming all areas within the park are not providing at least moderate habitat suitability. In this model all sites can have output HSI values below 0.25, which equates to no habitat suitability. Figures 27 - 29 describe how the model predicts winter foraging habitat suitability based on input parameters developed through literature review or adopted from previous HSI models.

Figure D27. Big tree index input/output parameters.

The presence and density of large diameter trees are being used in the model as indicators of older mature forests (Figure 27).

Figure D28. Snag density input/output parameters.

This index looks at the presence of snags in terms of snag density (Figure 28). Snags with 12 inches DBH or less were not included in the index.

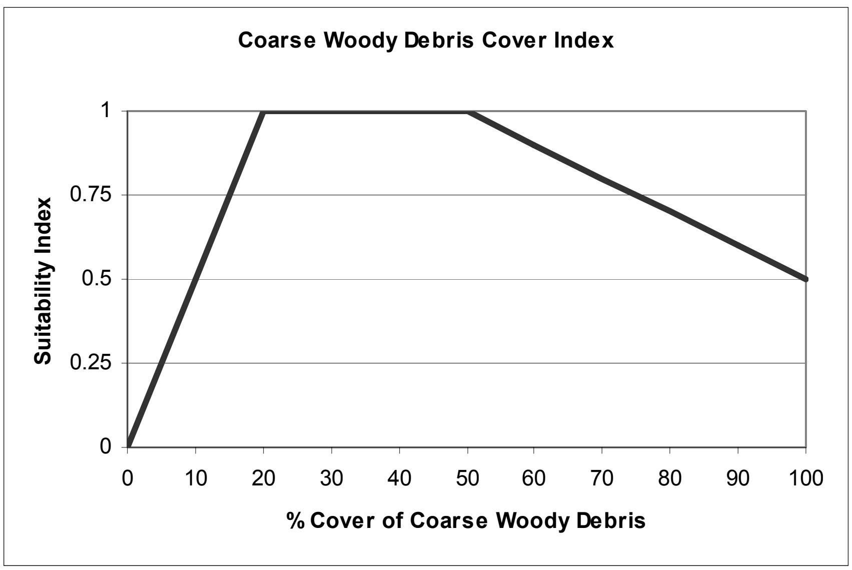


Figure D29. Coarse woody debris input/output parameters.

Appendix E – Fire Behavior Modeling: FCCS and NEXUS calculations

This section summarizes of fire behavior analysis and fuel modeling done with the programs Fuel Characteristic Classification System (FCCS) and NEXUS 2.0 for Mt. Spokane State Park.

The analyses in this section are grouped according to the fuel and fire behavior characteristics of fuel models used by Scott and Burgan (2005). All plots in the study fall into one of the fuel models listed below. Procedures used to characterize plot fuel models are described in detail in the remainder of this section.

- GS1 dry, low load grass-shrub (shrubs 1-ft high)
- GS2 dry, moderate load grass-shrub (shrubs 1-3 ft)
- GS3 humid, moderate load grass-shrub
- SH3 humid, moderate load shrub (2-3 ft bed)
- TU1 dry, low load timber-understory
- TU2 humid, moderate load timber-shrub
- TU4 dwarf conifer-grass
- TU5 dry, very high load (conifer litter) timber-shrub
- TL1 low load timber-compact litter (1-2 in deep) or burned forest
- TL2 low load broadleaf timber-litter (1-2 in deep)
- TL3 moderate load timber-litter (w/o coarse fuels)
- TL4 moderate load timber-litter (w/small logs
- TL5 high load timber-litter (w/o coarse fuels)
- TL7 high load timber-litter (w/large logs

FCCS and NEXUS were run on sets of averaged plot data to characterize the fuel models and fire behavior for the sets. The NEXUS output charts of these sets of data were used to compare the fire behavior of different fuel models. This comparison was used to help classify plots into the most similar Scott and Burgan (2005) fuel model and then to develop a map layer for use as input into the spatial fire modeling programs FlamMap and FARSITE.

After standardization of the fuel model parameters for the Scott and Burgan dynamic fuel models, the data was input as "custom" models into NEXUS by adding the file mt-spokane-spring-fuels.FMD, with the values shown in Table E1.

Table E1. Fuel model parameters used for exploratory input into NEXUS. SAV is the surface:area volume, Mx is the moisture of extinction. Fuel loads are in tons/acre and heat content is in BTU/pound. Values for SAV and moisture of extinction were modified from Scott and Burgan (2005) default values so as to be comparable to each other in the same chart.

Fuel model	1-hr fuel load	10-hr fuel load	100-hr fuel load	Live herb load	Live woody load	Fuel model type	1-hr dead SAV	Live herb SAV	Live woody SAV	Fuelbed depth (ft)	Dead fuel mx	Dead heat content	Live heat content
TU1	0.20	0.90	1.50	0.20	0.90	Dynamic	2000	1800	1600	0.6	25	8000	8000
TU2	0.95	1.80	1.25	0.00	0.20	N/A	2000	1800	1600	1.0	25	8000	8000
TU4	4.50	0.00	0.00	0.00	2.00	N/A	2000	1800	1600	0.5	25	8000	8000
TU5	4.00	4.00	3.00	0.00	3.00	N/A	2000	1800	1600	1.0	25	8000	8000
TL1	1.00	2.20	3.60	0.00	0.00	N/A	2000	1800	1600	0.2	25	8000	8000
TL2	1.40	2.30	2.20	0.00	0.00	N/A	2000	1800	1600	0.2	25	8000	8000
TL3	0.50	2.20	2.80	0.00	0.00	N/A	2000	1800	1600	0.3	25	8000	8000
TL4	0.50	1.50	4.20	0.00	0.00	N/A	2000	1800	1600	0.4	25	8000	8000
TL5	1.15	2.50	4.40	0.00	0.00	N/A	2000	1800	1600	0.6	25	8000	8000
TL7	0.30	1.40	8.10	0.00	0.00	N/A	2000	1800	1600	0.4	25	8000	8000

Output charts of fire behavior from each of the sets of plots were saved into separate run folders. These results are given below for plots that were analyzed with NEXUS.

Except where noted, the default input parameters for NEXUS for each run were as follows: WNDRlow (wind reduction factor; the ratio of the mid-flame wind speed to the 20-foot wind speed due to canopy or topograhpy) = 0.1; ROSMlow (a multiplier for the rate of fire acceleration) = 1; LADMlow (surface fuel load and depth multiplier that change fireline intensity without affecting bed bulk density) = 1; FLIMlow (fireline intensity multiplier used to change the heat/unit area without changing spreading rate) = 1; MC01 (1-hr fuel moisture) = 6; MC10 (10-hr fuel moisture) = 7; MC100 (100-hr fuel moisture) = 8; OWND (open wind speed) = 20; SLOP (slope) = 0; WDIR (wind direction) = 0.

Descriptions of the fuel models and their fire behavior

Fuel model GS1 - dry, low load grass-shrub

There is only one plot in this category – plot 084. This plot is covered with half rock and half grassland, but there is enough grass to carry a fire, so the fuel model is probably correct.

Fuel model GS2 - dry, moderate load grass-shrub

There are 2 plots in this category - plots 11 and 12. The fuel model is very similar to GS3, since the climate at Mt. Spokane is relatively humid.

Fuel model GS3 - humid, moderate load grass-shrub

There is only 1 plot in this fuel model category – plot 304. The fuel model for this plot is similar to GS4 (high load), but the herbaceous layer probably doesn't dry out long enough during typical summer seasons to result in the fire behavior of a GS4 fuel model, so the GS3 model was selected as a better fit.

Fuel model SH3 - humid, moderate load shrub

There are 22 plots classified as fuel model SH3. Some of these were reclassified from SH4, SH8 or SH9, which were all for different climates or ecosystem conditions. The SH3 fuel model best accounts for the low flammability of the shrubs in this area

Fuel model TL1 - low load timber-litter
There are 7 plots classified as fuel model TL1. Plots 79, 246 and 160 are at the high end of litter loads for this fuel model, which is borderline with fuel model TL3. Plot 160 was included in cluster 6, althouth it was determined to be a fuel model TL3.

Fuel model TL2 - (broadleaf) low load timber-litter
There are 4 plots classified as fuel model TL2 in the field. Although uncommon, these four plots seem to be classified correctly.

Fuel model TL3 - moderate load timber-litter
There are 110 plots classified as fuel model TL3, making it one of the most common fuel models at Mt. Spokane State Park. This fuel model is similar to the Anderson fuel model 8, compact timber litter. Initial analysis using NEXUS determined that this fuel model fits the sets of plots in "cluster 6", and "unit 4", although some of the individual plots vary toward other similar timber fuel models. Descriptions of the data sets analyzed are given below.

Fuel model TL3: Cluster 6 Plots (includes plots 151, 153, 160, 161, 175, 189, 226, 299)
Stands in cluster 6 are mixed conifer mature stands with high bulk density and little or no understory, classified as TSHE-THPL and with some PSME, ABGR and some understory (CLUN). Some of the individual plots varied from the mean fuel model characteristics used to characterize cluster 6. These plots are 160 (possible fuel model TL1), and plot 175 (possible fuel model TL5). Some of the other plots are similar to fuel model TL1, depending on the loading of litter fuels.

The fuel model was built either from FCCS pathway 023 (Figure E1) moist PSME or ABGR, 60-90 years old, following selective cutting or burning; or from pathway 035 (Figure E2) moist ABGR or TSHE, aged 60-90 years after harvest. Fuel model classification was analyzed using the fuel photo series (Maxwell and Ward, 1980), and field data. Plot 189 and 299 were used as endpoints for averaging the plot data.

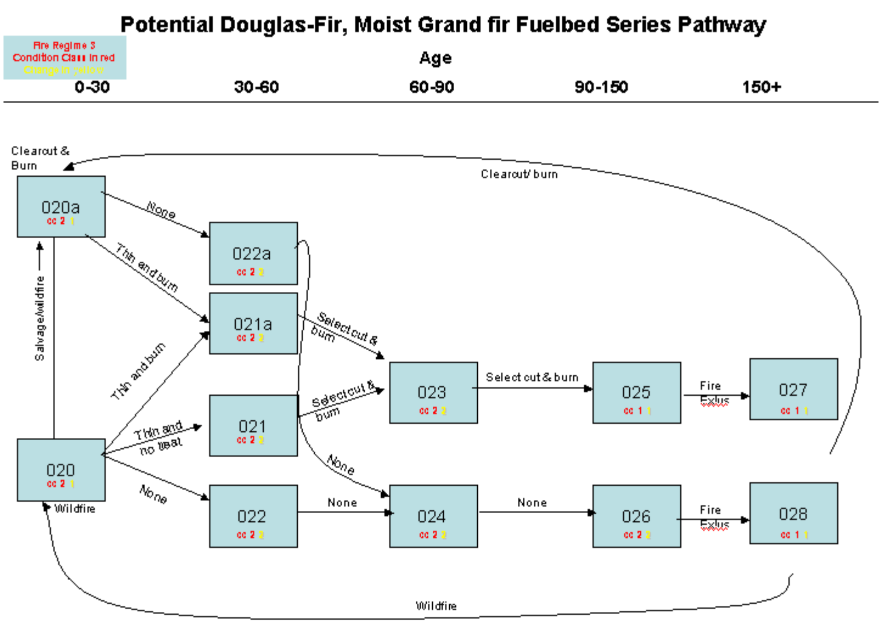


Figure E1. Diagram of FCCS pathway 023

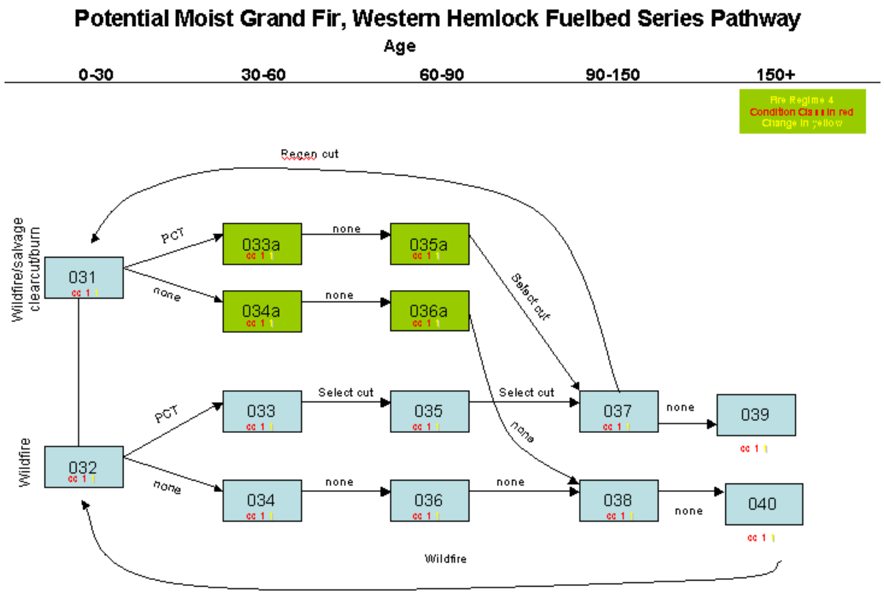


Figure E2. Diagram of FCCS pathway 035

Cluster 6 fuel characteristics were set as follows. The data was loaded into NEXUS 2.0 as a custom fuel model, and compared with fuel models TL1, TL3, and TL7 (Figures E3 and E4). Based on the comparisons in these charts, these plots were classified as fuel model TL3, with a second choice for some plots of fuel model TL7.

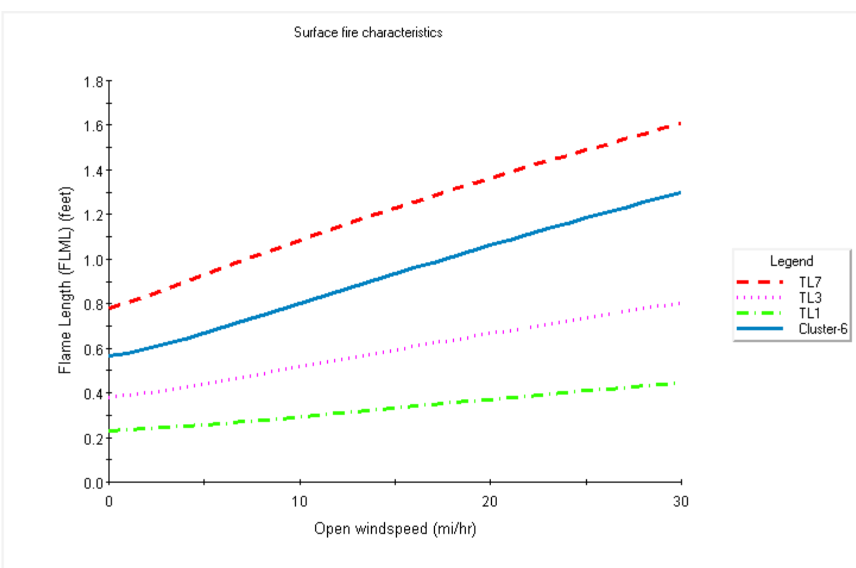


Figure E3. Flame lengths of cluster 6 plots varied by wind speed.

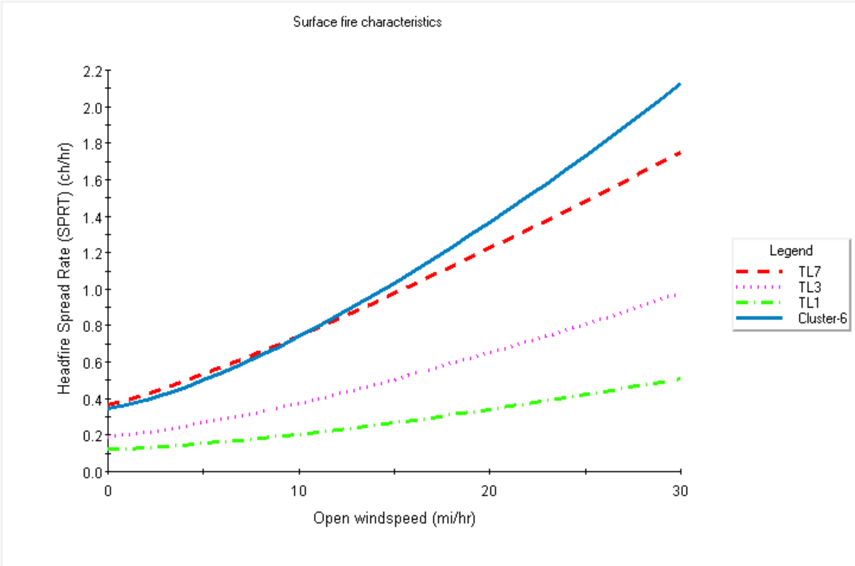


Figure E4. Spread rates of cluster 6 plots varied by wind speed.

The dead fuel moisture of the stands in cluster 6 was varied using the dead fuel moisture scenarios of Scott and Burgan (2005) p. 8, with the results shown in Figures E5, E6 and E7.

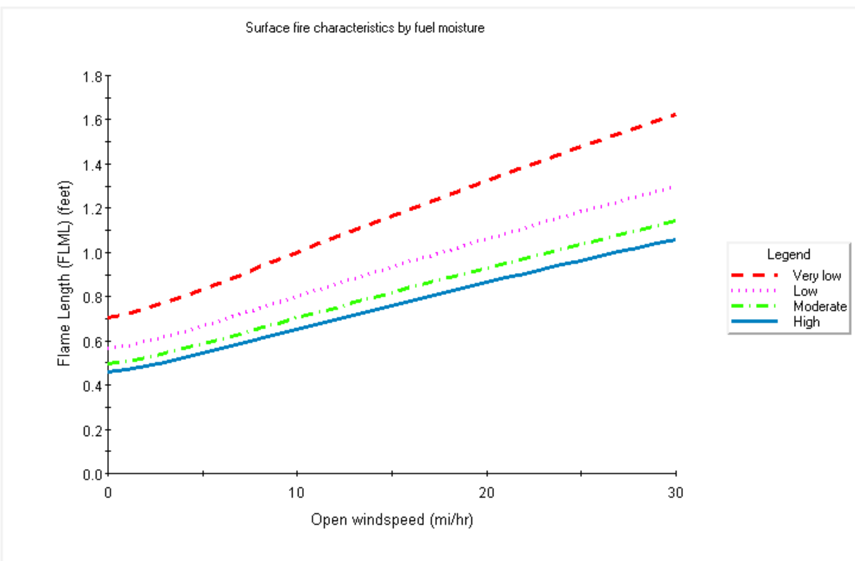


Figure E5. Flame lengths of cluster 6 plots determined by NEXUS, varied by wind speed.

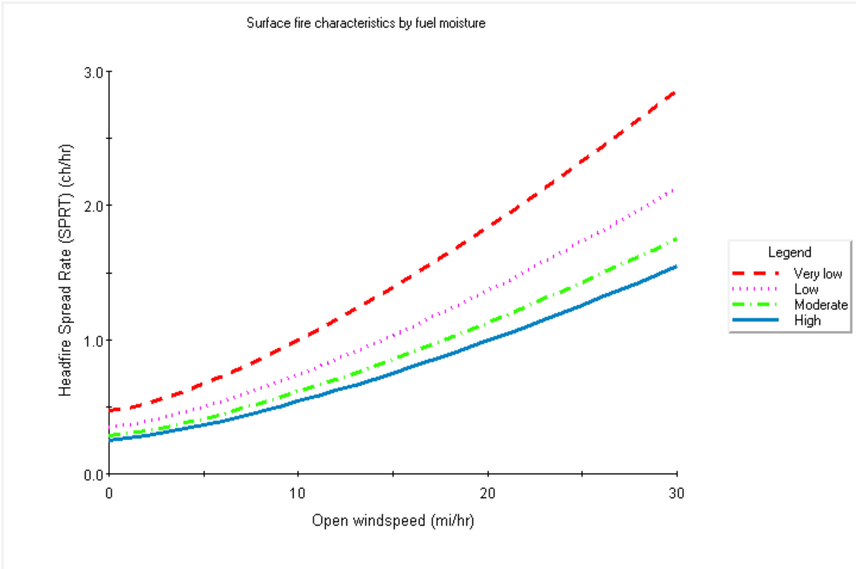


Figure E6. Spread rates of cluster 6 plots varied by wind speed.

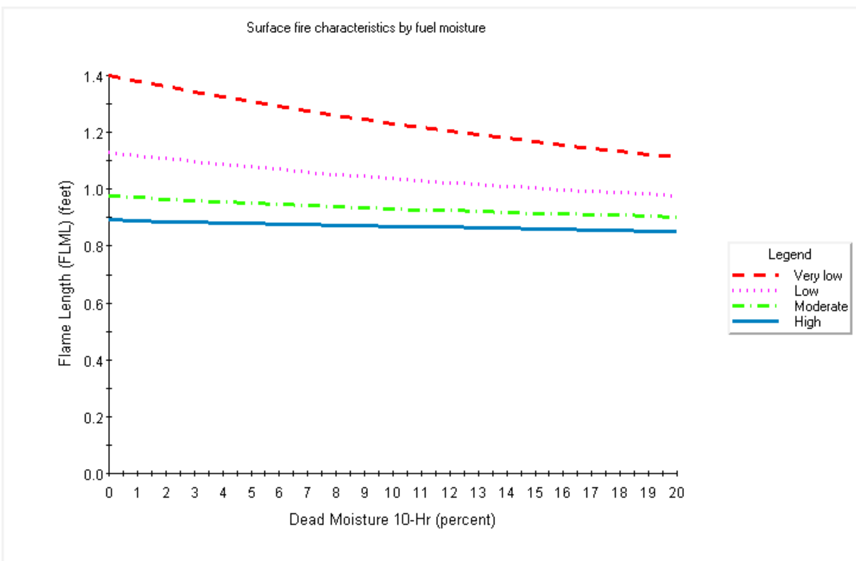


Figure E7. Flame lengths of cluster 6 plots varied by 10-hr fuel moisture.

Fuel Model TL3: Plot 73

Plot 73 fuel characteristics were determined based on comparison to photos of similar plot 250, and by comparison with the fuel model series (Maxwell and Ward, 1980, pp. 47-56) and by comparison with FCCS fuelbeds developed by consultant Tom Leuschen.

Plot 73 is a multi-canopy forest of ABGR/VAME without many small trees or Douglas maple, but with a cover of 50% VAME, and 19% herbs ATFI and MAST4. The Anderson fuel model was determined to be fuel model 10 (timber litter and understory) and the dynamic fuel model was determined to be intermediate between TU5 and TL3. The flame length under standard FCCS conditions was 5.9 feet and the Rate of Spread was 6.6 ft/min, however NEXUS calculated much lower flame lengths that were similar to fuel model TL3.

Surface fire behavior characteristics determined by NEXUS for plot 73 compared with standard fuel models are shown in Figures E8, E9 and E10. To match conditions found on plot 73, the slope was set to 33% and the wind reduction factor was set to 0.1. Wind speed was set to 20 mph.

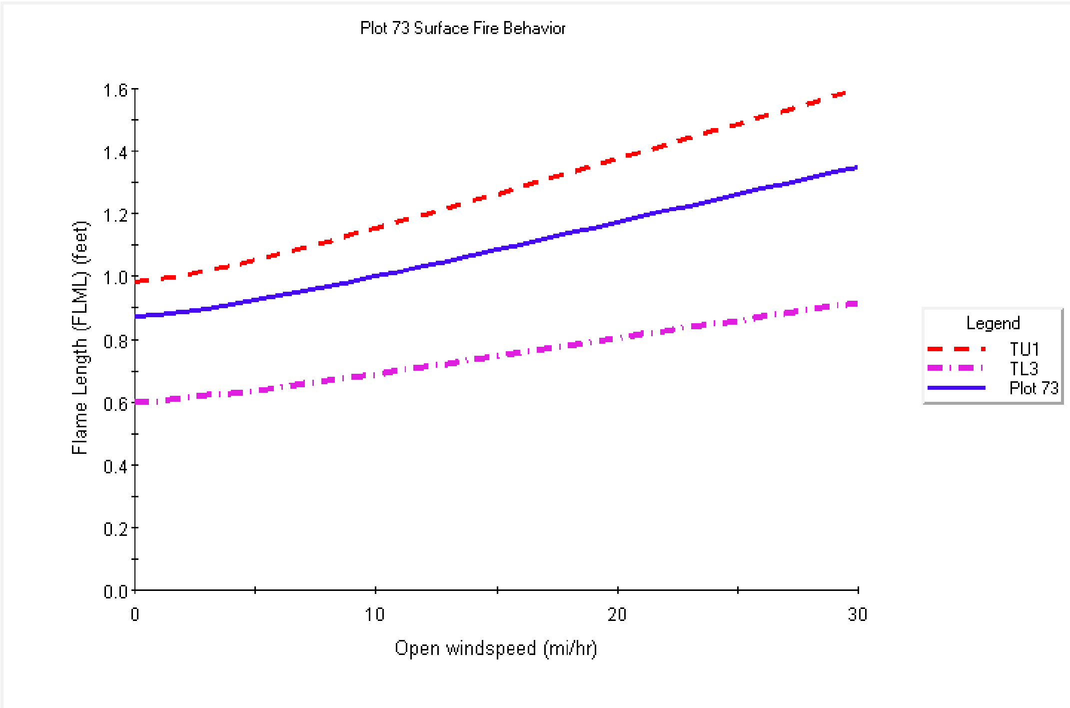


Figure E8. Flame lengths of plot 73 varied by wind speed.

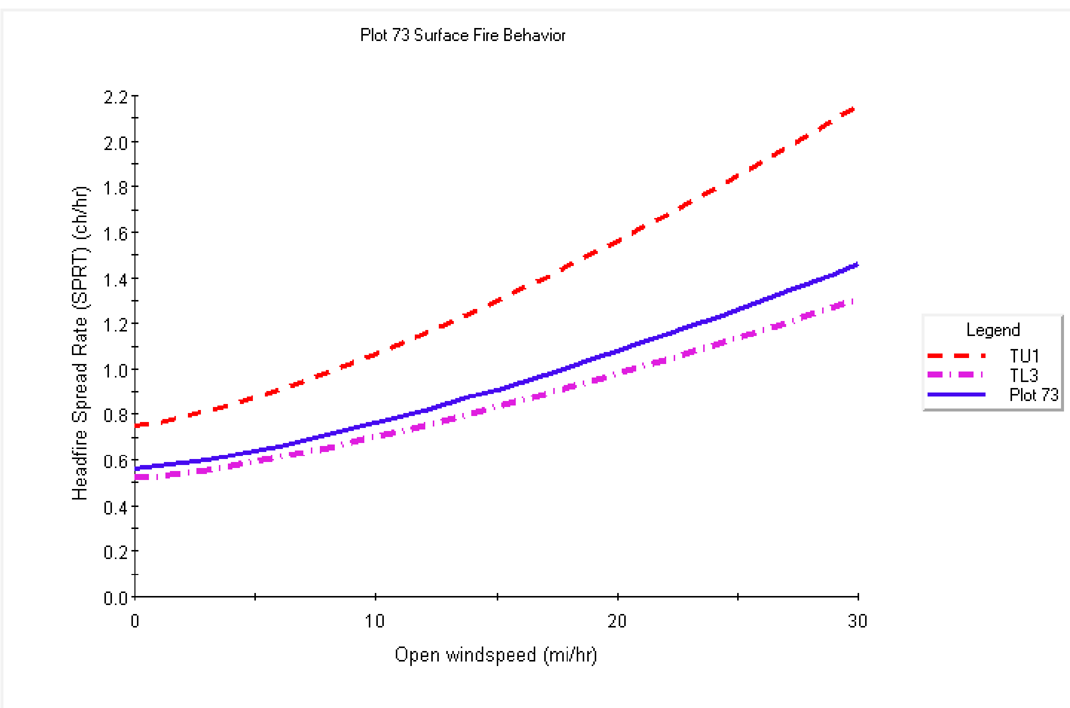


Figure E9. Spread rates of plot 73 varied by wind speed.

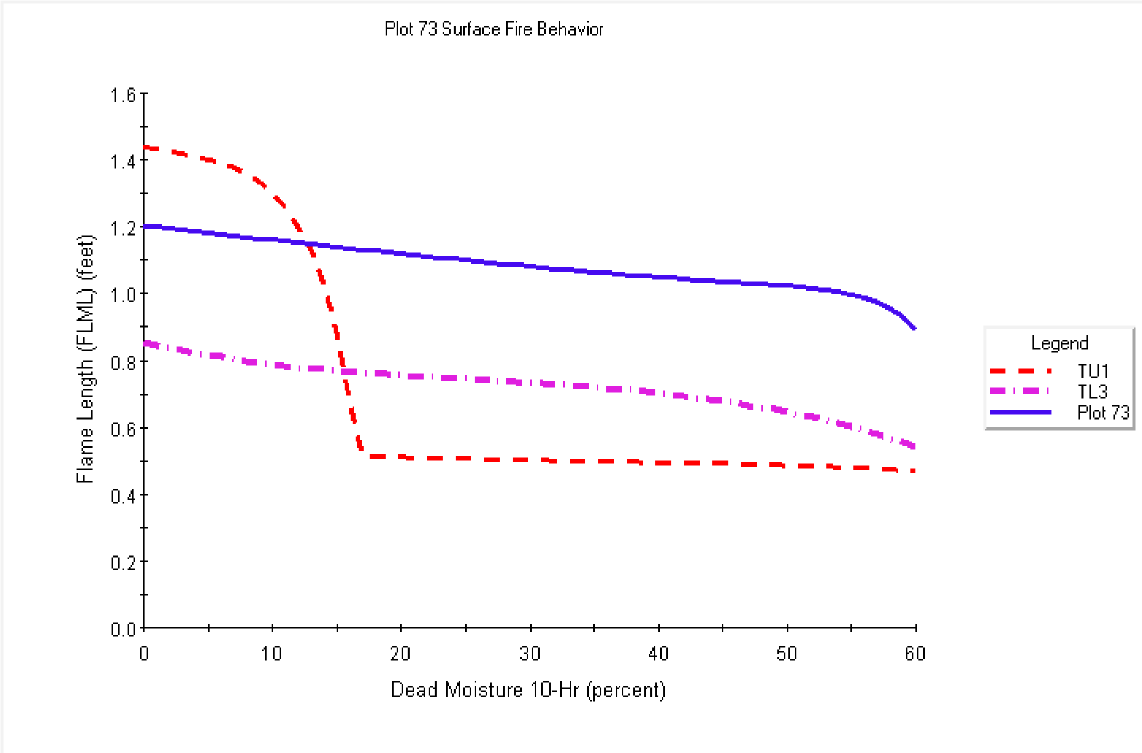


Figure E10. Flame lengths of plot 73 varied by 10-hr fuel moisture.

The dead fuel moisture of plot 73 was varied using the dead fuel moisture scenarios of Scott and Burgan (2005) p. 8, with the results shown in Figures E11, E12 and E13.

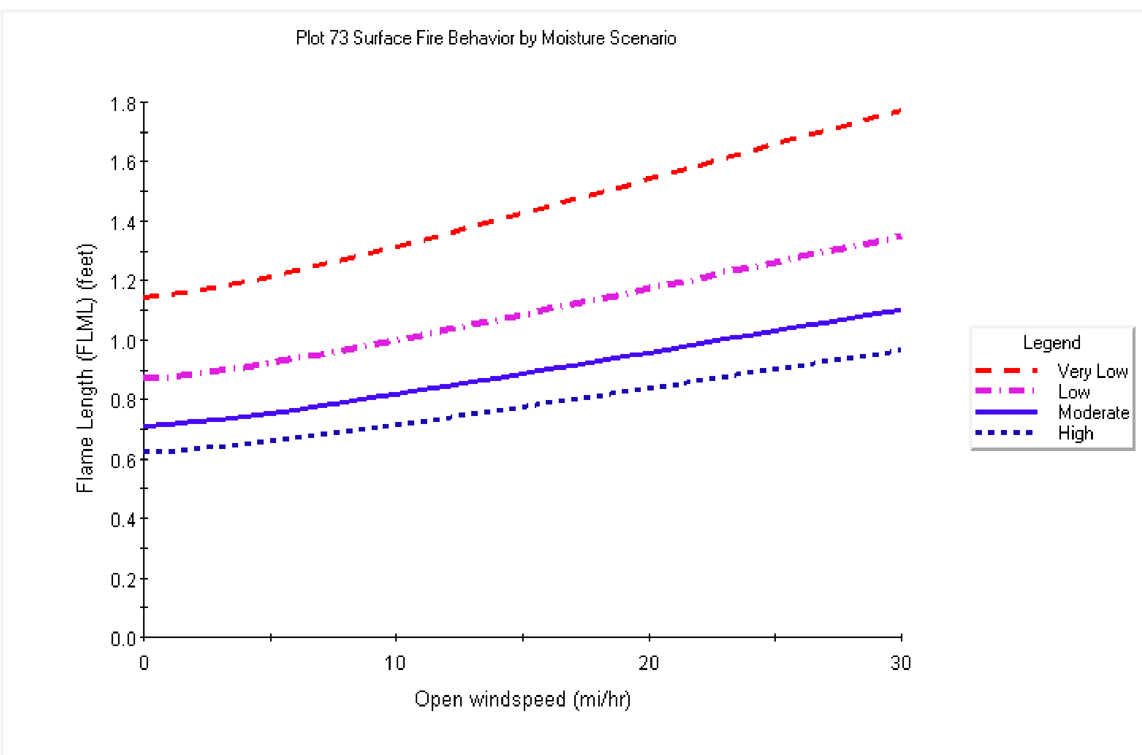


Figure E11. Flame lengths of plot 73 varied by wind speed.

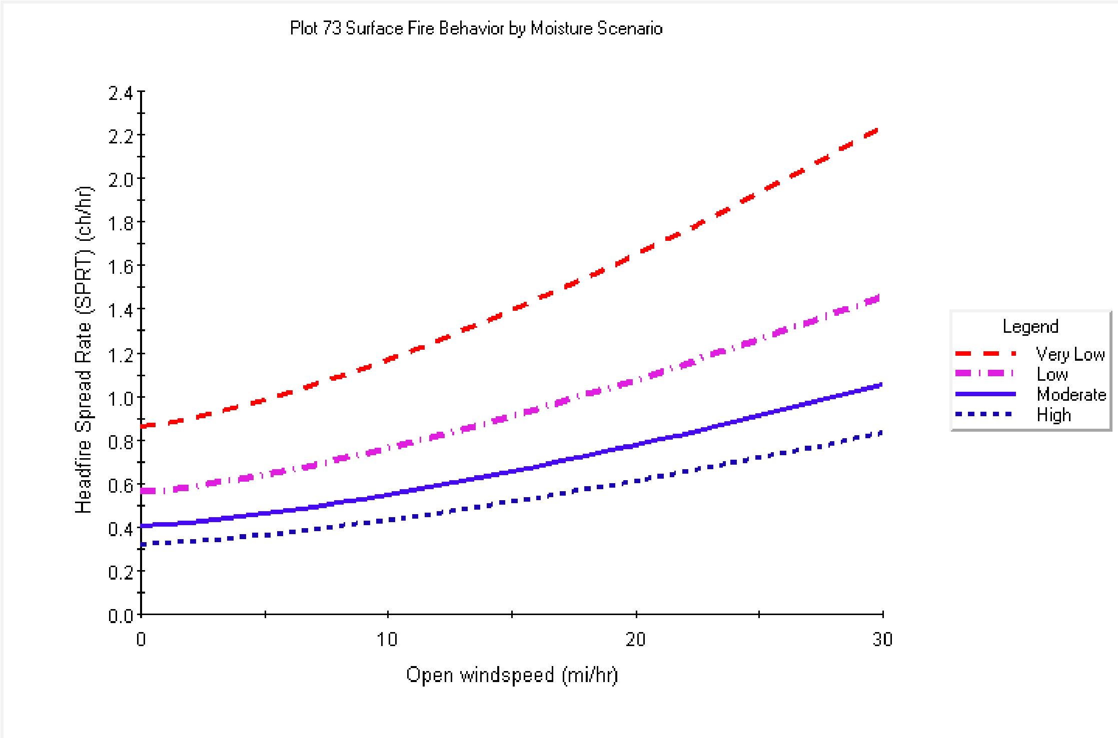


Figure E12. Spread rates of plot 73 varied by wind speed.

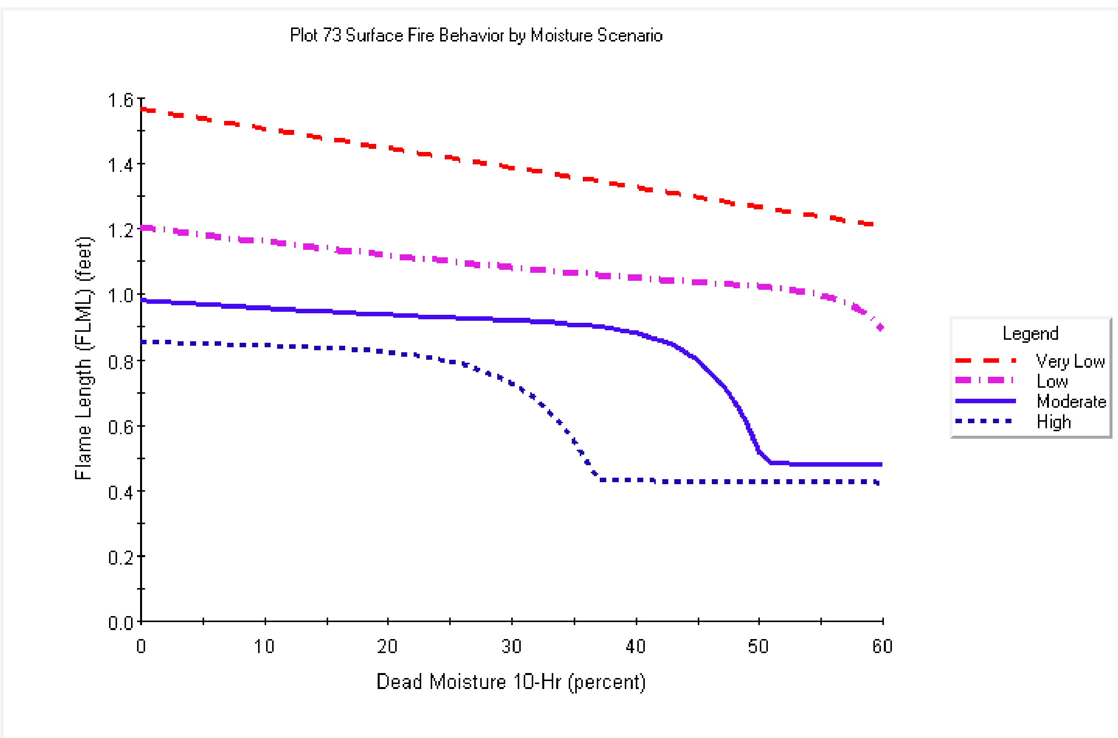


Figure E13. Flame lengths of plot 73 varied by 10-hr fuel moisture.

TL3: Unit 4 Plots (includes plots 140, 151*, 152, 153*, 164, 165, and 166 (*'d plots were also included in the "cluster 6" fuel model).

The plots in unit 4 are primarily classified as fuel model TL3. Some of these stands have riparian areas nearby or within the unit that differ from the central part of the unit, which might be classified differently. For example, plot 152 is very similar to fuel model TL5, with longer flame lengths.

These are stands with large numbers of small trees, but otherwise having only a low abundance of other understory plants. The small trees were modeled as 15% shrub cover, with the result that the fire behavior of plots in unit 4 was similar to plots in cluster 6.

Characteristics of individual plots in unit 4 are as follows. Plot 140 is a diverse mature TSHE/CLUN stand with only a low abundance of understory plants; plot 151 is second growth with some retained larger trees, many 12-15 inch logs and 600 trees per acre of understory trees; plot 152 is a single-canopied stand of 22-inch dbh TSHE/GYDR with (1,200 small trees / ac), and very many pole-sized logs; plots 153 and 164 are mature TSHE/CLUN with very little understory; plot 165 is an open, mature diverse TSHE stand with 900 understory trees per acre; plot 166 is a closed-canopy stand of TSHE/CLUN with 500 small trees per acre and a high load of fine fuels.

The most common structural forest characteristics of this set of plots correlate with one of the following:

- mixed conifer mature stands similar to cluster 6 plots (140, 153, 164), with high bulk density TSHE, THPL, PSME, and ABGR and sparse understory (CLUN).
- plots with second growth and some larger trees, but with high numbers of understory trees (plots 151, 152, 166).
- moderately open mature conifer stands with large numbers of regenerating understory trees; this fuel model has surface fuel characteristics similar to the second growth stands, but it has canopy characteristics similar to the mature stands. There is only one plot in this group, plot 165.

The treatment goal for this set of stands is to increase mortality of the pole-sized stems and decrease ladder fuels while minimizing mortality to old trees and without significantly opening up stands to shrub invasion or longer flame lengths. The fuels in unit 4 were developed by building a fuelbed based on stands in the cluster 6 set. FCCS was used to determine the amount of live woody fuels (young trees), calculated as 15% cover of up to 800 4-foot tall trees / ac (0.17 tons/ac).

Stands in unit 4 were attributed with a value for 100-hr fuels that was the average of cluster 6 and TL3 ((2.8 + 1.2)/2 = 2.0 tons /ac).

The fuelbed bulk depth was calculated as the average for a 10% cover of understory trees, 4-feet high (0.1 * 48 in) = 4.8 inches or 0.4 ft.

Unit 4 was loaded as a custom fuel model into NEXUS. Figure E14 shows fire behavior characteristics of unit 4 determined by NEXUS, in comparison with the set “cluster 6” and fuel models TL3 and TL1.

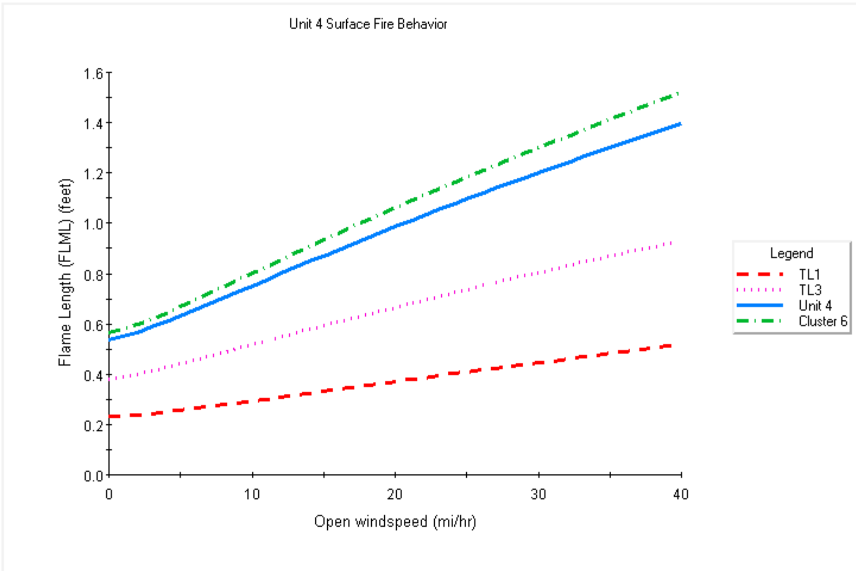


Figure E14. Flame lengths of unit 4 varied by wind speed.

TL4: moderate load timber-litter with small logs
There are 12 plots classified as fuel model TL4. This classification was retained based on the field determination.

TL5: high load timber-litter
There are 18 plots classified as fuel model TL5.

TL7: high load timber-litter with large logs
There are 4 plots classified as fuel model TL7. Two of these had an alternative classification as TU2. These probably do not have the high litter required to be fuel model TL7, however there is no other suitable moderate load fuel model with large logs. Although fire behavior modeling shows these stands to have spreading and flame lengths similar to fuel model TL3, the expected fire severity needs to account for the contribution of large logs, such as that of fuel model TL7.

TU1: dry, low load timber-understory
There are 50 plots classified as fuel model TU1. In addition to plots determined to be fuel model TU1 in the field, a number of other plots were reclassified to this model following evaluation of the litter loads. Sets of plots fitting this fuel model are unit 16 and unit 17, the latter of which is described below.

TU1: Unit 17 Plots (includes plots 030, 031, 032, all of which were originally classified as TU3 or TU3/TL3)
Unit 17 is dense, even conifer, ABGR/VAME/CLUN, with XETE and some subalpine understory plants.

Analysis with NEXUS determined the best fuel model for this set of plots to be TU1. This set of plots was originally classified as fuel model TU3/TL3. Following the analysis with NEXUS, 8 other plots originally classified as TU3/TL3 were also reclassified as fuel model TU1.

Fine fuel loads were created by comparing the plot photos with the TU3 fuel model and with the photo series (Maxwell and Ward, 1980). The photos appeared to have fine woody debris loads most similar to fuel model TL3, and thus fine fuels were modified to be closer to the values for TL3. The 10-hr and 100-hr loads were set about 10 times higher than the Scott and Burgan model, and the 1-hr load was set to about half.

The fuelbed was only about half that of the TU3 model, based on less continuous cover of XETE. The shrub fuel loads were calculated using FCCS with a shrub cover of 20% 2-ft tall VAME (=0.3 tons/ac). Herb fuel loads were calculated for 35% cover of 1.5 ft tall XETE. The value for herb fuel loading was taken from the TU3 model (0.65 tons/ac). The value for fuelbed depth was taken from the TU3 model (1.3 ft), and then lowered to 0.43 ft after comparison with the fuelbed depth spreadsheet.

These values were input into NEXUS as a custom fuel model. Figures E15, E16, E17 and E18 show fire behavior characteristics of unit 17 determined by NEXUS, in comparison with fuel models TU1, TU3 and TL3.

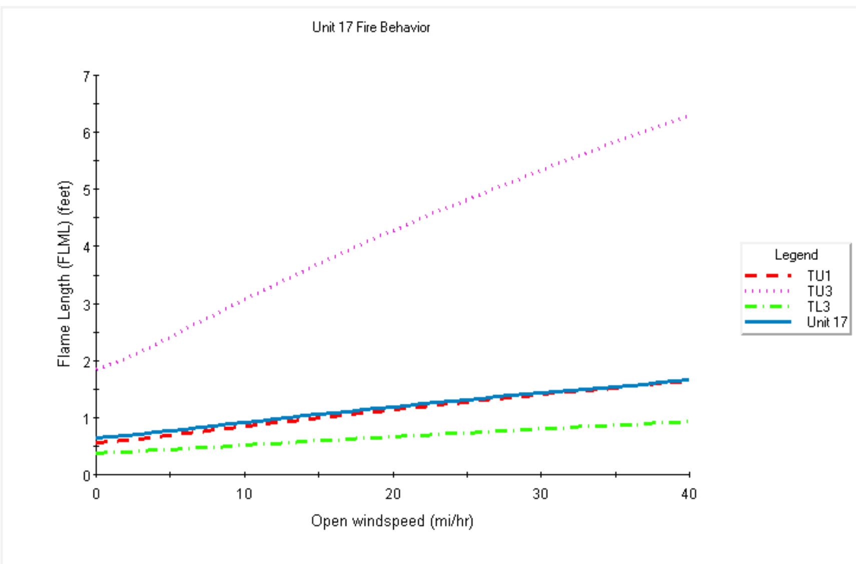


Figure E15. Flame lengths of unit 17 varied by wind speed.

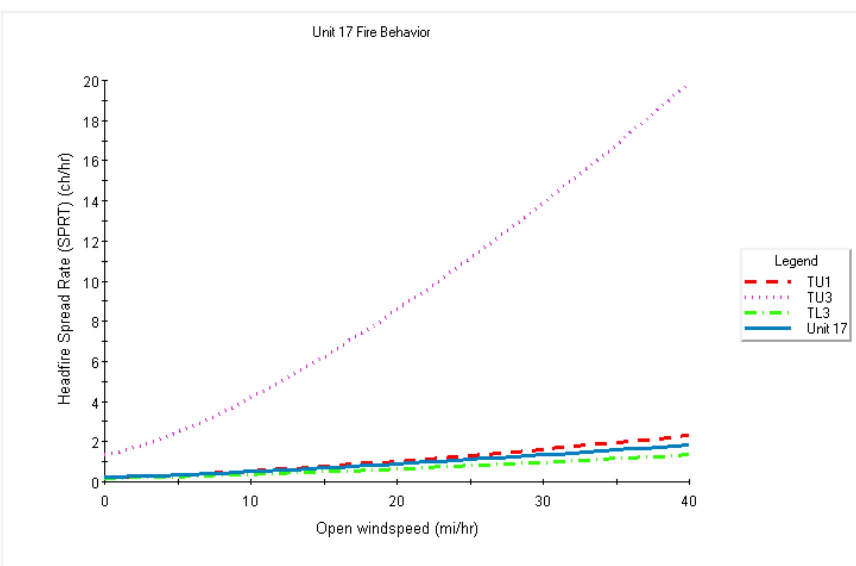


Figure E16. Spread rates of unit 17 varied by wind speed.

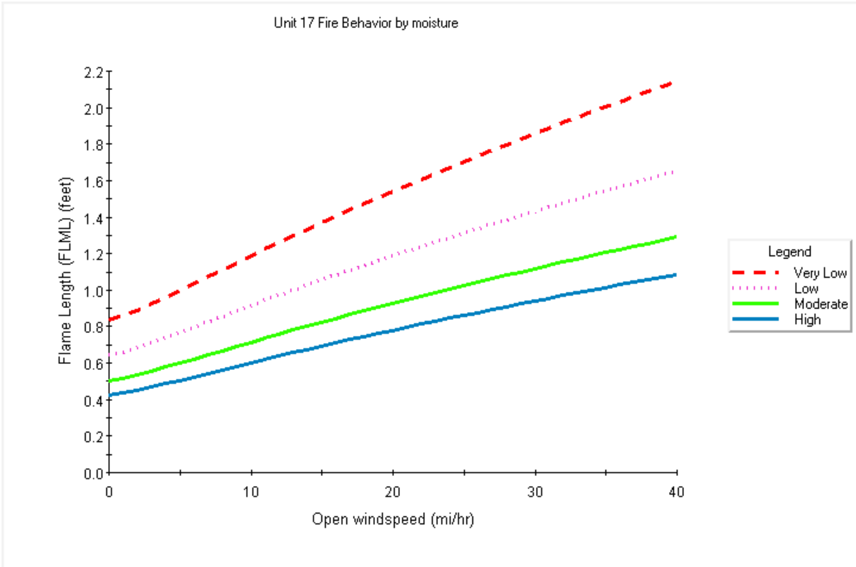


Figure E17. Flame lengths of unit 17 varied by wind speed.

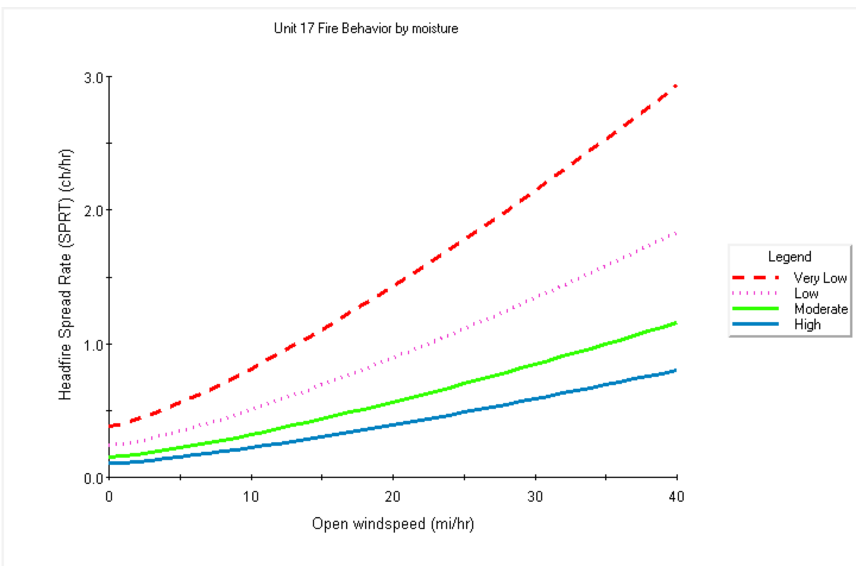


Figure E18. Spread rates of unit 17 varied by wind speed.

TU2 humid, moderate load timber-understory

There are 116 plots classified as TU2. Fuel model TU2 was characterized by set 235, containing plots 235, 236 and 237, as described below. A number of additional plots were added to the fuel model TU2 category.

TU2: Set 235 (includes plots 235, 236, 237 (Plant association ABGR/ACGLD/CLUN)

Plot set 235 fuel characteristics were based on comparison to photos of similar plot 250, the fuel model series guide (Maxwell and Ward, 1980, pp. 47-56), the classification of these plots as TU5, and the comparison with Tom Leuschen's FCCS fuelbeds for Moist Douglas fir-Grand fir 90-200 years old (Figure E19). This set was rated by FCCS as a slash fuel model, FM 13, SB3. FCCS fuel loads for 1-hr, 10-hr and 100-hr fuels for this fuelbed were 0.3, 2.4, 3.9 tons/ac. These values were close to the values estimated from the photo series for the same categories of 0.3, 1.8 and 2.5, respectively, so the FCCS loads were used, based primarily on the fact that they were published.

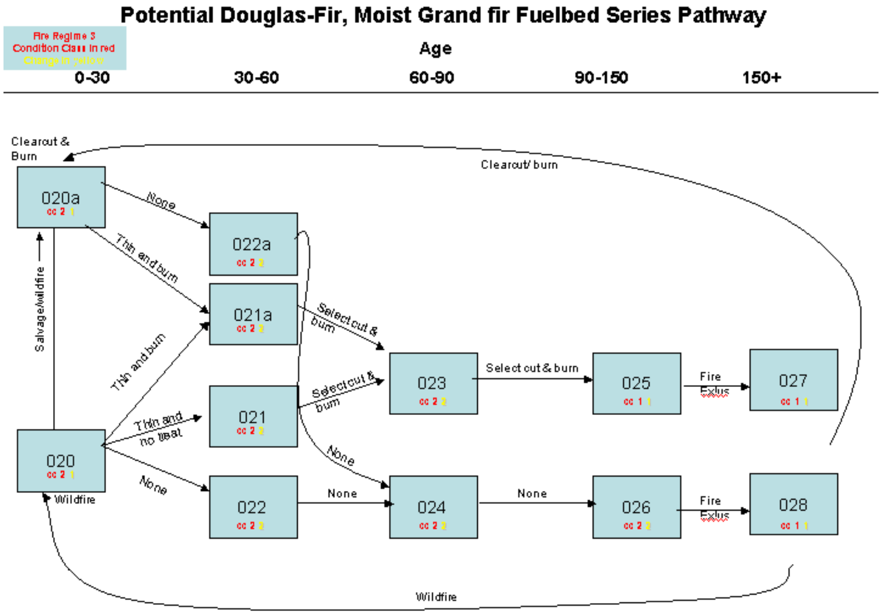


Figure E19. Diagram of FCCS pathway 028.

The shrub loads were calculated by FCCS using 20% cover of HODI (using a height of 6 ft) and 7% cover of PHMA 3.5-ft high. The fuelbed depth was based on these same values, i.e., (0.2 * 6 + 0.07 * 3.5) = 1.2 +.245 = ~ 1.5 ft. An additional 0.6 feet was added to represent half of the lower 6 ft of Acer glabrum cover, resulting in a final bed depth of 2.1 ft. The data was input into NEXUS as a custom model.

Fire behavior characteristics of set 235 determined by NEXUS are shown in Figures E20, E21 and E22, in comparison with Scott and Burgan (2005) models TU2, TU5 and TL7.

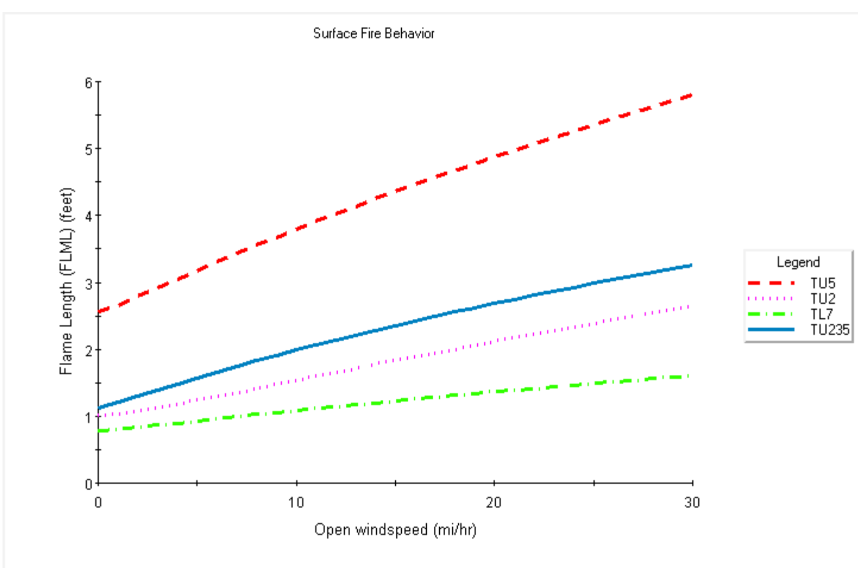


Figure E20. Flame lengths of set 235 varied by wind speed.

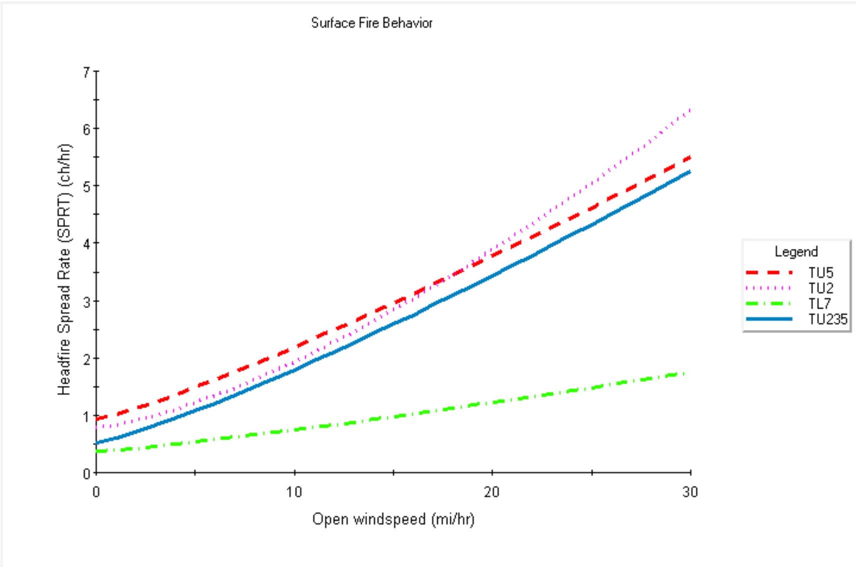


Figure E21. Spread rates of set 235 varied by wind speed.

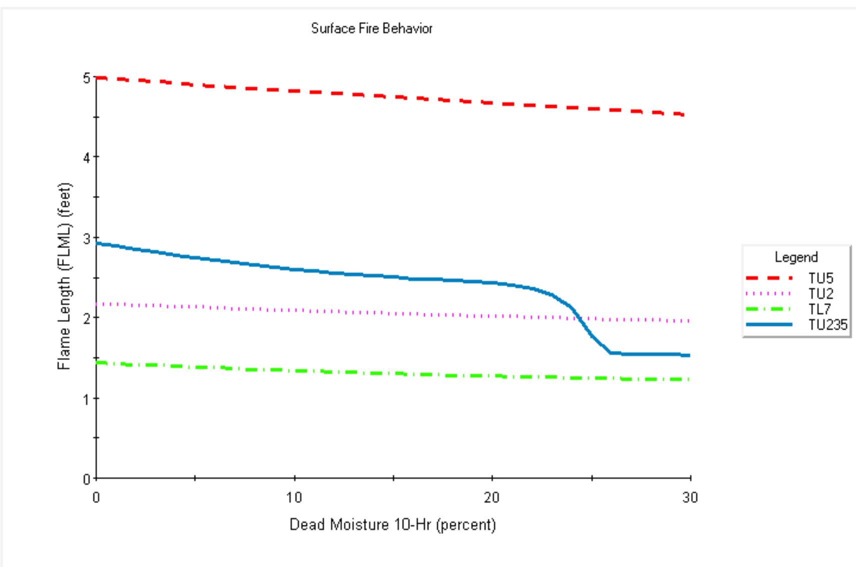


Figure E22. Flame lengths of set 235 varied by 10-hr fuel moisture.

The dead fuel moisture of set 235 was varied using the dead fuel moisture scenarios of Scott and Burgan (2005) p. 8, with the results shown in Figures E23, E24 and E25.

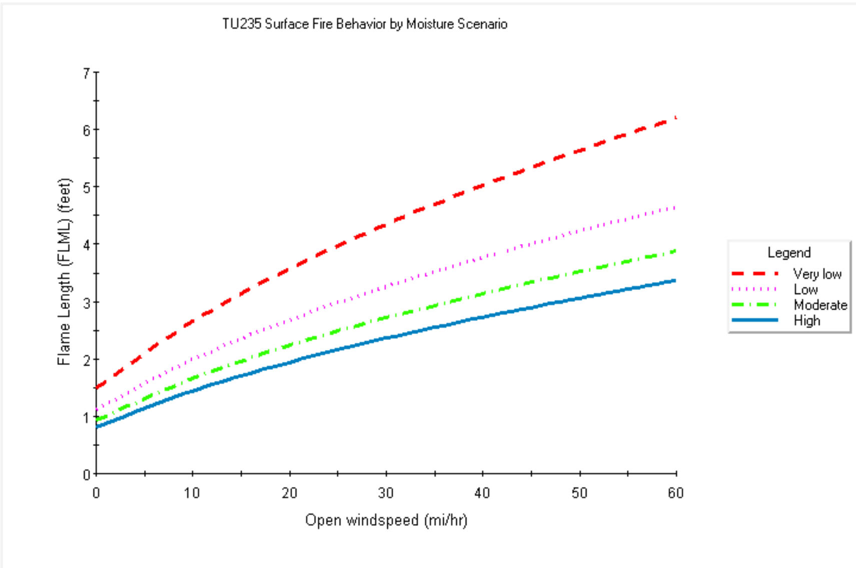


Figure E23. Flame lengths of set 235 varied by wind speed.

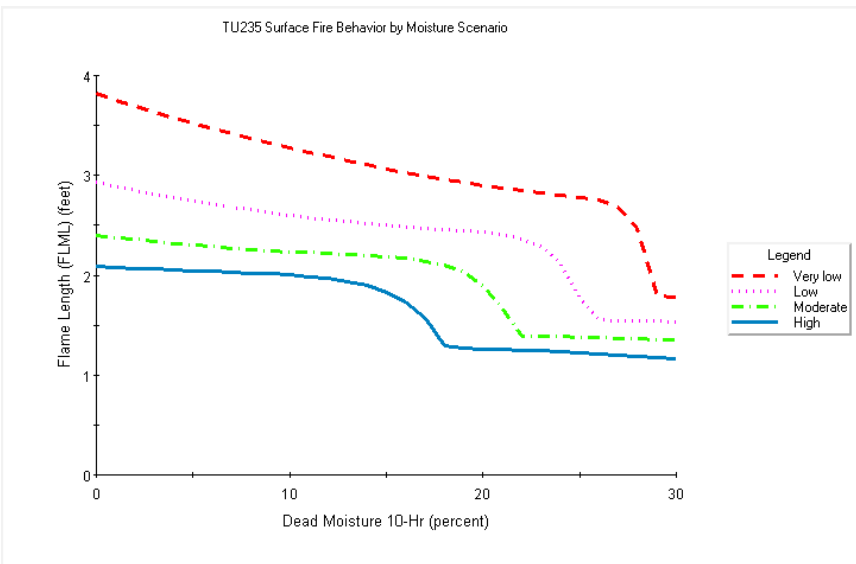


Figure E24. Flame lengths of set 235 varied by 10-hr fuel moisture.

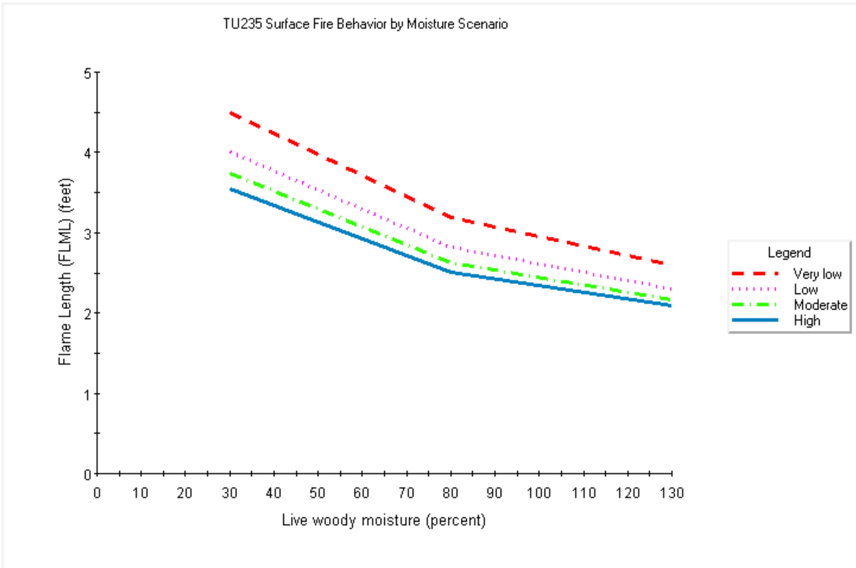


Figure E25. Flame lengths of set 235 varied by live woody fuel moisture.

TU4 dwarf conifer-grass
There are 24 plots classified as TU4.

TU5 dry, very high load timber-understory
There are 35 plots classified as TU5. Originally there were more, but following analysis, it was determined that many of the litter loads estimated for the plots in the field were actually lower (absolute measures were not part of the project protocol). Fuel and fire behavior characteristics were analyzed for fuel model TU5 for unit 11 and unit 13, as described below.

TU5: Unit 11 (includes plots 259 and 260)
This unit was categorized by NEXUS as being most similar to TU5 after lowering the bed depth given by Scott and Burgan. Since fuel model TU5 is in a dry climate, it doesn't account for the decomposition that would reduce 1-hr and litter fuels each year, nor for the fact that the shrubs have a high moisture content that would make them difficult to burn except during drought or late fall. Individually, plot 260 may be closer to fuel model TU2, although it was classified in the field as TU5.

This area is ABGR/ACCGLD/CLUN with 75% overstory canopy and 35-40% cover of shrubs PHMA5, RUPA, and AMAL2, and with 0-10% cover of herbs.

Fine fuel loads were developed by comparing plot photos with the assigned fuel model and the photo series (Maxwell and Ward, 1980). The photos most closely resemble fuel model TU5, however that model is for a dry climate. The FWD loads were calculated using the Scott and Burgan values for fuel model 5, and multiplying these by 75%, because the Scott and Burgan fine fuel loads were judged to be too high for this stand.

The fuelbed depth calculated from the average of values in the plot spreadsheet was 2.7 ft. During modeling a fuelbed multiplication factor of 0.6 was used for comparison with the uncorrected beds, because the fine fuel loads of the Scott and Burgan fuel model were judged to be too high.

The shrub fuel loads were calculated using FCCS with a shrub cover of 30% 6-ft tall PHMA (actual plot 260 = 30% 7-ft tall PHMA) and 4% 1.5-ft tall SYAL = 0.59 tons/ac. The FCCS calculation seemed too low, so the value used was 75% of the Scott & Burgan model for TU5, or 0.75 * 3.0 tons/ac = 2.25 tons/ac.

Herb fuel loads for the 2 plots were 0 and 10%, therefore the value of 0% was used to be consistent with the Scott and Burgan fuel model. The data was input into NEXUS as a custom fuel model.

This data was loaded into NEXUS 2.0 for comparison with similar fuel models using the following defaults. (The LADMlow fuelbed depth multiplier was varied to produce more realistic results): WNDRlow = 0.2; ROSMlow = 1; LADMlow = 0.6 or 1; FLIMlow = 1; MC01 = 6; MC10 = 7; MC100 = 8; OWND = 20; SLOP = 0; WDIR = 0

Figures E26 and E27 show fire behavior characteristics determined by NEXUS for unit 11. The best choice of fuel model should be either TU5 with LADMlow = 1.0 (but having too high of FWD and too low fuelbed depth) or a custom fuel model ("TU260") equivalent to fuel model TU5 with fuelbed depth as given, but with fire behavior outputs reduced by the use of a 0.6 fuelbed reduction factor, allowing the fuel bulk density to be held constant. Since custom fuel models were not developed in this study, unit 11 was classified as fuel model TU5 without any fuelbed factor adjustments.

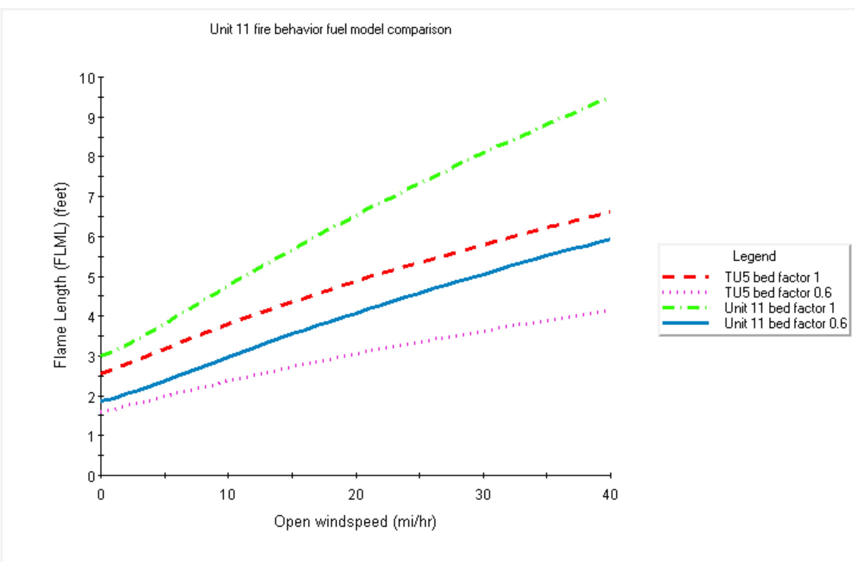


Figure E26. Flame lengths of unit 11 varied by wind speed.

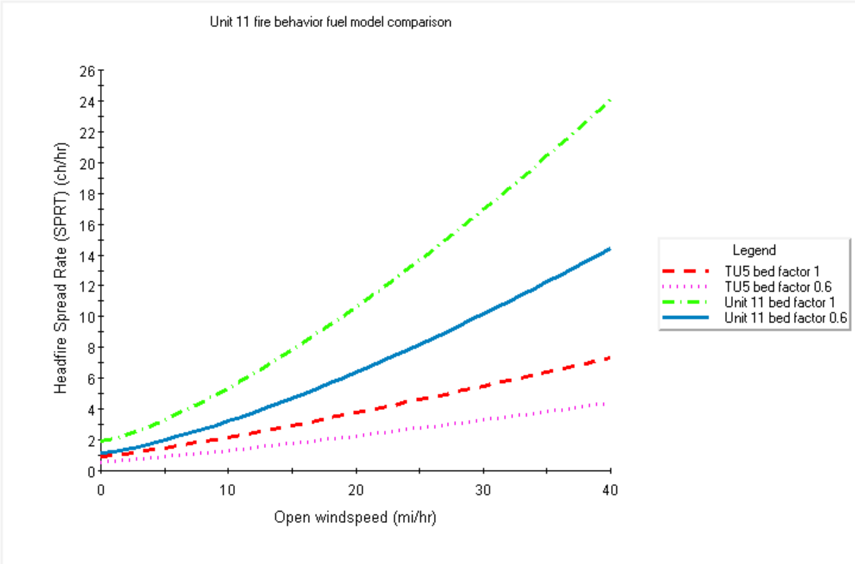


Figure E27. Spread rates of unit 11 varied by wind speed.

Figures E28, E29 and E30 show NEXUS runs for the Unit 11 data with the 0.6 fuelbed factor.

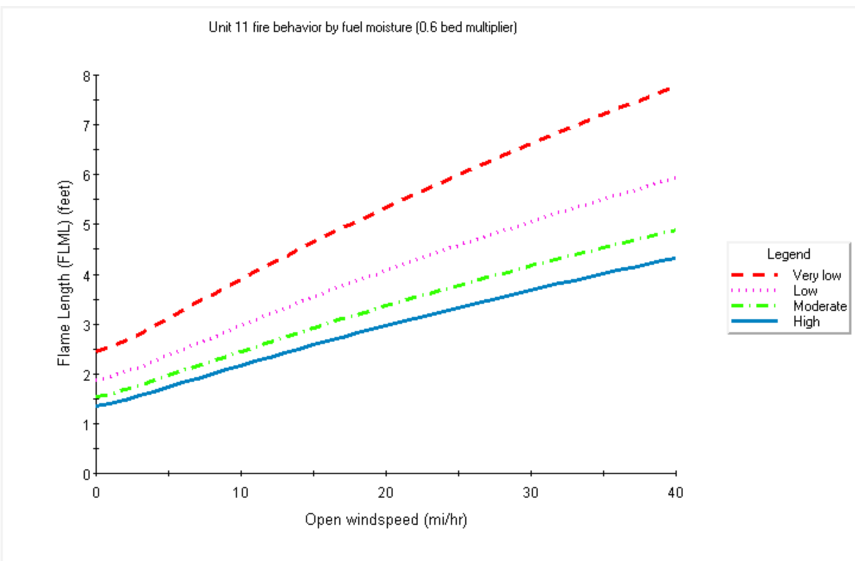


Figure E28. Flame lengths of unit 11 with a 0.6 fuelbed factor varied by wind speed.

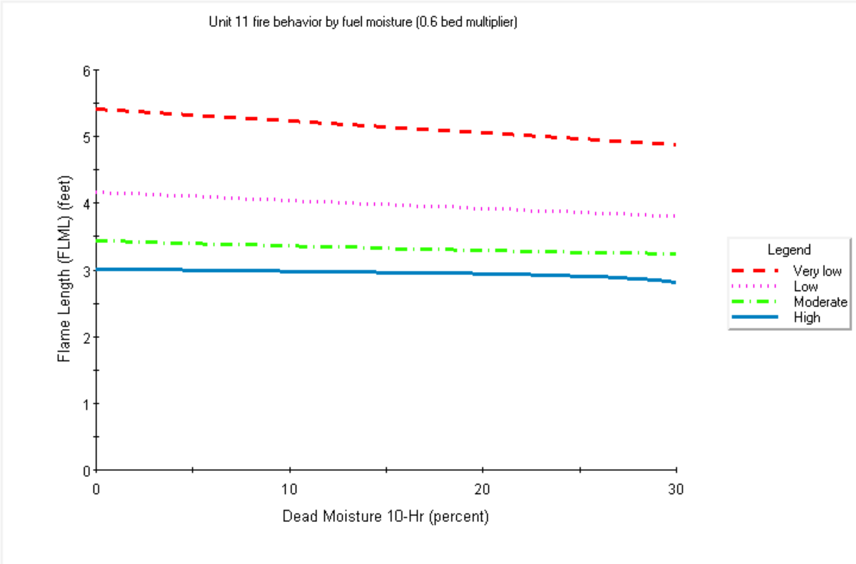


Figure E29. Flame lengths of unit 11 with a 0.6 fuelbed factor varied by 10-hr fuel moisture.

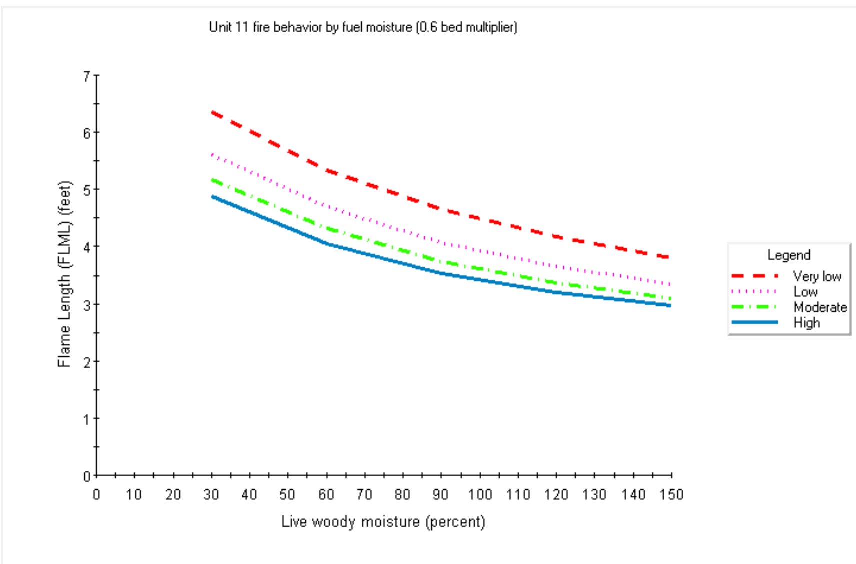


Figure E30. Flame lengths of unit 11 with a 0.6 fuelbed factor varied by live woody fuel moisture.

TU5: Unit 13 (includes plot 247)
Plot 247 is similar to unit 11 (which includes plots 259 and 260). The plot is ABGR/ACCGLD/CLUN with 75% overstory canopy, but with only 8% cover of shrubs ACGL, PHMA5, and ROGY, and no herbs. The plot was originally classified as TU5. However the unit has much less conifer overstory and there is more tall shrub over. The fuel model was adjusted to match the unit description, not the plot description.

Fine fuel loads were developed by comparing plot photos, aerial photos, the assigned fuel model and the photo series (Maxwell and Ward, 1980). The photos match a TU5 model. The modified TU5 fuel model of unit 11 was used as the basis for the FWD loading (this was 75% of the TU5 model). Although there is less conifer lower limb dieback, this is compensated by deciduous downfall, which appears in the plot photos.

The herbaceous fuel load was 0. The woody fuel loads were calculated using FCCS with a shrub cover of 8% 6 ft tall PHMA (0.16 tons/ac), and 70% cover of 6 foot tall understory trees (1.21 tons / ac) The sum of 1.37 tons per acre seemed too low, and in referencing the TU5 model and picture, it appeared that the fuelbed did not match the picture in the guide. Ultimately, the live woody fuel load was changed to 3.0 tons / ac, the same as in TU5.

The fuelbed depth calculated from the average of values in the plot spreadsheet was 1.0 ft, which is due to 8% cover of shrubs over 6 feet tall. However this doesn't account for 70% of small tree cover, which makes up about 78% cover when added to the shrubs. Therefore the fuelbed depth was re-calculated as 5.5 feet, but used with a fuelbed depth multiplier to maintain the bulk density of the live woody component.

Unit 13 was loaded into NEXUS as a custom fuel model. This data was run in NEXUS using the normal defaults as well as with varying fuel depth. The LADMlow fuelbed depth multiplier was varied to produce more realistic results.

Figures E31, E32 and E33 show fire behavior characteristics of unit 13 determined by NEXUS. The best choice of fuel model should be either TU5 with a LADMlow of 1.0 (but having too high of FWD and too low fuelbed depth) or a custom fuel model ("TU260") equivalent to fuel model TU5 with fuelbed depth as given, but with fire behavior outputs reduced by the use of a 0.5 fuelbed reduction factor, allowing the fuel bulk density to be held constant. Since custom fuel models were not developed in this study, unit 13 was classified as fuel model TU5 without any fuelbed factor adjustments.

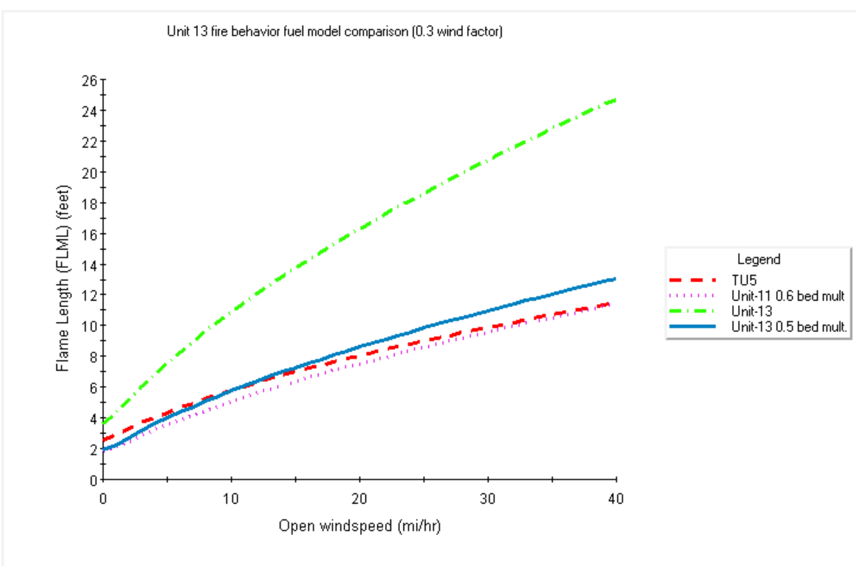


Figure E31. Flame lengths of unit 13 varied by wind speed.

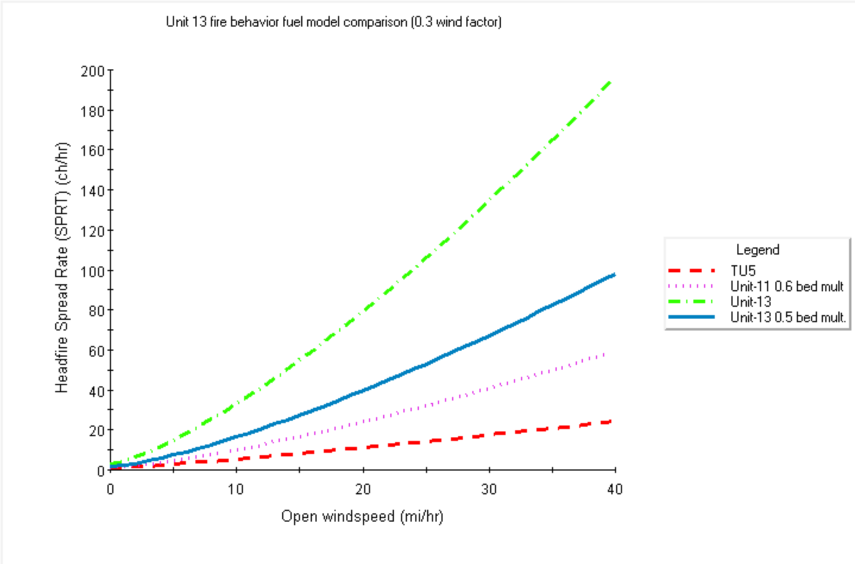


Figure E32. Spread rates of unit 13 varied by wind speed.

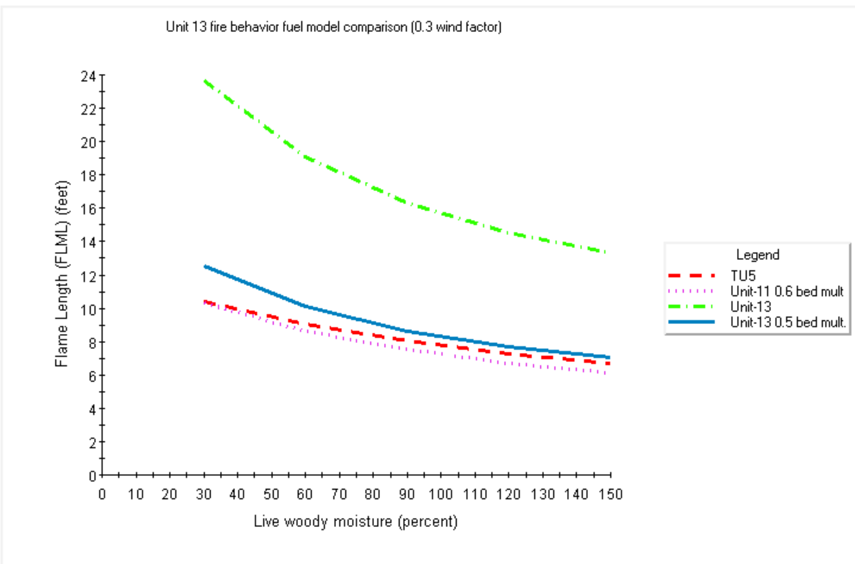


Figure E33. Flame lengths of unit 13 varied by live woody moisture.

Figures E34 and E35 show unit 13 fire behavior with a wind reduction factor of 0.3 and a fuelbed depth multiplier of 0.5

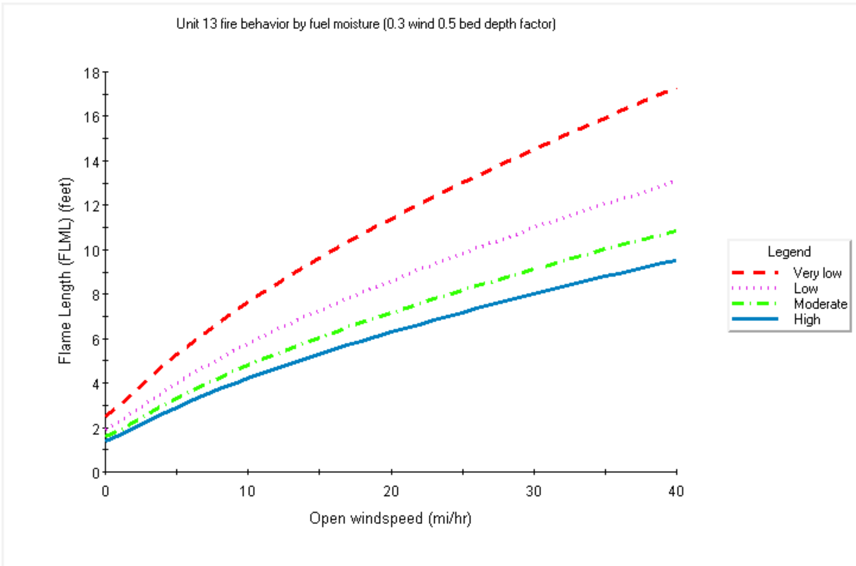


Figure E34. Flame lengths of unit 13 with a 0.3 wind reduction factor and a fuelbed depth multiplier of 0.5, varied by wind speed for different dead fuel moistures.

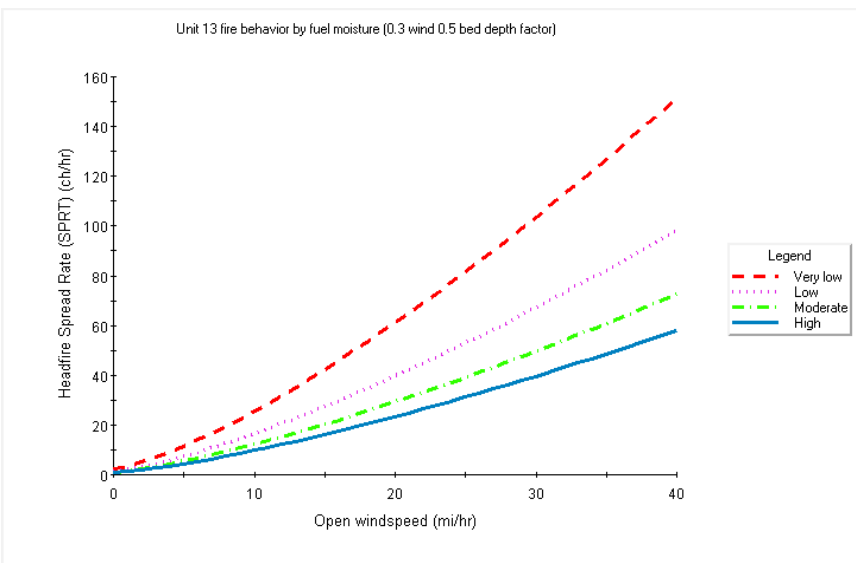


Figure E35. Spread rates of unit 13 with a 0.3 wind reduction factor and a fuelbed depth multiplier of 0.5, varied by wind speed for different dead fuel moistures.

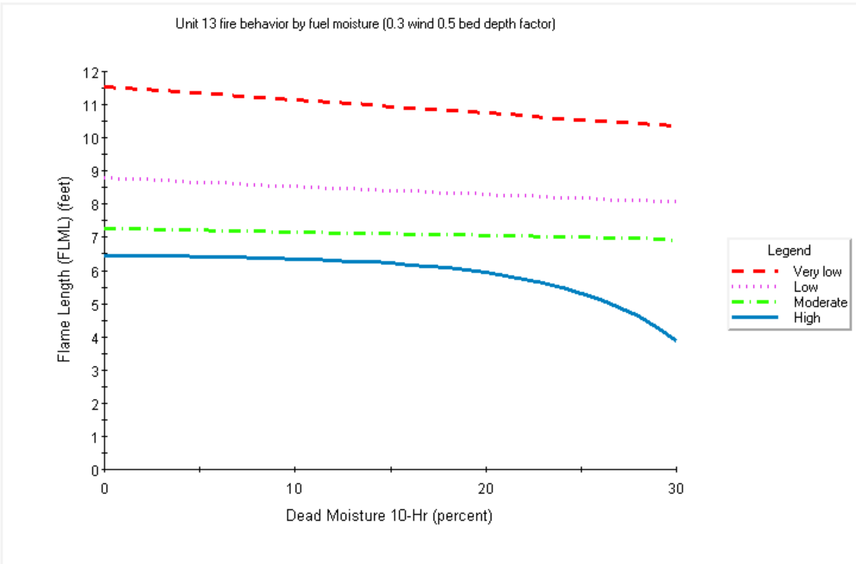


Figure E36. Flame lengths of unit 13 with a 0.3 wind factor and a fuelbed depth multiplier of 0.5, varied by 10-hr fuel moisture for different dead fuel moistures.

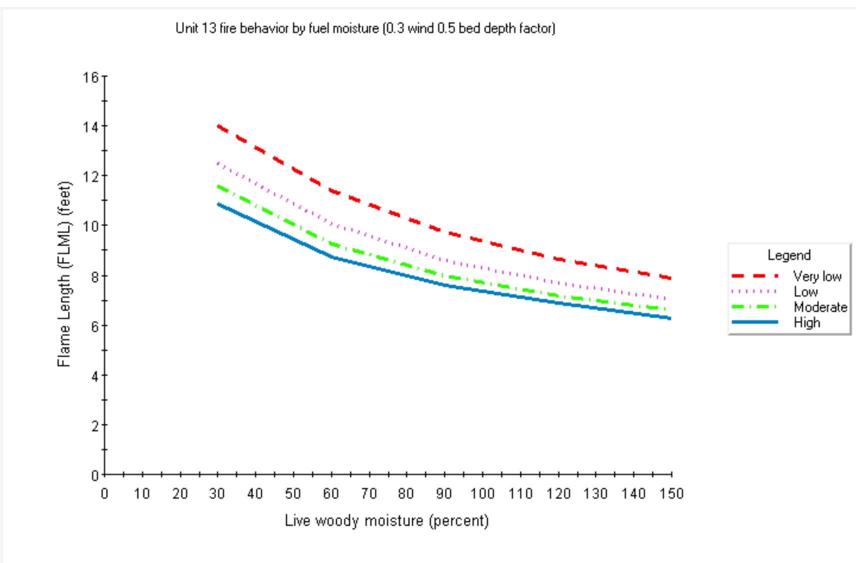


Figure E37. Flame lengths of unit 13 with a 0.3 wind factor and a fuelbed depth multiplier of 0.5, varied by live woody moisture for different dead fuel moistures.

Appendix F – Fire Behavior Modeling: Weather calculations

Weather characteristics (wind speed, direction, hourly temperatures and humidity) were determined using both online RAWS data and FireFamily Plus weather modeling software.

The RAWS data was collected from the public RAWS Internet site at shttp://www.raws.dri.edu/wraws/waF.html.

Weather calculated by FireFamily Plus used imported RAWS weather station data at http://famweb.nwcg.gov/weatherfirecd/washington.htm.

RAWS data was chosen to model Mt. Spokane weather based on criteria of proximity and elevation. The average elevation of Mt. Spokane is 3,921 feet. Over a dozen RAWS within 100 miles of Mt. Spokane were evaluated. However, some of the sites with weather and elevation most similar to Mt. Spokane State Park could not be used because they did not have complete data. The RAWS used are shown in Table F1. Overall, Tacoma Creek was judged to be the best overall site for modeling Mt. Spokane State Park weather based on a combination of proximity, elevation and data availability. Tacoma Creek is at an elevation of 2,318 feet and has data available from 1982 through 2006. Next, in order of similarity to Mt. Spokane State Park, were Flowery Trail, Washington and Hayden Lake, Idaho. A brief summary of the main RAWS used in this project is given in Table F1, along with an indication of the availability of data from each station.

Table F1. RAWS data used to model weather for Mt. Spokane State Park, listed in order of nearest to furthest location from the Park.

RAWS Station	Elevation (ft)	RAWS internet site Dates available (data quality notes)	FireFamily Plus RAWS import sites Dates Available
Hayden Lake, ID	2,318	2001-2005 (fair; no summary data)	1989-2005 (other dates available, but not used)
Hoodoo, ID	2,270	2004-2007 (fair; no summary data)	1954-1987 (other dates available, but not used)
Flowery Trail	2,600	1995-2007 (good)	(not available)
Pal Moore Orchard	3,120	1993-2007 (good)	1993-2006
Tacoma Creek	3,300	1985-2007 (good)	1982-2006
Midnight Mine	2,500	(not used)	1991-2006
Gold Mountain	4,686	1991-2007 (good)	(used only for wind –climate much drier)

Input data was developed for wind speed and direction by modeling the weather during extreme fire events, such as the firestorm that occurred in 1991 ("Firestorm '91", October 16, 1991). The hourly values for wind speed and direction during the 1991 fire were used to create a FARSITE wind file.

The national fire database was augmented by a set of historic fire data polygons provided as shapefiles by Eric Trimble, AFMO Fuels Specialist on the Newport/Sullivan Lake Ranger District of the Colville National Forest. Another detailed set of fire data was also reviewed during this analysis provided by Steve Harris, weather advisor and analyst for DNR Northeast Region.

Three large fires used for analysis were taken from the National Fire database: Holcomb (1991), Chattaroy (1991) and Red Lake (1997). Characteristics of these fires in the database are described below. The first two of these were separate incidents during the extreme fire weather event remembered as "Firestorm '91". This event had sustained high winds coupled with dry fuels during October, however the fuel types were different from those at Mt. Spokane.

The data from Firestorm '91 was used to develop a wind scenario to model extreme fire weather in and around the project area. The weather stations used for modeling this event were Midnight Mine and Gold Mountain, both of which are RAWS close to Mt. Spokane State Park, and likely to have similar wind conditions. The wind speed and azimuth data from these two sites was averaged and used to generate an hourly circadian wind pattern. The date was shifted to August 1 and repeated every day for 31 days, and this data was then used as input into FARSITE.

Three large fires used for weather analysis were taken from the National Fire database with the following characteristics:

- Large Fire No. 1 (Holcomb). 720 acre fire SW of Mt. Spokane; FID 25533; FSTATS 25534; FSTATS_ID 26802; OBJECT_ID 26802; FIREEVNT_D 32689; FIREEVNT_N 416; County Spokane; TRS 27, 44E, 14; Elev 2200; Date Started 10/16/1991; Date controlled 10/17/1991.
- Large Fire No. 2 (Chattaroy). 4,760 ac fire west of Mt. Spokane; FIREEVNT_I 32680 ; FIREEVEN_N 403; TRS 27, 42E, 2; Date 10/16/1991; Control Date 10/18/1991.
- Large Fire No. 3 (Red Lake). 1,151 ac fire west of Mt. Spokane; FIREEVNT_I 41886; FIREEVNT_N 200; TRS 27, 40E, 11; Elev 1600; Date 8/14/1997; Control Date 8/18/1997.

The circadian weather pattern was developed for FARSITE input data from the July 29 and 30, 2003 weather chart for Flowery Trail as follows: The low temperature was taken between 1:00 AM and 6:00 AM on both days (average 60 degrees); the high temperature was taken between 3:00 and 5:00 PM on the 29th and 1:00 PM and 6:00 PM on July 30th (average 99 degrees). The low RH on the 29th occurred between 4:00 PM and 5:00 PM and the low RH on the 30th occurred between 3:00 PM and 5:00 PM. The high RH on the 29th was at 9:00 AM, and the high RH on the 30th was between 3:00 AM and 6:00 AM. Based on these scores, the hourly times used for the highs and lows for the FARSITE weather file were 5:00 AM for the low temperature/high RH and 4:00 PM for the high temperature/low RH.

Default values for determining the 98th percentile fuel moisture using the RERAP procedure of FireFamily Plus used the following default values for the Tacoma Creek RAWS:

Data years: 1981-2006; Enable Auxiliary Years overlay: Yes; Analysis Period (days): 1; Filter Period: May 1 – Oct 31; StationID: Tacoma Creek (#453413); NFDRS Fuel Model: H – Short needle pine normal dead; Station Type: 4 (RAWS SAT NFDRS); Use 88 Model: Checked; Slope Class: 1 : 0 - 25%; Climate Class: 3 – Sub-humid to Humid (rainfall adequate all seasons); Green Up Day of Year: (May 15); Earliest Freeze Date: (Sep 15); Start KBDI: 100 (this is the starting drought index given for this station); Start FM 1000: 30 (this is the initial 1000-hr fuel moisture); Average Precipitation: 55 (this was changed from 35 for Tacoma Creek to 55 for extrapolating the model for Mt. Spokane weather); FM1 = FM10: Unchecked; Herbs are Annuals: Unchecked;

Deciduous Shrubs: Checked; Aspect: 5 (S); Slope Position: M (Mid Slope); Elevation: 3,240; Latitude (Degrees): 48; Longitude (Degrees): 117

The percentile seasonal fuel moisture was calculated by clicking Weather – Season Reports – Percentile Weather – Spread Component. Winds were specified from the SW, and the final output was calculated by clicking the Calculate(1) and Calculate(2) buttons.

The results of fuel moisture calculations were saved in file may-june-fire-fam.fms; the weather file was saved as file may-june-firefam.wtr; and the wind speed was saved as file may-6mph.wnd.

Appendix G – Fire Behavior Modeling: FARSITE and FLAMMAP input data and detailed methods

FARSITE and FlamMap were used to model fire behavior on Mt. Spokane, using a set of eight raster input files containing landscape data for the project area. FARSITE was used primary to prepare the data for input into both programs, while FlamMap was used to determine fire behavior based on fuel characteristics across the landscape.

The set of raster input files was processed as described in the wildlife HSI modeling section. Also, a companion set of raster input files was developed for comparison with the Mt. Spokane data using downloaded data from the LANDFIRE project (Rollins and others 2006). The raster grids were exported from ArcCatalog as ASCII raster files with the following units:

Elevation (feet). These were created from the digital elevation model.
Slope (degrees). These were created from the digital elevation model.
Aspect (degrees). These were created from the digital elevation model.
Fuel model. For Mt. Spokane State Park, the standard Scott and Burgan set of 40 fuel models were used as input into the FARSITE.
Canopy cover (file cnpy_covr, in percent cover). Canopy cover was determined for the Mt. Spokane landscape using IDW (inverse distance weighting) of the mean overstory canopy cover.
Canopy height (file cnpy_ht, in feet). Canopy height was determined for the Mt. Spokane landscape using IDW of the mean overstory canopy heights.
Canopy base height (file frst_cnpy_bs in feet). Canopy cover was determined for the Mt. Spokane landscape using IDW of the mean overstory canopy base heights.
Canopy bulk density (file cnpy_blk_dns, in kg/m3). Canopy cover was determined for the Mt. Spokane landscape using IDW of the mean overstory canopy bulk density (Cruz and others 2003; Scott and Reinhardt 2002; Brown 1978).

FARSITE Landscape files were loaded using the command Input - Landscape Utilities – Generate, followed by specifying the raster input files and the following default parameters:

Latitude = 48; Distance units = meters; Adjustments (*.adj) = default.adj (all factors = 1.0); Conversions (*.cnv) = none; Custom fuel models (*.fmd) = none; Coarse Woody (*.cwd) = none.

Fuel Moisture files (*.fms) were chosen from several sets of data, e.g., fire-fam98th.fms was used to model fuel moistures closest to the FireFamily Plus 98th percentile fuel moistures given on p. 8 of Scott and Burgan (2005. Wind files (*.wnd) were chosen from one of the wind files, e.g., aug-firestorm91.wnd was used to model weather patterns similar to that of Firestorm '91. Weather files (*.wtr) were chosen from several sets, e.g., aug-hot-dry-even-96th.wtr, which was used to model 96th percentile weather. An example line from this weather file for a single summer day is illustrated in Table G1.

Table G1. An example of one day of weather (August 1) specified in the weather file aug-hot-dry-even-96th.wtr. Mo = month; day = day; ppt = inches of rain; hr1 = hour of lowest temperature (0-2400); hr2 = hour of highest temperature (0-2400); tmp1 = low temperature (F); tmp2 = high temperature (F); rh1 = maximum daily humidity; rh2 = minimum daily humidity; elev = elevation above sea level.

Mo	day	ppt	hr1	hr2	tmp1	tmp2	rh1	rh2	elev
8	1	0	300	1600	60	99	12	34	3921

FARSITE Model Parameters and Duration options were initially set as follows: Time Step = 30 min; Visible Steps = 2 hrs; Permieter Resolution = 60 m; Distance Resolution = 30 m; Units = Metric.

FARSITE Model - Fire Behavior options were initially set as follows: Enable Crownfire = NO; Link Crown Density & Cover = NO; Embers from Torching Trees = NO; Enable Spot Fire Growth = NO; Ignition Delay (mins) = 0; NWNS Backing ROS = ON; Fire Level Distance Checking = ON.

FARSITE Model - Fire Acceleration options were initially set as follows: Acceleration = OFF.

FARSITE Model - Post-Frontal Combustion options were initially set as follows: Simulate Post-Frontal Combustion = OFF; Use Surface Fuels when CWD absent; Calculation Precision = Normal.

FARSITE Model - Dead Fuel Moisture options were initially set as follows: Calculate Moisture Map As Needed = OFF.

FARSITE Simulate – Options were initially set as follows: Reset Duration at Restart = OFF; Restore Ignitions at Restart = OFF; Rotation Sensitive Ignition Patterns = ON; Display Fire Growth as Completed = OFF; Adjust Ignition Spread Rates = ON; Preserve All Inactive Enclaves = ON; Number of Simulation Threads = 1.

FARSITE Simulate – Duration options were initially set as follows: Use Conditioning Period for Fuel Moistures = No.

FARSITE canopy characteristics were specified by clicking Input - Canopy Characteristics and setting the following options: Foliar Moisture = 100%; Species expected to torch = Grand fir; Shade tolerance of torching trees = High; Units = English; Diameter = 18 in.

The progress of simulations was followed by turning on the clock with the command Output - Current Time and Output - Elapsed Time. Additional files were added to help clarify the map view using the Attached Vector Files command.

FlamMap input was initialized by loading a landscape file created with FARSITE. The command Analysis Area – New Run was used to create a new run. In the run window, input parameters were set as follows. A fuel moisture file (*.fms) was specified, e.g., moderate.fms, which matches the moderate fuel moisture scenario given on p. 8 of Scott and Burgan (2005). Winds were set from the SW (240 deg) at 11 mph to match the 98^{th} percentile wind determined by FireFamily Plus. Foliar moisture was set at 100%. FlamMap outputs presented in this appendix were run with fuel moisture conditioning turned off, but when fuel moisture condition was turned on, wind and weather files were specified along with a conditioning period.

Desired FlamMap raster outputs were chosen on the Fire Behavior Outputs tab along with the desired fire behavior calculation method (although Scott's method is more widely accepted, Finney's is considered more accurate, which was the one we used). When the run was complete, the output files were saved ASCII raster files for importing into the GIS.

Appendix H - FlamMap fire effects

This section summarizes the results of fire behavior effects determined by FlamMap for three scenarios in addition to those presented in the main section of the report. Two fire weather and fuel moisture scenarios are used with the pre-treatment landscape file. The landscape file was changed in the last scenario to reflect post-treatment conditions. The scenarios are described further and their basic parameters are presented below:

1. Pre-treatment conditions with extreme fire weather ("August") (wind speed 20 mph; azimuth 240 degrees; summer fuel moistures: firefam98th.fms)
2. Mild fire weather ("May-June") pre-treatment (wind speed 10 mph; azimuth 240 degrees; may june-firefam.fms)
3. Post-treatment conditions with extreme fire weather ("August") (wind speed 20 mph; azimuth 240 degrees; summer fuel moistures: firefam98th.fms))

Scenario One

The August fire behavior effects determined by FlamMap with fuel preconditioning using 98^{th} percentile weather and modeled after the August 1991 firestorm are shown in Figures H1, H2 and H3.

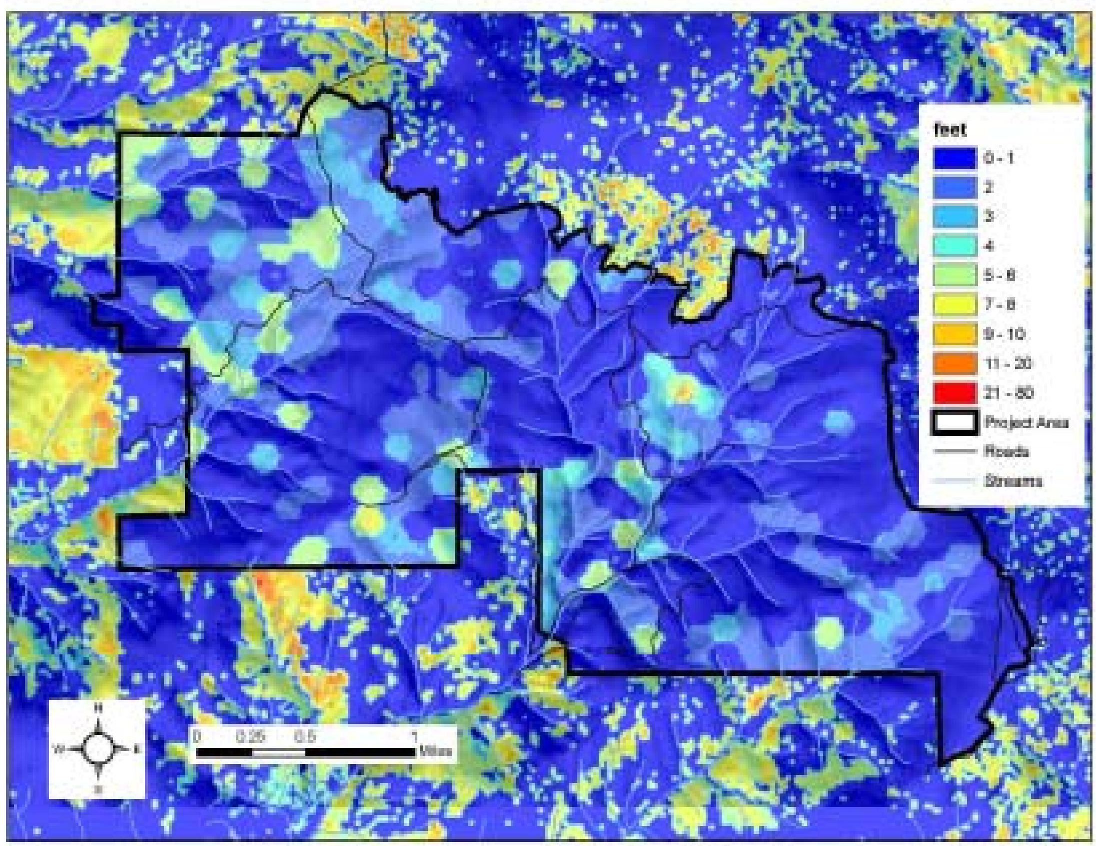


Figure H1. Pre-treatment flame lengths in the Mt. Spokane project area, modeled for summer weather with fuels conditioned using 98^{th} percentile weather and wind modeled after the Firestorm 1991.

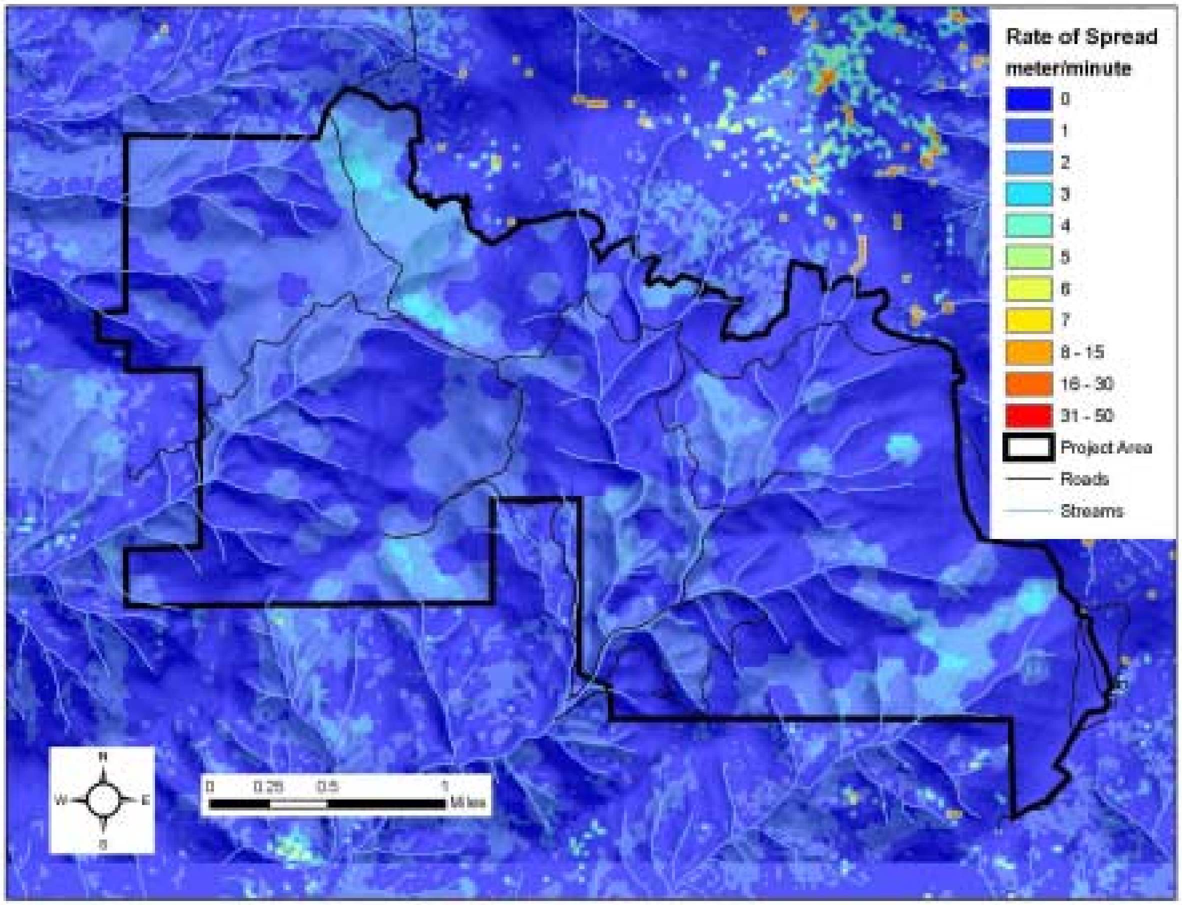


Figure H2. Pre-treatment rate-of-spread in the Mt. Spokane project area, modeled for summer weather with fuels conditioned using 98th percentile weather and wind modeled after the Firestorm 1991.

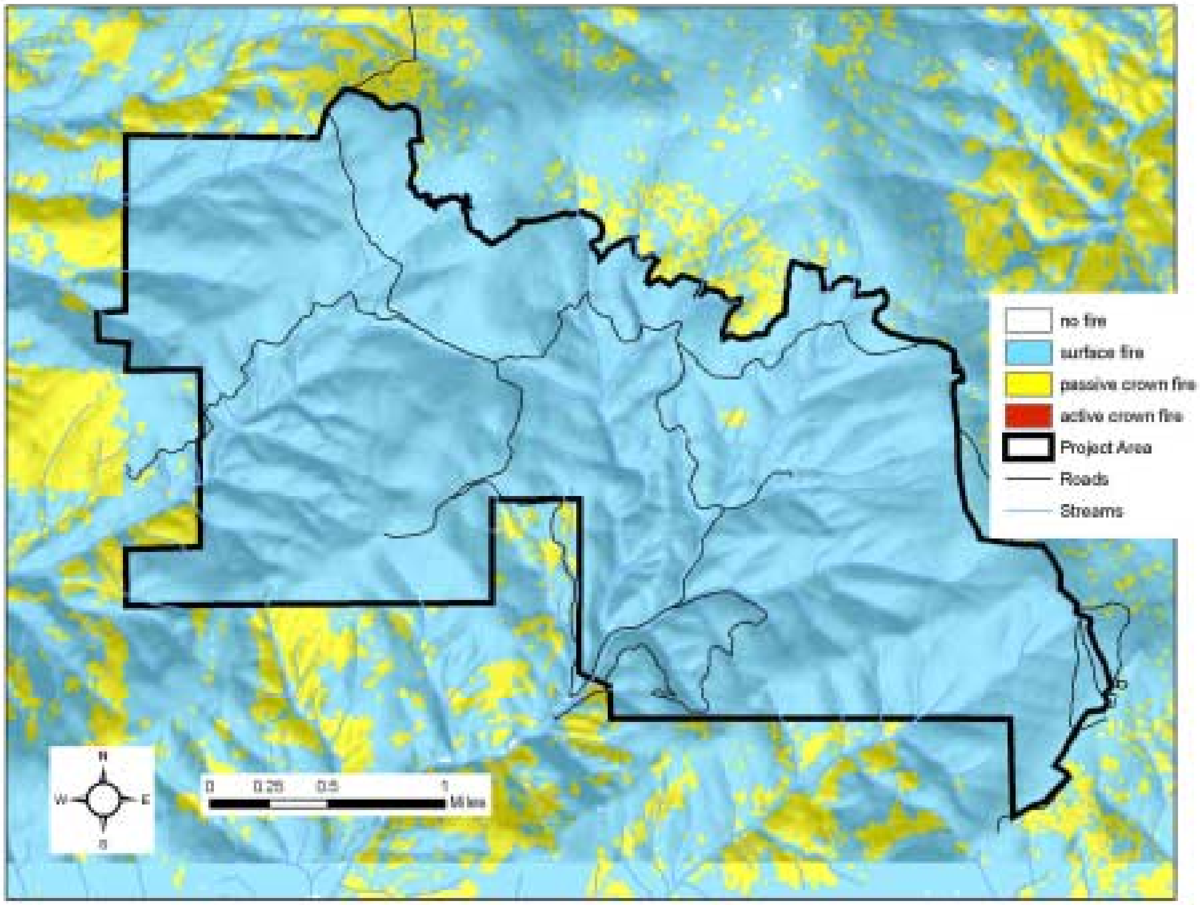


Figure H3. Pre-treatment crown fire potential in the Mt. Spokane project area, modeled for summer weather with fuels conditioned using 98th percentile weather and wind modeled after the Firestorm 1991.

Scenario Two

The May-June pre-treatment fire conditions determined by FlamMap are shown in Figures H4, H5 and H6.

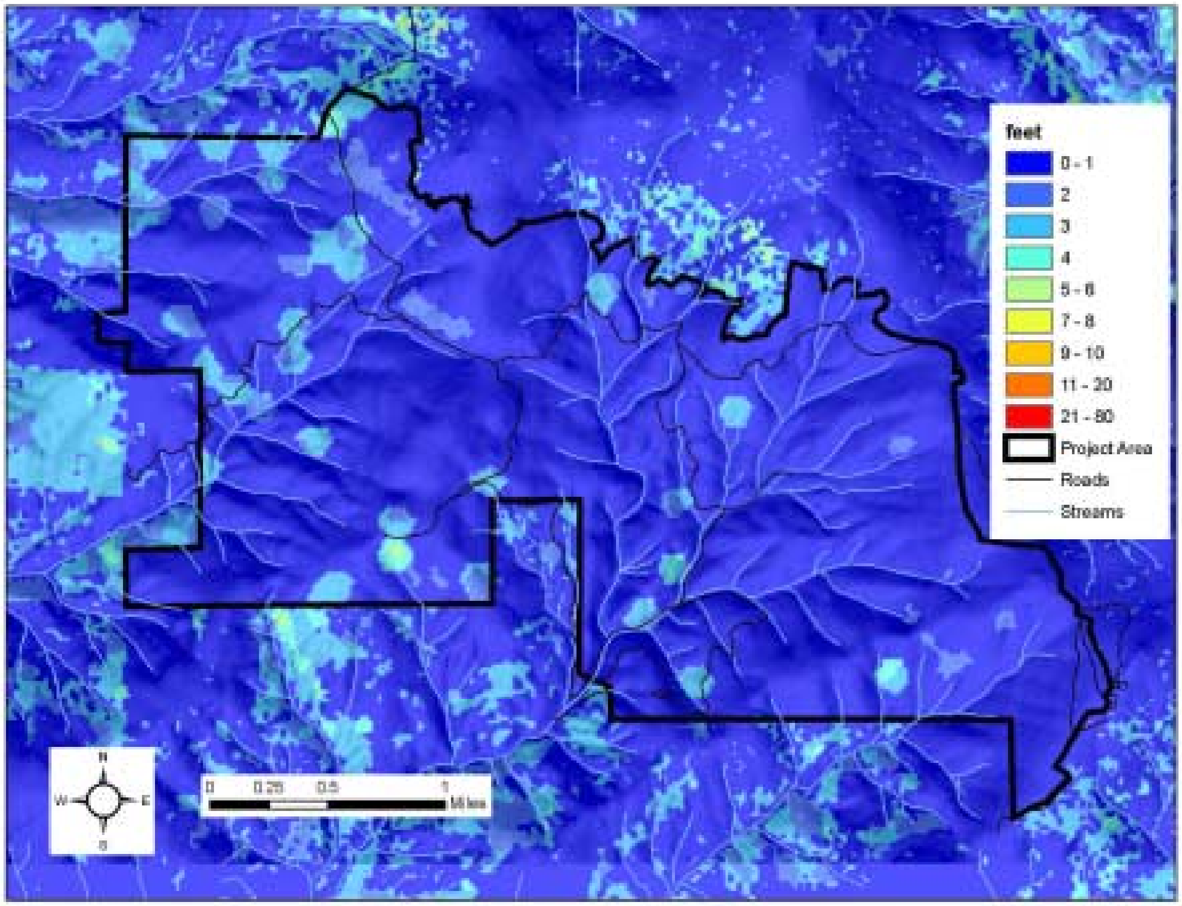


Figure H4. Pre-treatment flame lengths in the Mt. Spokane project area, modeled for mild burning wind and weather conditions typical in the spring (May-June).

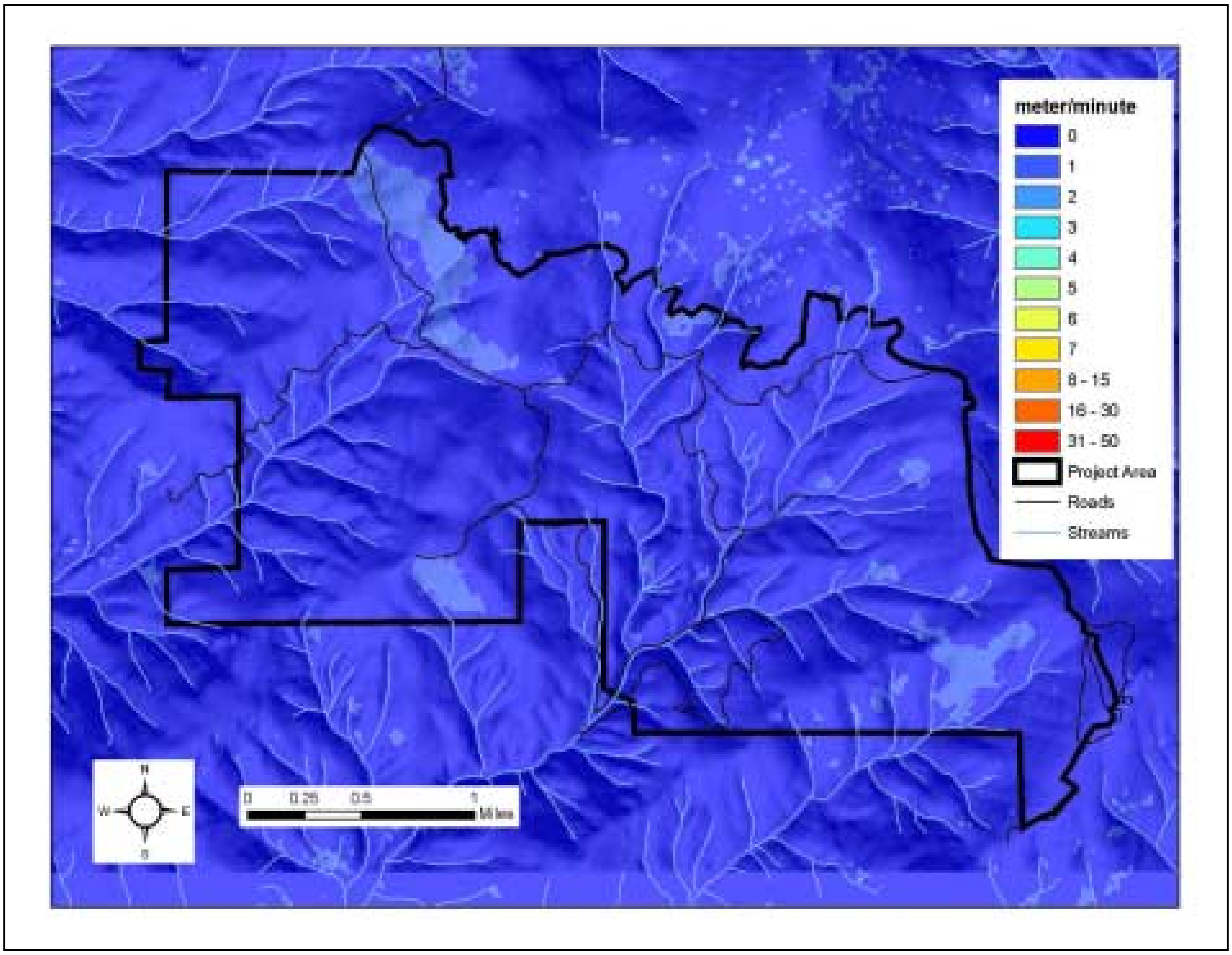


Figure H5. Pre-treatment rates-of-spread in the Mt. Spokane project area, modeled for mild burning wind and weather conditions typical in the spring (May-June).

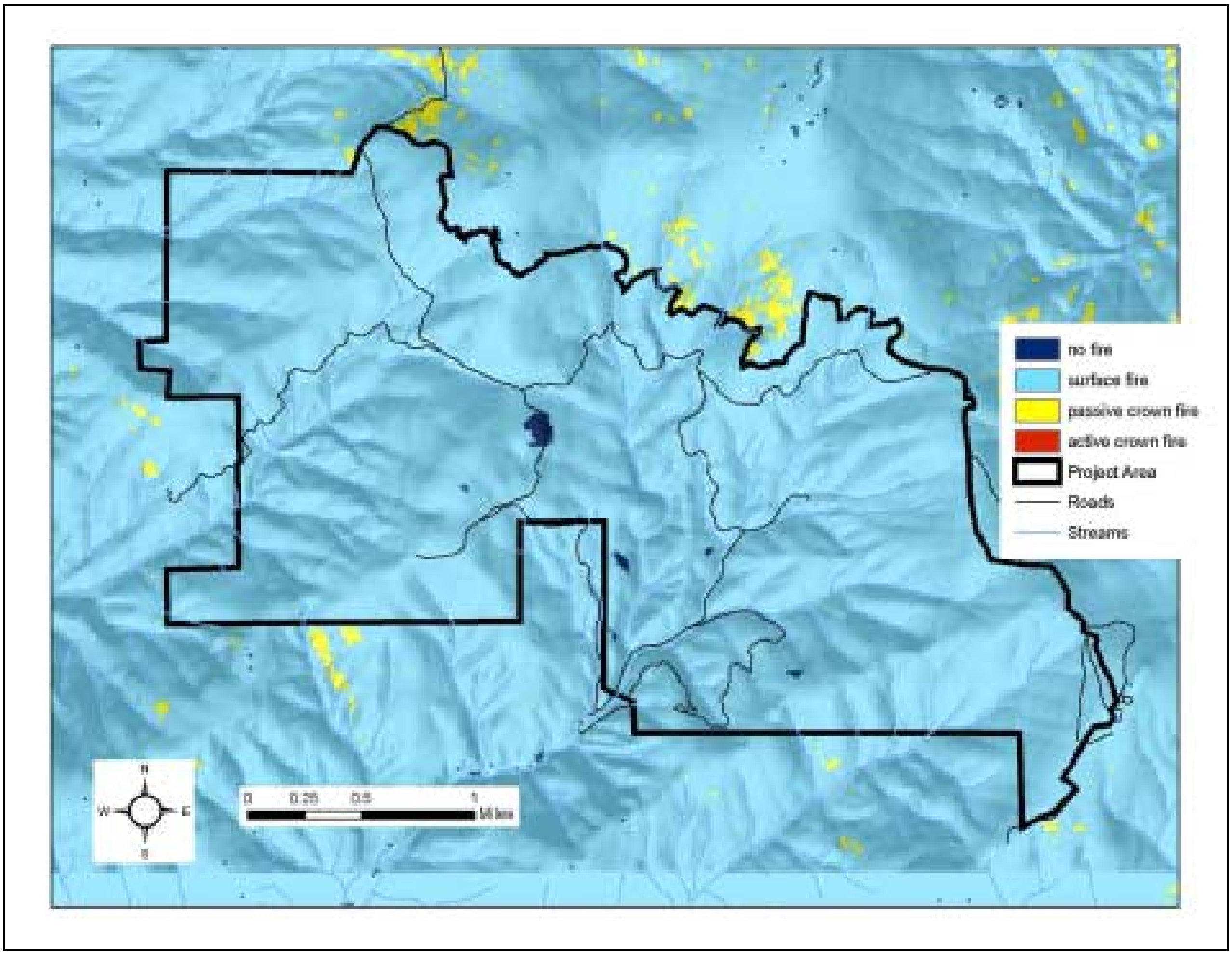


Figure H6. Pre-treatment crown fire potential in the Mt. Spokane project area, modeled for mild burning wind and weather conditions typical in the spring (May-June).

Scenario Three

The August post-treatment fire conditions determined by FlamMap are shown in Figures H7, H8 and H9.

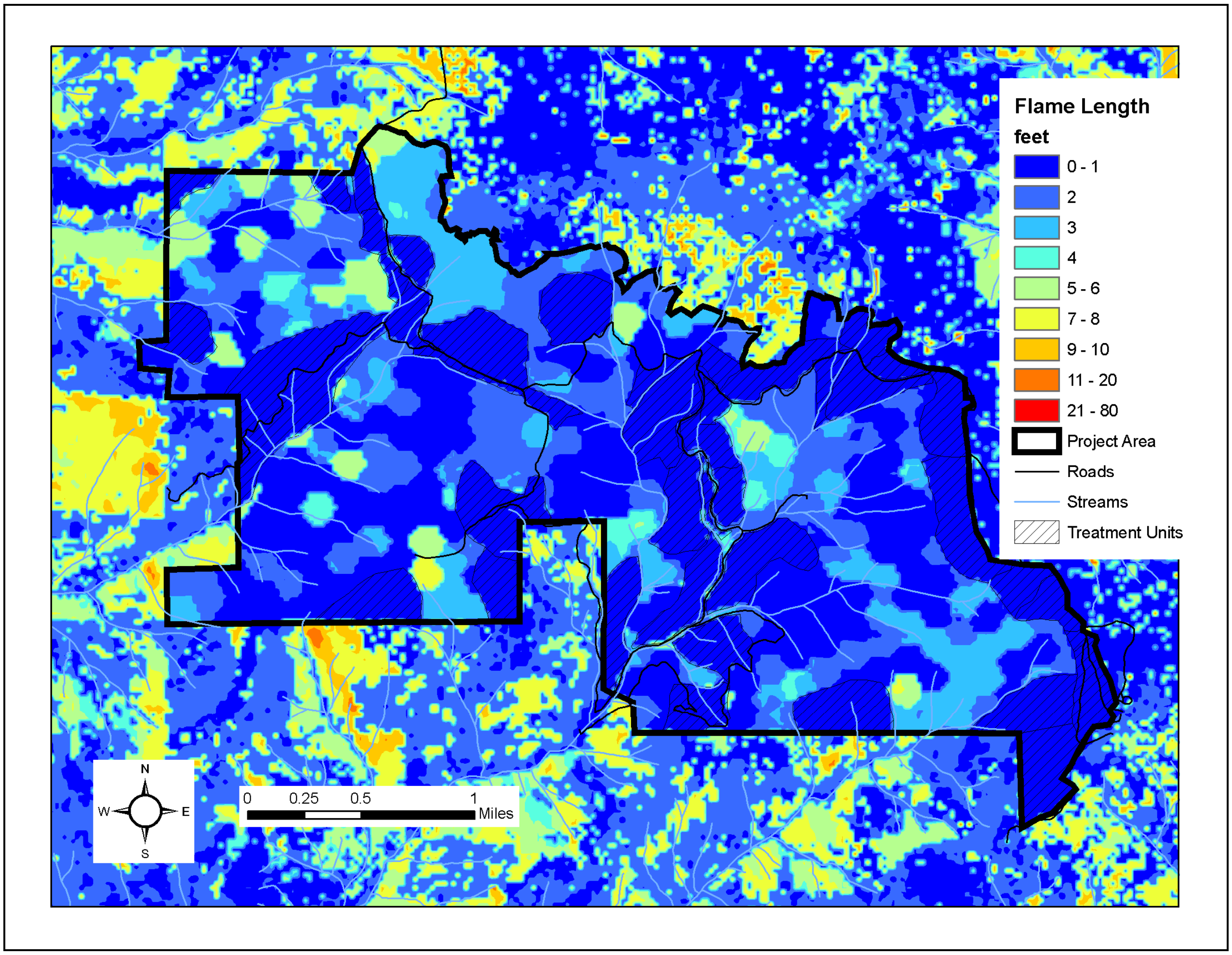


Figure H7. Post-treatment flame lengths in the Mt. Spokane project area, modeled for summer weather with fuels conditioned using 98th percentile weather and wind modeled after the Firestorm 1991.

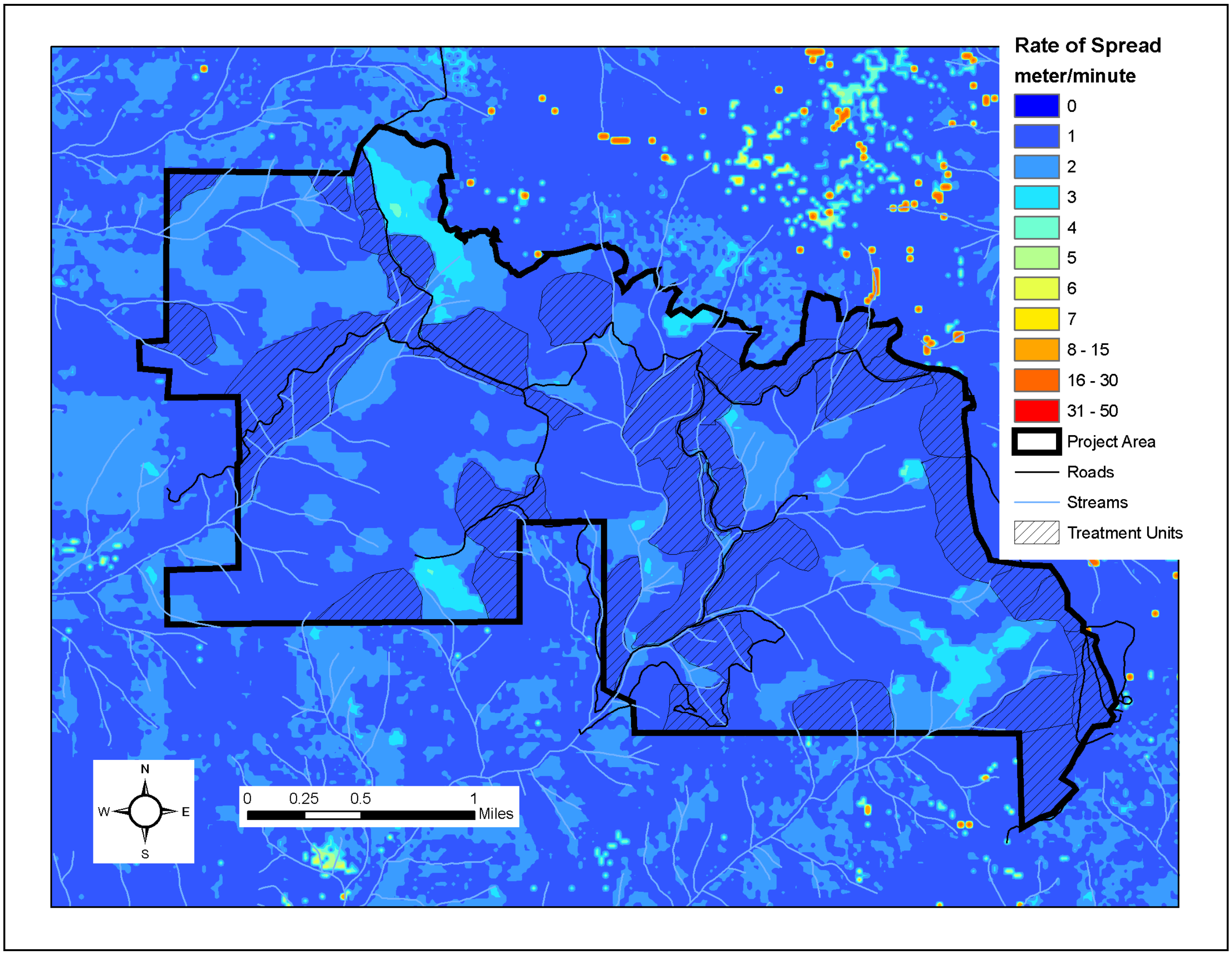


Figure H8. Post-treatment rates-of-spread in the Mt. Spokane project area, modeled for summer weather with fuels conditioned using 98th percentile weather and wind modeled after the Firestorm 1991.

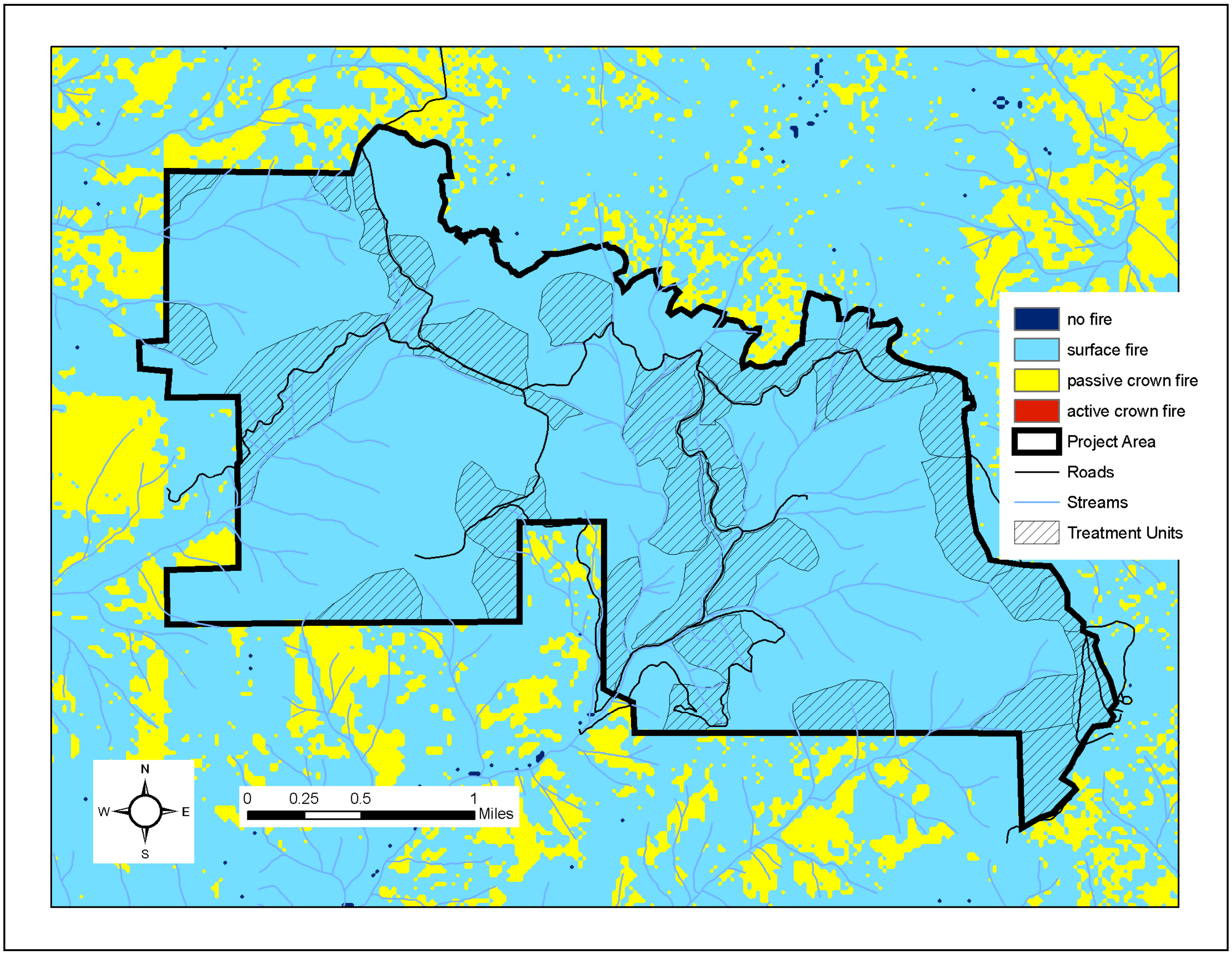


Figure H9. Post-treatment crown fire potential in the Mt. Spokane project area, modeled for summer weather with fuels conditioned using 98th percentile weather and wind modeled after the Firestorm 1991.

Appendix I – Fire Behavior Modeling: FOFEM fire effects and NEXUS flame lengths predicted for controlled spring burns

This section summarizes calculations of fire behavior effects predicted for spring controlled spring burning on Mt. Spokane St. Park. The fire behavior effects were calculated by FOFEM, using spring flame lengths determined by NEXUS, which used May-June fuel moistures and weather determined by FireFamily Plus.

Figures I1 to I6 show flame lengths calculated by NEXUS for the timber fuel models found in Mt. Spokane St. Park, that were used as input into FOFEM.

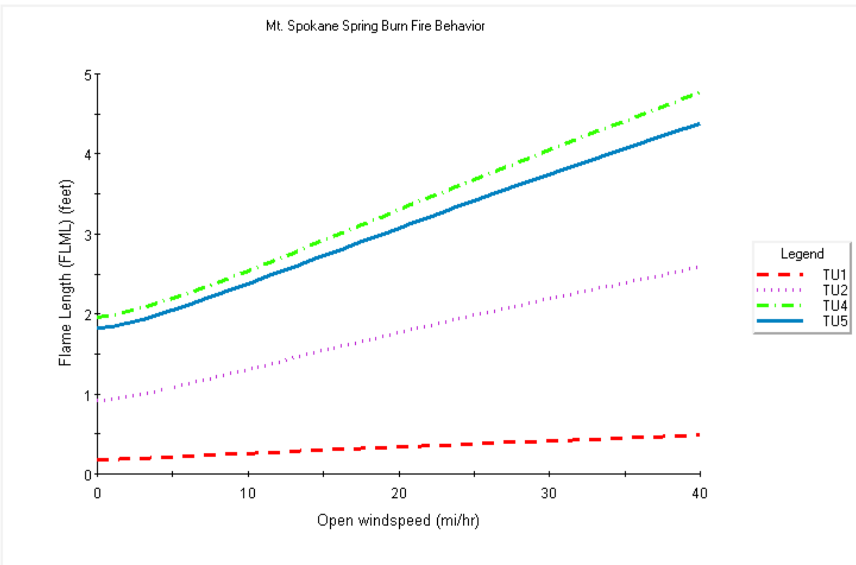


Figure I1. Flame lengths of fuel models TU1, TU2, TU4, TU5, varied by wind speed.

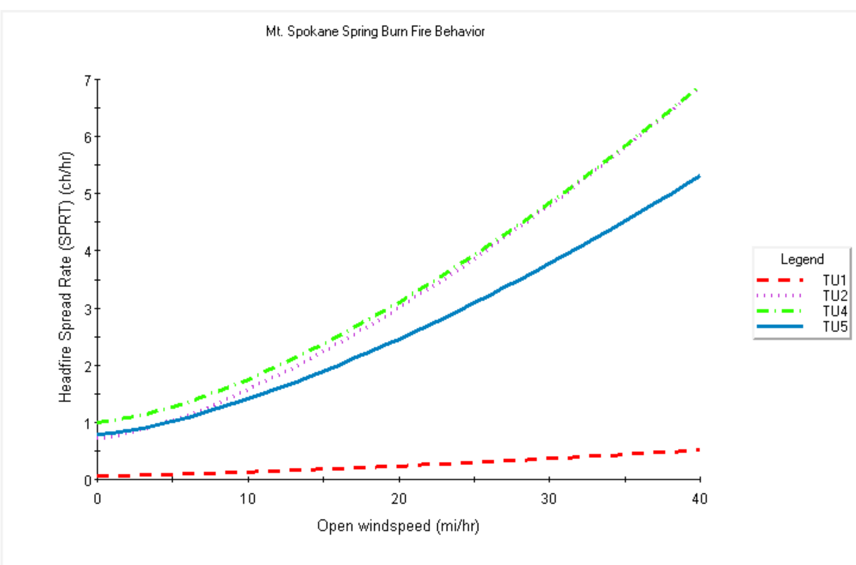


Figure I2. Spread rates of fuel models TU1, TU2, TU4, TU5, varied by wind speed.

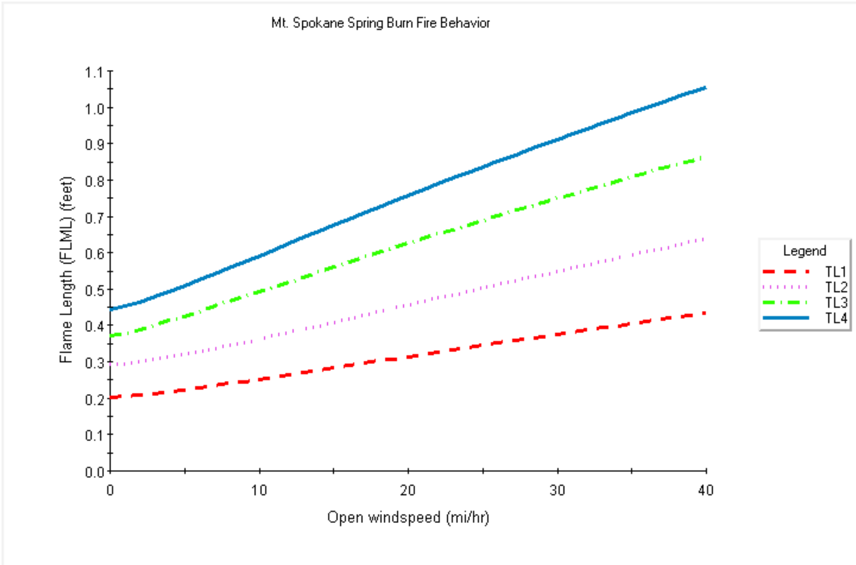


Figure I3. Flame lengths of fuel models TL1, TL2, TL3, TL4, varied by wind speed.

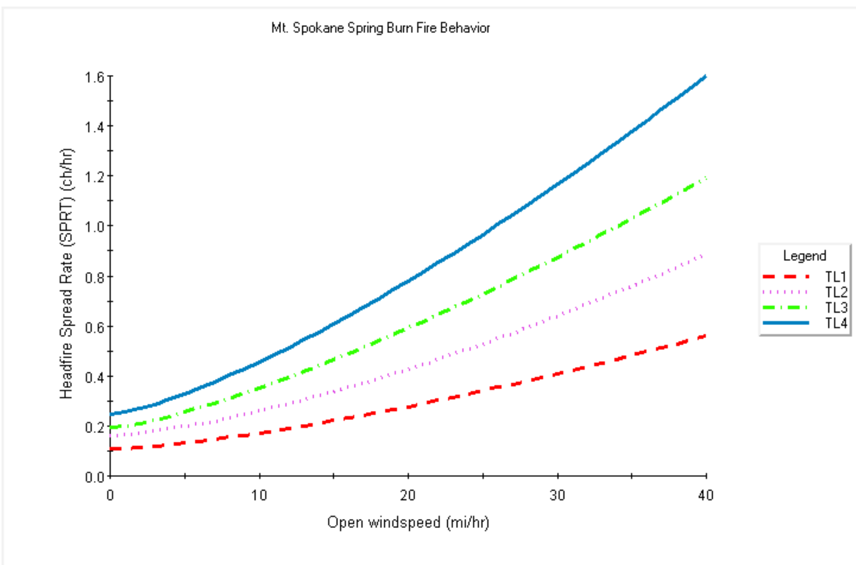


Figure I4. Spread rates of fuel models TL1, TL2, TL3, TL4, varied by wind speed.

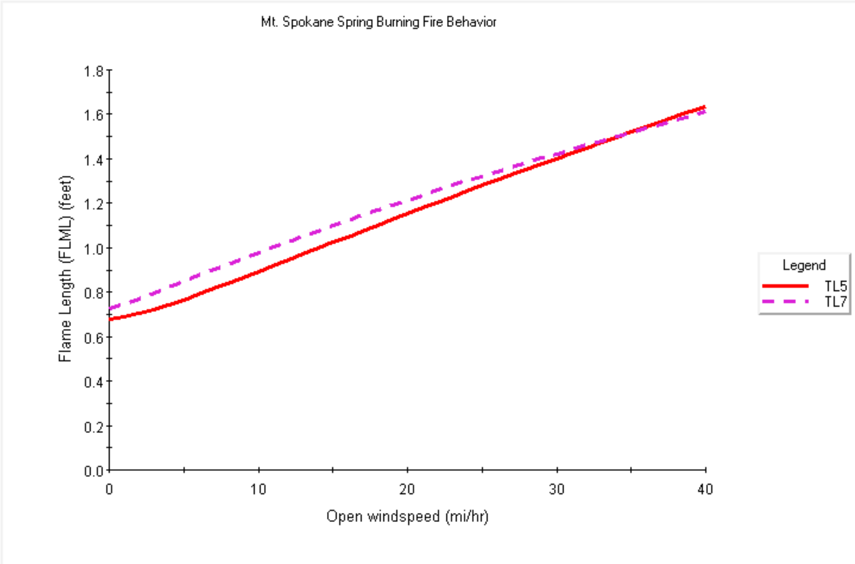


Figure I5. Flame lengths of fuel models TL5, TL7, varied by wind speed.

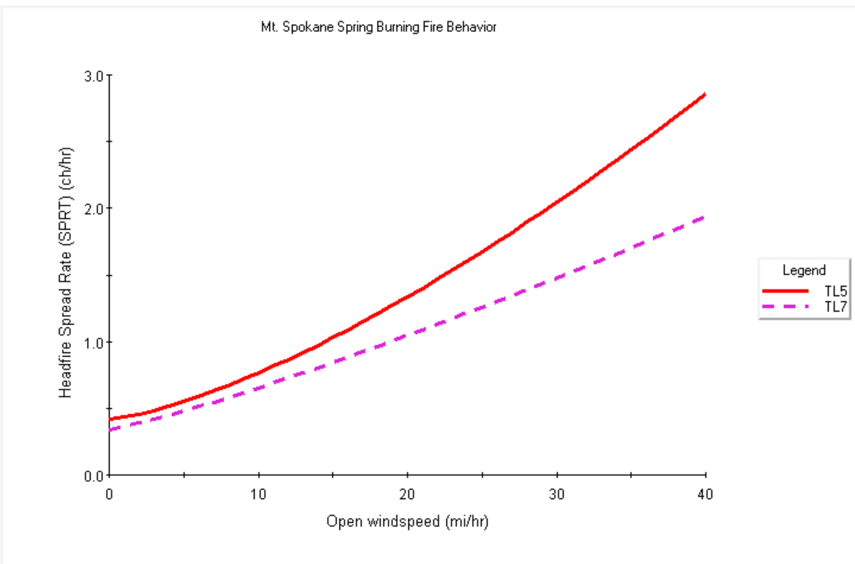


Figure I6. Spread rates of fuel models TL5, TL7, varied by wind speed.

FOFEM was used to predict mortality during spring burning conditions using the flame lengths calculated by NEXUS and the stand characteristics of representative plots within the units (Table I1).

Mortality was determined for plots representative of a large number of units and fuel conditions in Mt. Spokane Park. These plots were: Plot 146 (fuel model TU5; units 2, 15, 34, 35; predicted flame lengths 1.8 feet); Plot 141 (fuel model TU5; units 8, 9, 32, 33; flame lengths 1.8 feet); Plot 31 (fuel model TU1; units 16, 17, 21, 23, 24; flame lengths 0.2 feet); Plot 3 (fuel model TU1; units 26, 27, 38, 39, 40; flame lengths 0.2 feet); Plot 309 (fuel model TU4; units 28, 29; flame lengths 2.0 feet).

Table I1. Summary results are given in the following spreadsheet, followed by output graphs below.

Plot	Fuel Model	Flame length (ft)	Species	DBH (in)	Trees/ac	Height (ft)	Crown ratio (1-10)	Mortality (%)
146	TU5	1.8	ABGR	14	25	60	7	25
146	TU5	1.8	PSME	16	10	70	7	10
146	TU5	1.8	ABGR	2	1000	15	10	100
141	TU5	1.8	ABGR	14	65	50	9	28
141	TU5	1.8	ABGR	10	40	35	9	45
141	TU5	1.8	ABGR	2	1000	15	10	100
31	TU1	0.2	ABGR	18	21	80	6	18
31	TU1	0.2	ABGR	10	120	70	9	40
31	TU1	0.2	ABGR	2	40	15	10	85
31	TU1	0.2	PICO	14	48	70	4	50
3	TU1	0.2	PSME	20		70	7	6
3	TU1	0.2	PIMO	16	10	70	6	34
3	TU1	0.2	ABLA	8	18	30	10	55
3	TU1	0.2	PICO	10	48	60	5	60
3	TU1	0.2	PSME	14	40	50	9	15
3	TU1	0.2	ABLA	2	680	15	10	85
309	TU4	2	LAOC	20	28	130	2	5
309	TU4	2	PSME	30	8	90	6	3
309	TU4	2	LAOC	18	28	100	5	5
309	TU4	2	ABGR	12	110	50	9	5
309	TU4	2	ABGR	6	150	20	9	90
309	TU4	2	ABGR	2	1100	15	10	100

Mortality calculations were determined for plot 146 representing units 2, 15, 34 and 35, for fuel model TU5 with flame lengths of 1.8 feet (Table I2 and Figure I7).

Table I2. Input parameters for plot 146 mortality calculations.

Sp	dens	dbh	ht	CR
ABIGRA	25	14	60	7
PSEMEN	10	16	70	7
ABIGRA	1000	2	15	9.9

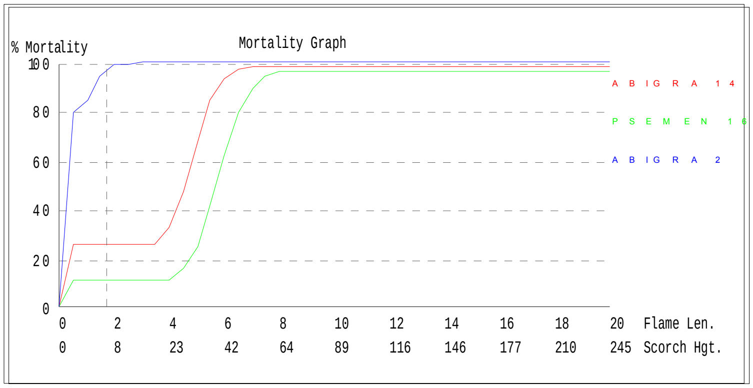


Figure I7. Results of mortality calculations for plot 146.

Mortality calculations were determined for plot 146 representing units 8, 9, 32 and 33 for fuel model TU5 with flame lengths of 1.8 feet (Table I3, Figure I8).

Table I3. Input parameters for plot 146 mortality calculations.

Sp	dens	dbh	ht	CR
ABIGRA	65	14	50	9
ABIGRA	40	10	35	9
ABIGRA	1000	2	15	9.9

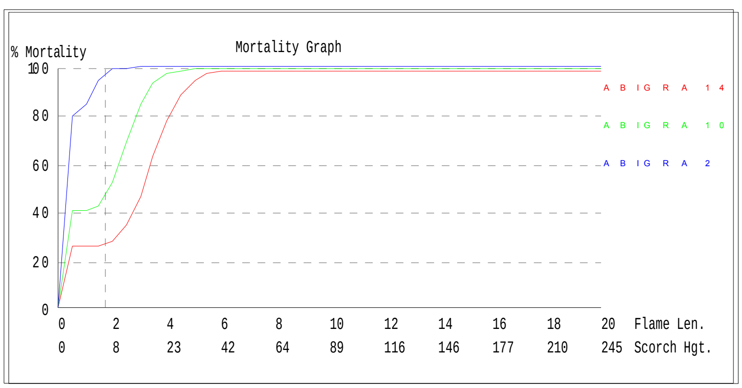


Figure I8. Results of mortality calculations for plot 141.

Mortality calculations were determined for plot 31 representing units 16, 17, 21, 23 and 24 for fuel model TU1 with flame lengths of 0.2 feet (Table I4 and Figure I9).

Table I4. Input parameters for plot 31 mortality calculations.

Sp	dens	dbh	ht	CR
ABIGRA	21	18	80	6
ABIGRA	120	10	70	8.5
ABIGRA	40	2	15	9.9
PINCON	48	14	70	4

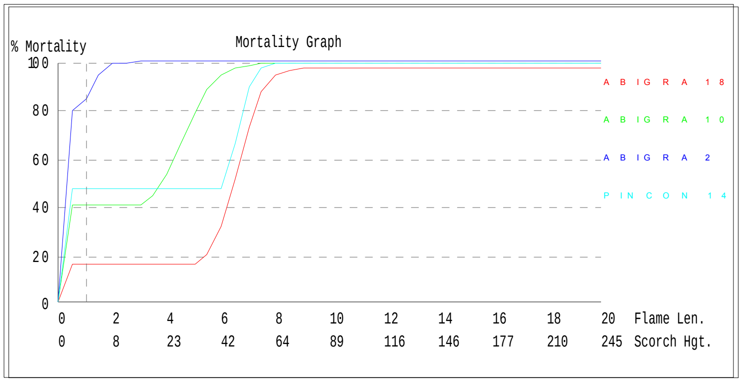


Figure I9. Results of mortality calculations for plot 31.

Mortality calculations were determined for plot 3 representing units 26, 27, 38, 39 and 40 for fuel model TU1 with flame lengths of 0.2 feet (Table I5 and Figures I10 and I11).

Table I5. Input parameters for plot 3 mortality calculations.

Sp	dens	dbh	ht	CR
PSEMEN	8	20	70	7
PINMON	10	16	70	6
ABILAS	18	8	30	9.5
PINCON	48	10	60	5
PSEMEN	40	14	50	8.5
ABILAS	680	2	15	9.9

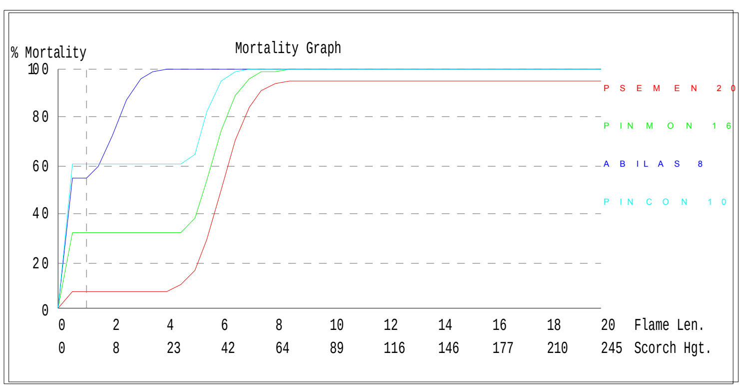


Figure I10. Results of mortality calculations for plot 3.

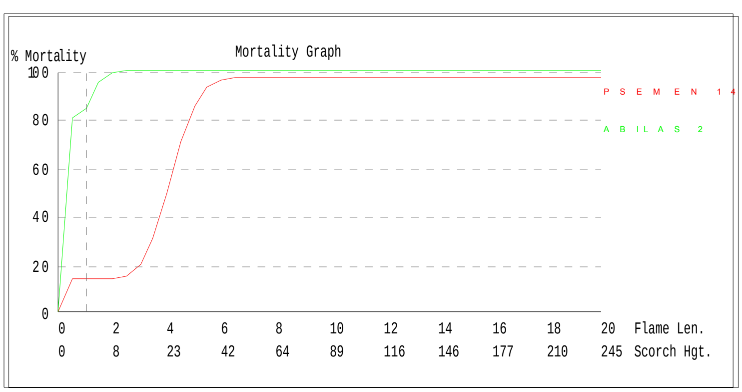


Figure I11. Results of mortality calculations for plot 3.

Mortality calculations were determined for plot 309 representing units 28 and 29 for fuel model TU4 with flame lengths of 2.0 feet (Table I6 and Figures I12 and I13).

Table I6. Input parameters for plot 309 mortality calculations.

Sp		dens	dbh	ht	CR
LAROCC	28	20	130	2	
PSEMEN	8	30	90	6	
LAROCC	28	18	100	5	
ABIGRA	110	12	50	8.5	
ABIGRA	150	6	20	9	
ABIGRA	1100	2	15	9.9	

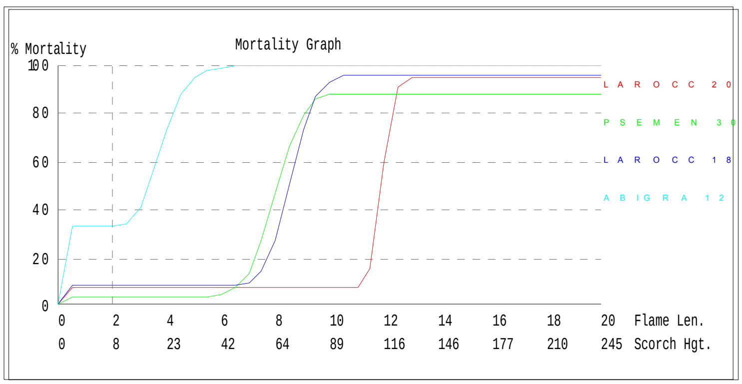


Figure I12. Results of mortality calculations for plot 309.

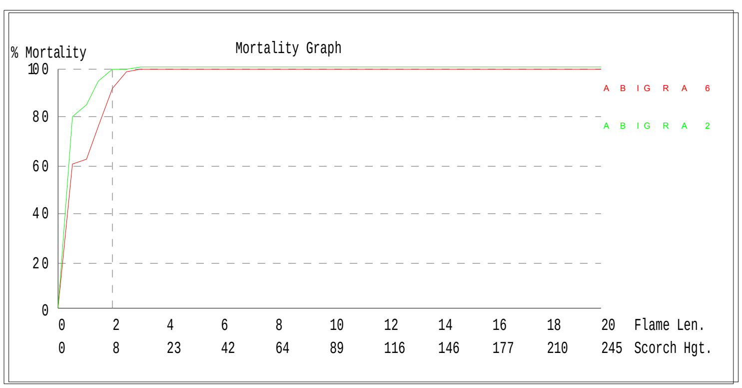


Figure I13. Results of mortality calculations for plot 309.

Appendix J – ESRI Arc Macro Language (AML) scripts used in data analysis and forest plan development

AML used to determine forest health priority zones

```
/*  AML used to determine forest health priority zones
&echo &br

/* The following are the definitions of the variables used in the AML:

/* pipo1 is a grid containing the number of ponderosa pine trees on a per acre basis

/* savetrees is a grid containing the number of fire resistant conifer trees on a per acre basis and is the sum of Douglas fir, western larch and ponderosa pine

/* smltpa1 is a grid containing the number of small trees less than 4 inches DBH of all species on a per acre basis.

/* smltrcov1 is a grid containing the % cover of small trees less than 4 inches DBH of all species

/* abgr8dbh1 is a grid containing the number of small grand fir trees less than or equal to 8 inches DBH on a per acre basis.

/* fh1 is a grid containing the first forest health priority zone

/* fh2 is a grid containing the second forest health priority zone

/* fhzones is a grid combined forest health priority zones

fh1 = con((pipo1 > 0.5 or savetrees > 20) and ((smltpa1 > 200 and smltrcov1 > 10) or abgr8dbh1 > 40),1,0)

fh2 = con((pipo1 > 1 or savetrees > 50) and ((smltpa1 > 350 and smltrcov1 > 15) or abgr8dbh1 > 60),2,0)

fhzones = con(fh2 == 2, 2, fh1)

&echo &off
&return
```

AML used to determine snag and log priority zones

```
/* AML to calculate snag and log priority zones

&echo &br

SNAGLOG2 = con((snags1 < 5 or (CWDnum1  < 30 and CWDcov1 < 5)),2,0)
SNAGLOG1 = con((snags1 < 15 or (CWDnum1  < 60 and CWDcov1 < 10)),1,0)
SL2ZONES = con(snaglog2 == 2, 2, snaglog1)

&echo &off
&return
```

Appendix K – Mt Spokane Database Documentation

Documentation for queries, tables, and reports within the database can be found:

1) In the "Description" field, which can be viewed by right-clicking on the table/query/report and choosing "Properties" from the drop-down menu. Additional explanation for a few key tables/queries are provided below.
2) For tables, additional information may be found in the "Description" for each field. This is located in the Design view for the table.
3) Some variables within the database were calculated in Excel. Often, a database query was used to export data to Excel, the Excel spreadsheet was then edited to make necessary calculations (and document those calculations), and the results were imported back to the database as a new table. This is documented in the table/query descriptions, but also more fully described for certain key variables, below.
4) For more recent versions of Microsoft Access, additional helpful information can be obtained by viewing the "Object Dependencies" for a given table/query/report. This is accessed by right-clicking on the table/query/report and choosing "Object Dependencies", at the bottom of the drop-down menu. It will list objects that depend upon that item and objects that that item depends upon.

Tables

Trees & Snags

Original data for trees and snags are contained in 6 separate tables, identified by the BAF (eg. BAF10, 20, or 40) for each plot. To combine the tree and snag data for all BAF's for querying and reporting, a new table called "BAF102040-Empty-Live stem-Snag records appended" was created. This table contains all the basic data for trees and snags used by most queries and reports in the database. **If changes are made to tree/snag data in the original tables, this table needs to be updated in order for the queries and reports to reflect the new information.** To update the table, select and delete all records within it (but do NOT delete the table itself). Then, run each of the 7 "Append" queries (e.g. "Append BAF10 Live stems with added fields query") – in any order. The data in the table will then be updated and complete. This table also contains many "Empty" records (identified by the "RecordType" field in the table). These are necessary, and are also added to the "BAF102040-Empty-Live stem-Snag records appended" table from the "Empty Records" table through one of the "Append" queries. The "Empty" records allow the tree/snag data to be displayed in histograms in the reports, which include *all* potential data categories, as opposed to just those categories for which there is data in a given plot (e.g. the histograms in the "DBH class report showing ALL DBH classes" versus those in the "DBH class report showing only DBH classes in each plot").

Understory

Original data for understory are contained within the "Plot_data_base" table. To make the data suitable for queries and reporting, it was reformatted in Excel, and imported as a new table called "All understory records for all plots". All the understory-related queries and reporting within the database are based on this table. Therefore, **if changes are made to the original understory data in the Plot_data_base table, the data in this table also need to be updated accordingly.** The updates need to be made manually.

Reports

All reports are based on queries that are titled "Report Query" (e.g. "Report Query Live Stems DBH cls gr 4"). Histograms within a plot have their data source identified separately from the data source for the report itself, however in all cases the histograms have the same data source as the overall report, except for the "Plot Base Report".

The "Plot Base Report" is based on the "Plot Base Report Query". Histograms within the report are based on the following additional queries: "Report Query Live Stems DBH cls gr 4"and "Report Query Snags DBH gr 6". (The data source of a histogram can be identified by right-clicking on the chart and choosing "Properties".).

If the formatting of the Plot Base Report gets messed up, such that it is no longer showing 1 plot per page, it can be fixed by previewing the report, then choosing Page Setup from the File dropdown menu. Change the margins to 0.5 for top, bottom, left & right.

Calculation of Key Variables

The database contains many queries & tables related to these calculations, in addition to Excel spreadsheets, and these are documented below.

1) Canopy Bulk Density (CBD)

CBD was calculated in 2 ways: 1) Using the regression equations for 4 broad fuel types, from Table 4 of Cruz (2003), and 2) On a per tree basis, using the equations in Cruz (2003) pg. 43, with specific foliage weight tree data from Brown (1978) (for all species except birch and aspen) and Loomis & Roussopoulos (1978) (source for aspen & birch data).

The "CBD-Compare methods" query contains CBD values calculated for each plot, using both methods.

a) CBD using Cruz regression equations

"Cruz-Fuel type" table – Assigns each plot to one of the 4 broad fuel types for the CBD regression formulas used in Cruz (2003), Table 4: MC- mixed conifer, DF- Douglas-fir, PP-Ponderosa pine, and LP-Lodgepole pine. These assignments were made by Susan Snetsinger by quickly reviewing the plot-tree species histograms. Unless there was a very strong dominance of DF, PP, or LP, plots were assigned by default to MC. This table is accessed by the “Data for Cruz Regression CBD” query, which generates the data from which CBD is calculated.

“Cruz CBD Coefficients” table – contains the regression formula coefficients from Table 4 of Cruz (2003), and is accessed by the “Data for Cruz Regression CBD” query, which generates the data from which CBD is calculated.

“Data for Cruz Regression CBD” query – Provides the data needed from which to calculate CBD according to the regression equations: appropriate regression coefficients for each plot, based on its assigned fuel type, Trees per acre, and Total Basal area per acre of trees.

“Cruz regression CBD.xls” – Excel file in which the CBD calculations were made. Contains documentation in headers to explain data and equation sources. Imported into database (minus the headers) to create “CBD by Cruz regressions” table.

“CBD by Cruz regressions” table – Contains the final CBD values, which were calculated in Excel. This table was created by importing the Excel file “Cruz regression CBD.xls”.

b) Per tree CBD calculations

“CBDcalc_code” field within the “Tree list” table – Cross-references species codes of trees within the Mt Spokane database with species classification codes used in Brown (1978) or Loomis & Roussopoulos (1978). These 2 papers contain the species-specific information needed for calculating foliage weights, which is then used to calculate CBD on a per-tree basis.

“Foliage Weight Data” query – Provides the base data for making foliage weight calculations. Lists basic tree information for each plot, plus calculates numerous variables required by CBD and foliage weight formulas. Results of this query were exported to Excel file “Foliage_Weight_Data.xls”.

“Foliage Weight Data.xls” – The “All species raw data” worksheet within this file contains the information exported from the “Foliage Weight Data” query. Each record represents a tree within the plot. Each record was sorted & copied to the appropriate worksheet within the file, according to species (using the CBDcalc_code field) and dominance (generally using dbh). Worksheets are labeled according to species/dominance, and correspond to equations for calculating foliage weights in Tables 16 and 17 of Appendix III in Brown (1978). In Tables 16 and 17, the “P1” equations were used, which correspond to the foliage portion of the live crown (see page 8 of the document). Calculations for “A” species (aspen/birch) were based on Loomis & Roussopoulos (1978), Table 1. Foliage weight and associated variables were calculated for each species/dominance class worksheet (associated headers document data or equation source), then all of the records were re-compiled into a single worksheet (called “CBD calc data” in the Excel file) and imported into the Mt. Spokane database in the “CBD calc data” table.

“CBD calc data” table – Contains data generated in the “Foliage_Weight_Data.xls” file, which is needed to calculate CBD on per tree basis.

“CBD calc data_Total Plot Cl by species crosstab” query – uses data from the “CBD calc data” table to calculate average canopy length per plot, which is used in final CBD calculation.

“CBD calc data-Total TPH by species crosstab” query - uses data from the “CBD calc data” table to calculate total trees per hectare per plot, which is used in final CBD calculation.

“CBD calc-Total Plot CFL by species crosstab” query - uses data from the “CBD calc data” table to calculate canopy fuel load per plot, which is used in final CBD calculation.

“CBD calc for plot” query – uses the 3 crosstab queries above to create additional variables and make final calculation of CBD, based on all trees for each plot.

2) Stand Density Index (SDI)

“SDI calc” query – Serves as the basis for the “SDI calc_Crosstab” query, which generates the data needed to calculate SDI.

“SDI calc_Crosstab” query – Generates reformatted data from the “SDI calc” query to calculate SDI for plots. This query was exported to excel file “SDI calculation.xls”, where the calculations were made.

“SDI calculation.xls” – Contains calculations for SDI per plot. SDI calculations were made according to formula in Woodall and Miles (2004), "New Method for Determining the Relative Stand Density of Forest Inventory Plots".

“SDI” table – SDI results imported from excel file “SDI calculation.xls”, “SDIvalue” worksheet.

3) Canopy Base Height

“Canopy Base Height data” query – Generates data for calculating average canopy base height for plots. Data exported to “Canopy Base Height calculation.xls” for calculations.

“Canopy Base Height calculation.xls” – calculations made for canopy base height by plot, exported to database.

“Canopy Base Height” table – contains calculations made in excel spreadsheet above for average canopy base height by plot.

4) Shannon Diversity Index for Species

A cross-tab query was used to generate a listing of trees per acre for plots, by species class, using trees with dbh >4”. This was exported to excel – the query was deleted from the database.

“ShannonDiversityIndex-species.xls” – Calculations were made based on the proportions of Trees per acre in each species category, using the Shannon Diversity index formula (see spreadsheet).

“Shannon Diversity Index Species” table - Imported from “ShannonDiversityIndex-species.xls” and used as source data for reporting this index in database reports.

5) Shannon Diversity Index for Tree DBH

A cross-tab query was used to generate a listing of trees per acre for plots, by dbh class, using trees with dbh >4”. This was exported to excel – the query was deleted from the database.

“ShannonDiversityIndex-dbh.xls” - Calculations were made based on the proportions of Trees per acre in each dbh category, using the Shannon Diversity index formula (see spreadsheet).

“Shannon Diversity Index DBH” table - Imported from “ShannonDiversityIndex-species.xls” and used as source data for reporting this index in database reports.

6) Variance & Skew of DBH

"Variance & Skewness.xls" – Spreadsheet where variance, skew, and std. deviation were calculated for dbh (trees > 4” dbh). Formulas were entered by hand instead of canned “Variance” and “Skew” formulas in Excel, since data was in a format of counts by class (i.e. trees per acre for dbh classes) as opposed to a full listing of the data. (e.g. for a plot with 3 TPA of dbh class 6 and 2 TPA of dbh class 20, to use the canned formulas the data would have need to be written: 6,6,6,20,20). The query in the database used to create the raw data to export to Excel was deleted.

“DBH Variance & Skew” table - Variance, Skewness and stand. dev. of DBH values for each plot. Table was imported from Excel spreadsheet "Variance & Skewness.xls", where calculations were made.

Appendix L - Key to Potential Plant Associations

Adapted from *Forested Plant Associations of the Colville National Forest* (Williams et al 1995). Actual plant associations found in Mt. Spokane 2006-2007 project area highlighted in green.
Page number refers to description in Williams et al (1995).

Douglas-Fir Series

Ninebark and/or oceanspray ≥5%
Twinflower and/or western larch ≥1%……………………………..….PSME/PHMA-LIBOL Association p. 61
Twinflower and/or western larch<1%…………………...…………..……….....PSME/PHMA Association p. 55
Dwarf huckleberry ≥5%……………………………………………………………... PSME/VACA Association p. 76
Big huckleberry and/or low huckleberry 5%…………...…………………....…..…PSME/VAME Community Type p. 82
Common snowberry ≥5%…………………………………...…………..………...PSME/SYAL Association p. 66
Mountain snowberry ≥5%...………………………………………………………..…..PSME/SYOR Association p. 71
Pinegrass or heartleaf arnica ≥5%………………………………...…..…..…………..…PSME/CARU Association p. 49
Bluebunch wheatgrass ≥5%…………………………………….....…...……....…..PIPO-PSME/AGSP Association p. 44

Grand Fir Series

Dwarf huckleberry and/or bearberry ≥5%……………………………..……………ABGR/VACA Association p. 105
Big huckleberry ≥5%…………………………………....…………..……….ABGR/VAME/CLUN Association p. 110
Douglas Maple ≥5%……………………………………………...……...…ABGR/ACGLD/CLUN Association p. 95
Ninebark and/or oceanspray ≥5%…………………………………….……..……....ABGR/PHMA Association p. 100

Subalpine Fir Series

Horsetail species ≥5%………………………………………………….…...………..PIEN/EQUIS Association p. 184
Cascades azalea and/or rusty menziesia ≥5%
Beargrass ≥1%……………………………………….……...………..ABLA2/RHAL-XETE Association p. 152
Beargrass <1%……………………………………...……………….….ABLA2/RHAL Association p. 146
Bunchberry dogwood ≥5%……...……………………………………..……………ABLA2/COCA Association p. 136
False bugbane ≥5%…………………………………………………………………..ABLA2/TRCA3 Association p. 157
Beargrass ≥5%……………………………………………………………………...ABLA2/XETE Association p. 178
Queencup Beadlily ≥5%……………………………………………………………ABLA2/CLUN Association p. 131

Dwarf huckleberry and/or bearberry ≥1%……….…………………………..……….ABLA2/VACA Association p. 162

Big huckleberry and/or low huckleberry 5%………...…………………….……ABLA2/VAME Community Type p. 168

Twinflower ≥5%……………………………………………………….………..ABLA2/LIBOL Association p. 141

Grouse huckleberry ≥5%……………………..……………………………..……….ABLA2/VASC Association p. 173

Pinegrass ≥5%…………………………..……………………….………………ABLA2/CARU Association p. 126

Western Hemlock Series

Devils club ≥5%…………………………………………………..…..………………THPL/OPHP Association p. 251

Oak-fern ≥5% and five-leaved bramble <1%……………………..…….......………TSHE/GYDR Association p. 209

Rusty menziesia and/or Cascades azalea ≥5%……………………………………......TSHE/MEFE Association p. 215

Beargrass ≥5%……………………………………………………………...…...TSHE/XETE Association p. 226

Five-leaved bramble ≥1…………………………………………...……………………TSHE/RUPE Association p. 221

Wild sarsaparilla ≥1…...………………………………………………………………….TSHE/ARNU3 Association p. 199

Queencup beadlily ≥1%…………………..……………………………………………… TSHE/CLUN Association p. 204

Western Redcedar Series

Devils club ≥5%…………………………………………………………………..…THPL/OPHO Association p. 251

Wild sarsaparilla, baneberry, wild ginger, and/or bunchberry dogwood ≥5%………..THPL/ARNU3 Association p. 240

Big huckleberry ≥5%……………………………...…………………..……….….THPL/VAME Community Type p. 256

Queencup beadlily and/or round-leaved violet ≥1%……………………………...….…THPL/CLUN Association p. 246

Other Plant Associations

Whitebark pine…...…………………………………...………….………………………PIAL Association p. 262

Lodgepole pine and russet buffaloberry………………………..……………...………PICO/SHCA Association p. 267

Quaking aspen…………………………………………………..……………...…………...…POTR Association p. 271

Quaking aspen and common snowberry…………………….………..…………………POTR/SYAL Association p. 271

Quaking aspen and pinegrass………………………...………………………………POTR/CARU Association p. 274

Douglas-fir and bearberry……………………………………………………………PSME/ARUV Association p. 277

Pinegrass and Idaho fescue……………………………………………………………..CARU-FEID (PBI)

Sitka alder and mesic forbs…………………………………………………………….. ALSI/mesic forb (PBI)

Appendix M – Plot Data Summaries

Contained in an associated Adobe Acrobat PDF file.