REVISED 'INIMIM FOREST MANAGEMENT PLAN ANALYSIS REPORT

Prepared for
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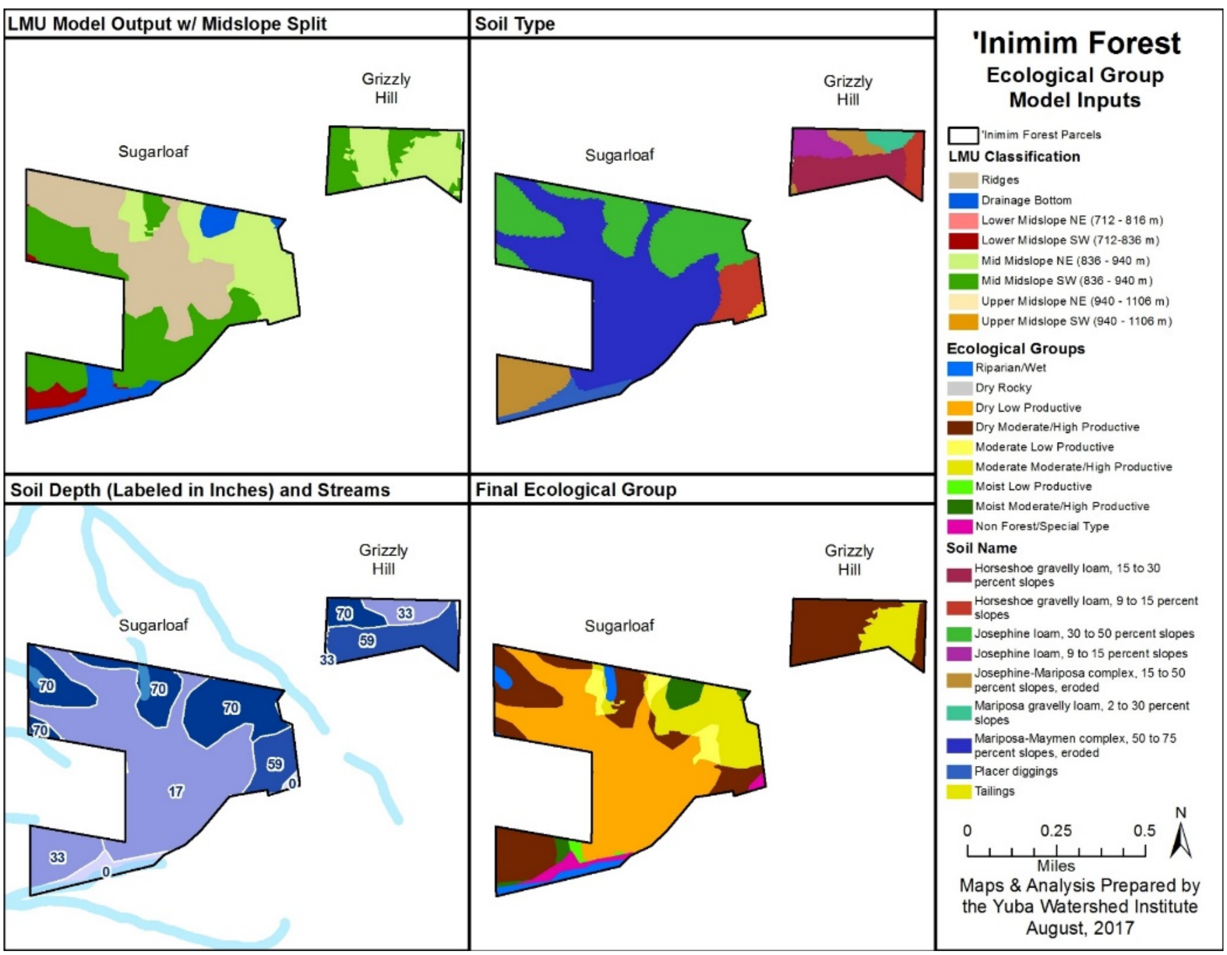

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ABBREVIATIONS OR ACRONYMS

Plant abbreviations are listed in the main body of this analysis document.

Abbreviation of Acronym	**Description**
CDFG	California Department of Fish and Game
CDFW	California Department of Fish and Wildlife (formerly Game)
CNPS	California Native Plant Society
Cov or cov	canopy cover
CWHR	California Wildlife Habitat Relationships (habitat types)
dbh	diameter at breast height (4.5 feet), of tree boles
GIS	geographic information system
GPS	global positioning system
LANDFIRE	Landscape Fire and Resource Management Planning Tool
LMU	landscape management unit
LSOG	Late Successional/Old Growth Index
OS	overstory (trees)
n/a	not applicable
NRV	natural range of variability
US	Understory (trees, shrubs, herbs or grasses)
VCC	Vegetation Condition Class from LANDFIRE

1 Introduction

There were several analyses conducted for the *Revised ‘Inimim Forest Management Plan*. These included:

1) Mapping and characterizing ecological units;
2) Mapping additional management data, including tree mortality, access routes, wetlands, and past treatment areas;
3) Mapping treatment limitations;
4) Mapping recommended treatment priorities; and
5) Fire behavior modeling.

This report contains a description of these analyses, associated data collection, and a brief description of the primary findings. Some of the results were utilized directly in the text of the *Revised ‘Inimim Forest Management Plan*. For example, data on species composition and indicator plants were used directly in the description of ecological groups in the *Revised ‘Inimim Forest Management Plan* without numeric analysis. These data are not analyzed here but data observations are available on the data sheets. Other information, data collection protocols, analysis methods, and a brief summary of findings are included in this document.

2 Ecological Groups

Ecological groups are fundamental to several aspects of the *Revised 'Inimim Forest Management Plan*. They represent groups that share similar natural range of variability (NRV) for vegetation and fire characteristics. In order apply them to the plan, the ecological groups were mapped. The maps were verified in the field with quick plots. More detailed plots were collected at representative sites to aid in characterizing vegetation and ecological conditions of the primary ecological groups that are most prevalent in the 'Inimim Forest.

Descriptions of the ecological groups were included in Appendix A of the *Revised 'Inimim Forest Management Plan* and are not repeated here. The maps are included in the project GIS geodatabase and can be accessed using ArcGIS software (Environmental Systems Research Institute [ESRI] 2017). Here, the process for making the maps, verifying the maps, and associated plot data collection are described. This section contains:

1) A description of the mapping methodology and resulting maps;
2) Plot sampling methodology; and
3) Key findings from the detailed plots.

2.1 Mapping

2.1.1 Methodology

Maps of the ecological groups were developed in a two-step process. First, an initial map of ecological groups was created by applying a model to several input map layers (i.e., soil type). Then, field validation of the initial map was conducted from June to August 2017. This included visiting areas in the 'Inimim Forest to verify that the initially mapped ecological groups matched ecological groups on the ground.

The modeling process was modified from one developed and used to map ecological groups on the Tahoe National Forest by Jo Ann Fites-Kaufman and Steve Beckwitt in 1999-2000. Environmental characteristics of the ecological groups from Fites (1993) were applied using Boolean algebra to the input layers using ArcGIS software. For this plan update, the same process was applied with modifications to the topographic position input layer. Previously, a custom layer was used. Here, the landscape management unit (LMU) algorithm from North et al. (2012) was used in a slightly modified form. The input map layers used included:

1) Soil depth: from the Nevada County soil survey (Brittan 1975), with classes described in the plan update;
2) Topography: aspect categories combined with modified LMU (slopes subdivided into lower-, mid- and upper-slopes); and
3) Soil type: mine diggings and tailings were separated out using the Nevada County soil survey.

Soil productivity levels and soil types were used to classify six soil categories:

1) High Productive: soils greater than 40 inches deep;

2) Moderate Productive: soils between 20 and 40 inches deep;
3) Low Productive: soils between 10 and 20 inches deep;
4) Rocky: soils less than 10 inches deep;
5) Rock Outcrop: no measurable soil depth; and
6) Diggings or Mine Tailings: soils shallow or highly altered by hydraulic mining.

Soil surveys typically map and describe soils as map units comprised of complexes of two or more intermingled soil types, or soil series. Soil complexes are not mapped spatially and, in these models, the input information for the primary (comprising most of the area) soil type was used for ecological group modeling. For most soil complexes, the primary and secondary soil types share similar characteristics used in this modeling. For example, the primary soil type may have deep (high productive) soils, while the secondary soil type could be moderately deep (moderate productive). Both the primary and secondary soil types in this example would fall into a productive soil category, associated with productive ecological groups. When the soil characteristics of the primary and secondary soil types are not the same, then the characteristic for the primary soil type was used.

The topography data were organized into three soil moisture groups:

1) Moist: mid-slope and lower areas on north- and east-facing slopes or lower slopes on south and west aspects;
2) Dry: ridges on all aspects, and mid- and upper slopes on south and west aspects; and
3) Moderate: upper slopes on north- and east-facing slopes.

The LMU model is designed for use in areas with similar landscape topography. For example, an area with deep canyons and tall ridges produces different results in the LMU model than areas with a gentler topography. In gentler topography, ridges may get modeled as comprising a greater proportion of the landscape than in steeper topography. To reflect these differences, the model parameters need to be calibrated for each particular landscape. Landscapes with gentle topography, as are found in this part of the San Juan Ridge area, are the most difficult to calibrate. The LMU model was adjusted to reflect the gentle landscape, but the boundaries between ridges and upper slopes, or bottoms and lower slopes, may not always be precise. These possible imprecise boundaries do not impact ecologically modeling much because the adjacent topographic categories are usually combined into the same ecological group. The calibrations are documented in the geodatabase.

The soil moisture group and soil productivity and type category layers were combined to map the ecological groups. A set of rules, or Boolean algebra models, were coded in the Python programming language to model the ecological group map layer. These Python models are included in the geodatabase.

After the initial maps were created, field validation was conducted by visiting sites in the field or collecting plot data. Areas were visited in the field to verify that the mapped ecological groups were accurate. In addition, the boundaries between contrasting ecological groups were visited to evaluate the location of boundary on maps compared to observations in the field. The emphasis was on the boundaries of contrasting ecological groups, such as between the moist ecological group and dry or moderate groups. Sites were visited where geology results in moisture near ridges and upper slopes, which is not common. In this part of the northern Sierra Nevada, moist or wet soils can occur on upper slopes where there is a change in bedrock type, such as between granite and volcanic bedrock. In these areas, groundwater rises closer to the ground surface resulting in moist soils and a corresponding moist ecological group, or seeps and springs. These areas are difficult to model. These areas were identified and the ecological group map boundary was adjusted.

2.1.1.1 Limitations

Maps approximate actual patterns on the ground and have limitations. In the case of these maps, they portray the overall patterns of ecological groups in the ‘Inimim Forest. Changes in ecological groups on the ground may be gradual and broad or complex (moves up and down unevenly). Where there are broad transitions between different ecological groups, determining where the line should go was based on professional judgement. Most of the ‘Inimim Forest contains broad transitions. In some areas, there are complex boundaries that are not smooth or straight between different ecological groups. Again, this makes drawing a line difficult. Despite these limitations, the maps serve the purpose for supporting an ecological vegetation and fire plan. It is assumed that, for individual projects, site-specific examination and evaluation of the ecological groups will occur when greater detail is needed.

2.1.2 Results Summary

The input maps and resulting ecological group layers are shown in **Figure 1** through **Figure 5** below. In each of the figures, four maps are shown:

1) Topography, top left - landscape map unit (LMU) and aspect classes;
2) Soil type, top right – soil map unit from the Nevada County Soil Survey;
3) Soil depth, bottom left – rooting depth from the Nevada County Soil Survey;
4) Ecological group, bottom right.

Aspect abbreviations are: NE for northeast; SW for southwest.

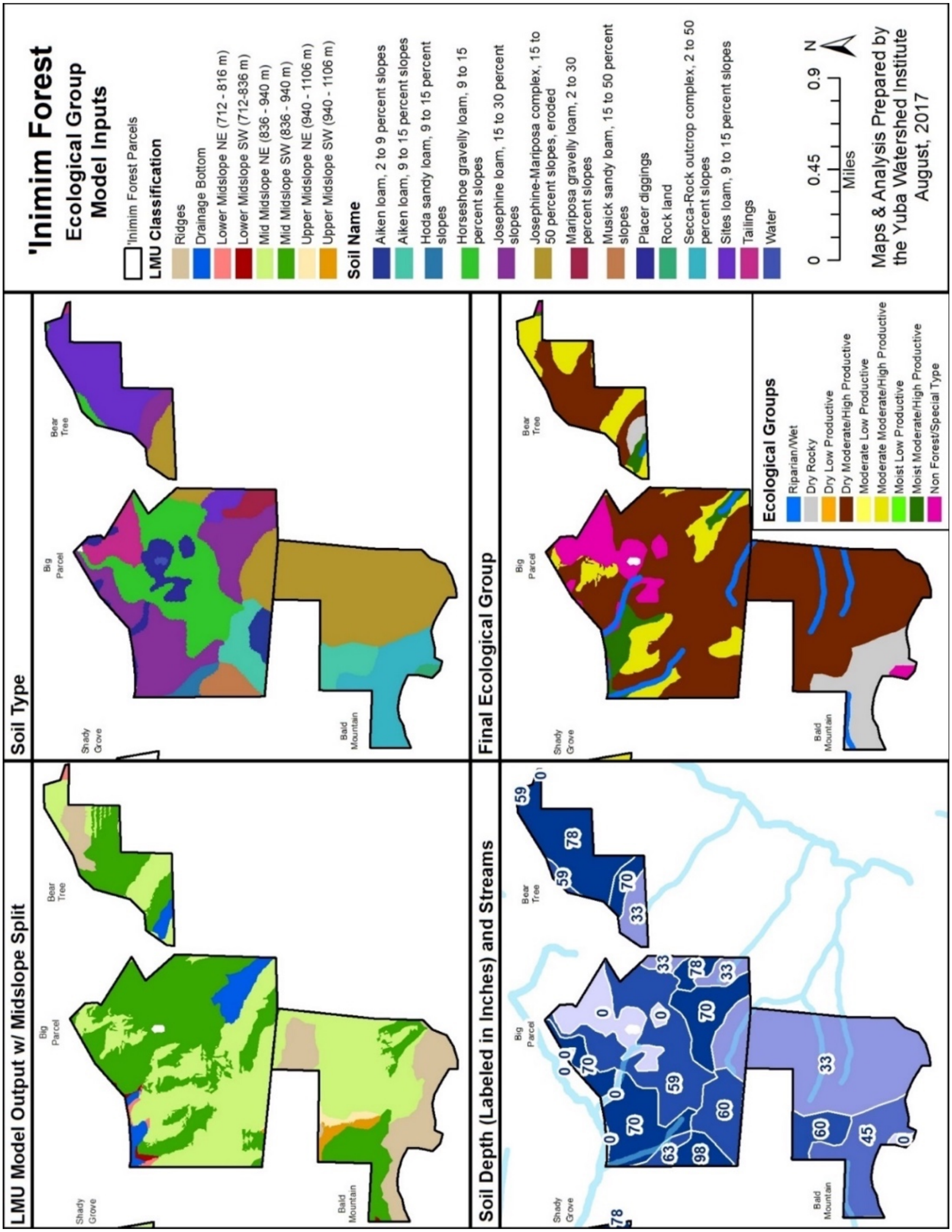

Figure 1. Ecological group model input layers and resulting ecological group map for the Bald Mountain, Big, and Bear Tree Parcels.

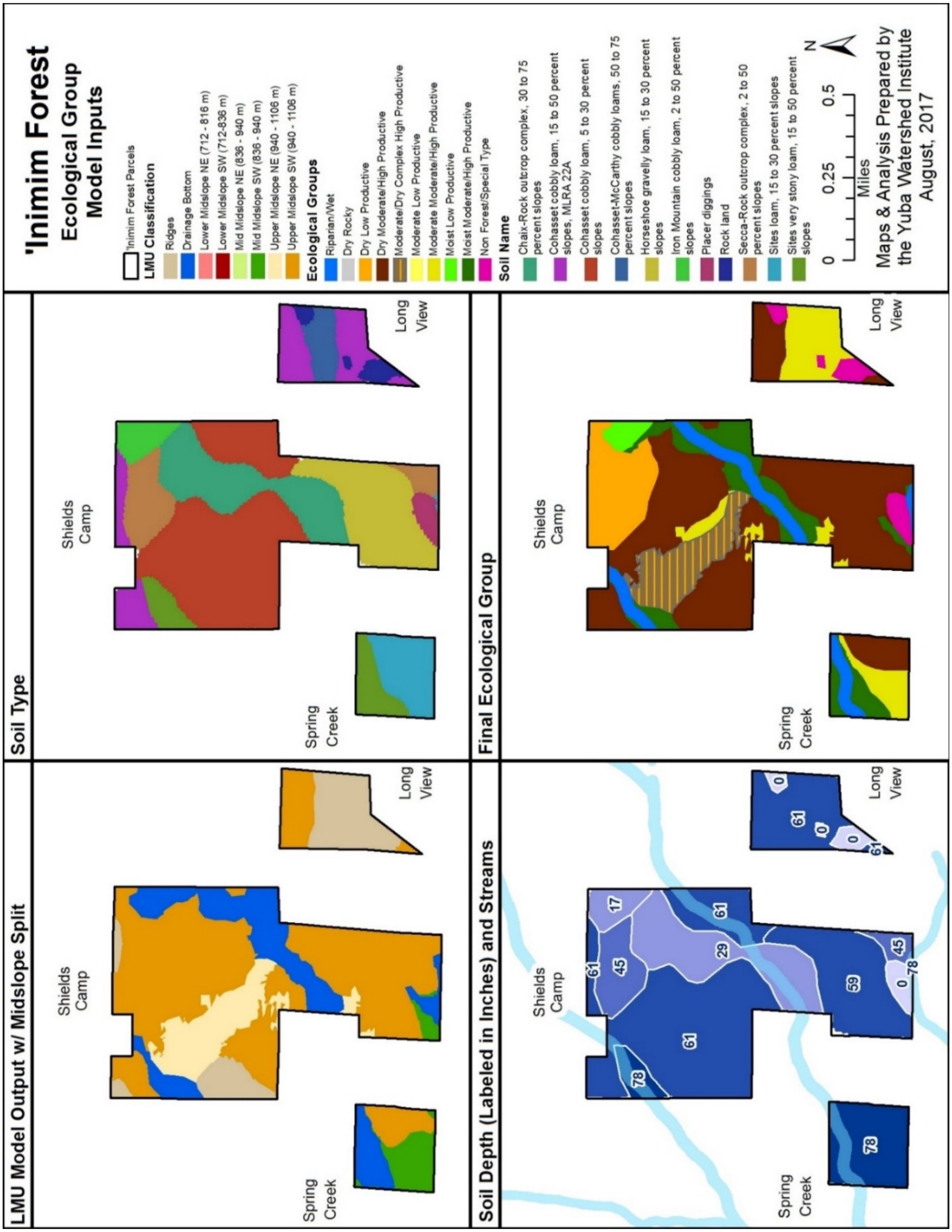

Figure 2. Ecological group model input layers and resulting ecological group map for the Shield's Camp, Spring Creek, and Long View Parcels.

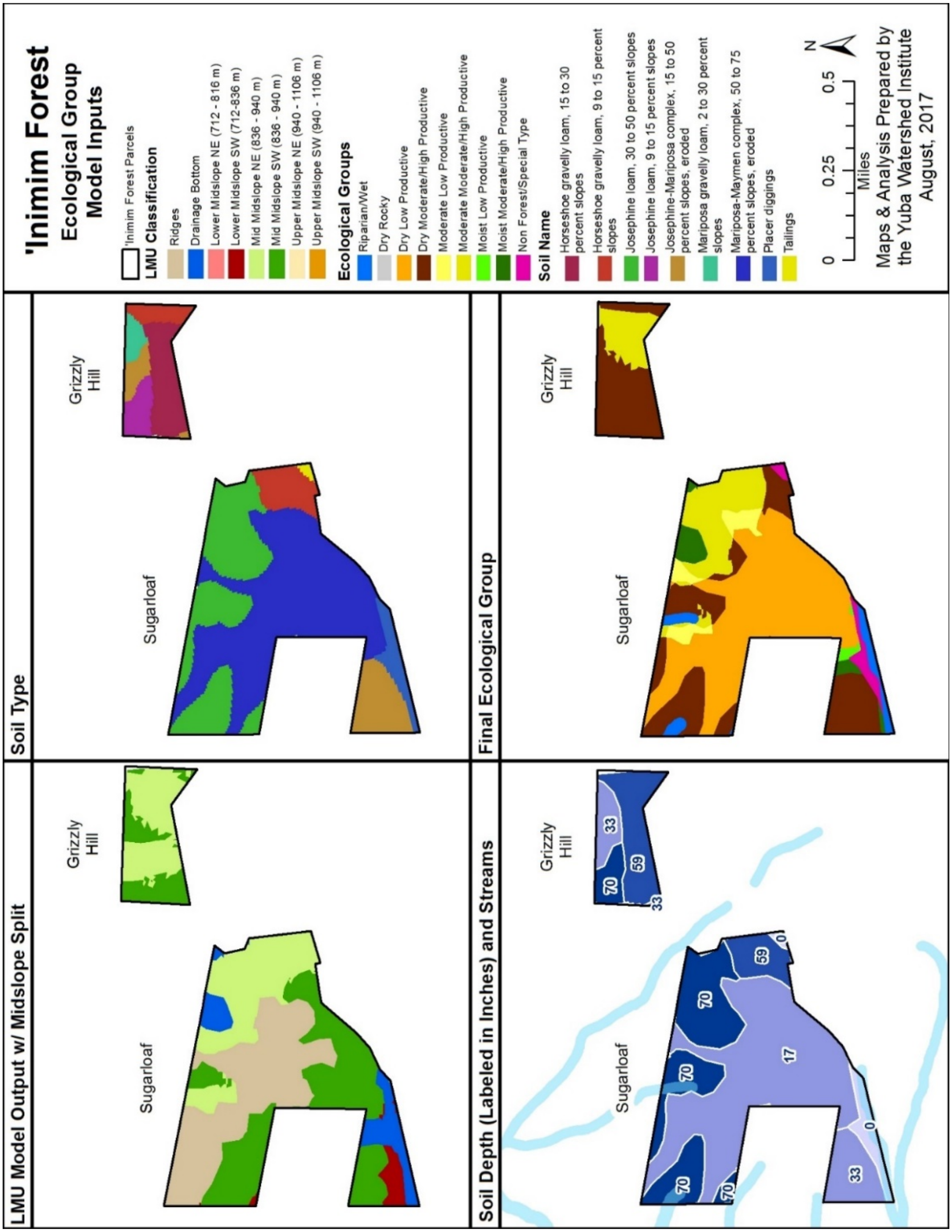

Figure 3. Ecological group model input layers and resulting ecological group map for the Sugar Loaf and Grizzly Hill Parcels.

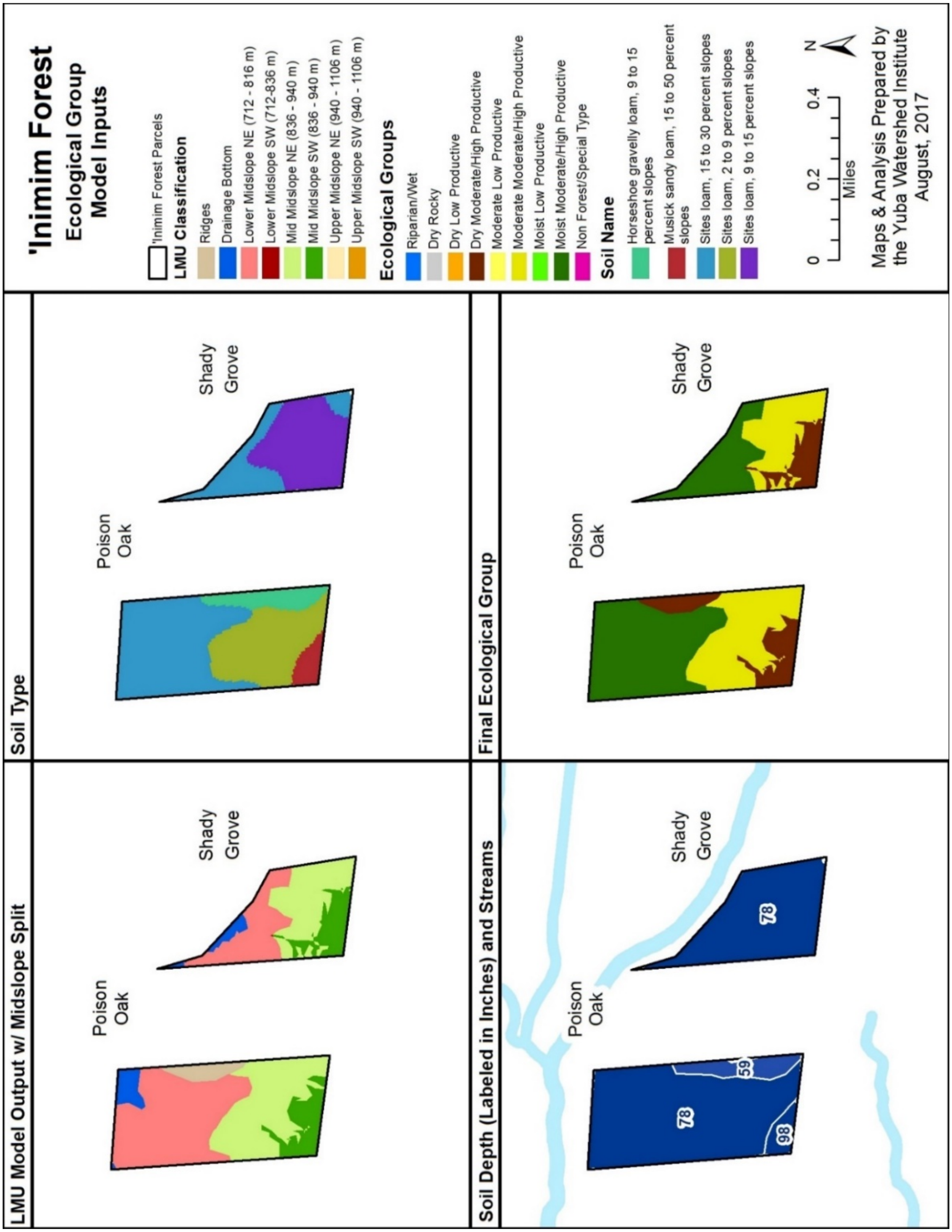

Figure 4. Ecological group model input layers and resulting ecological group map for the Poison and Shady Grove Parcels.

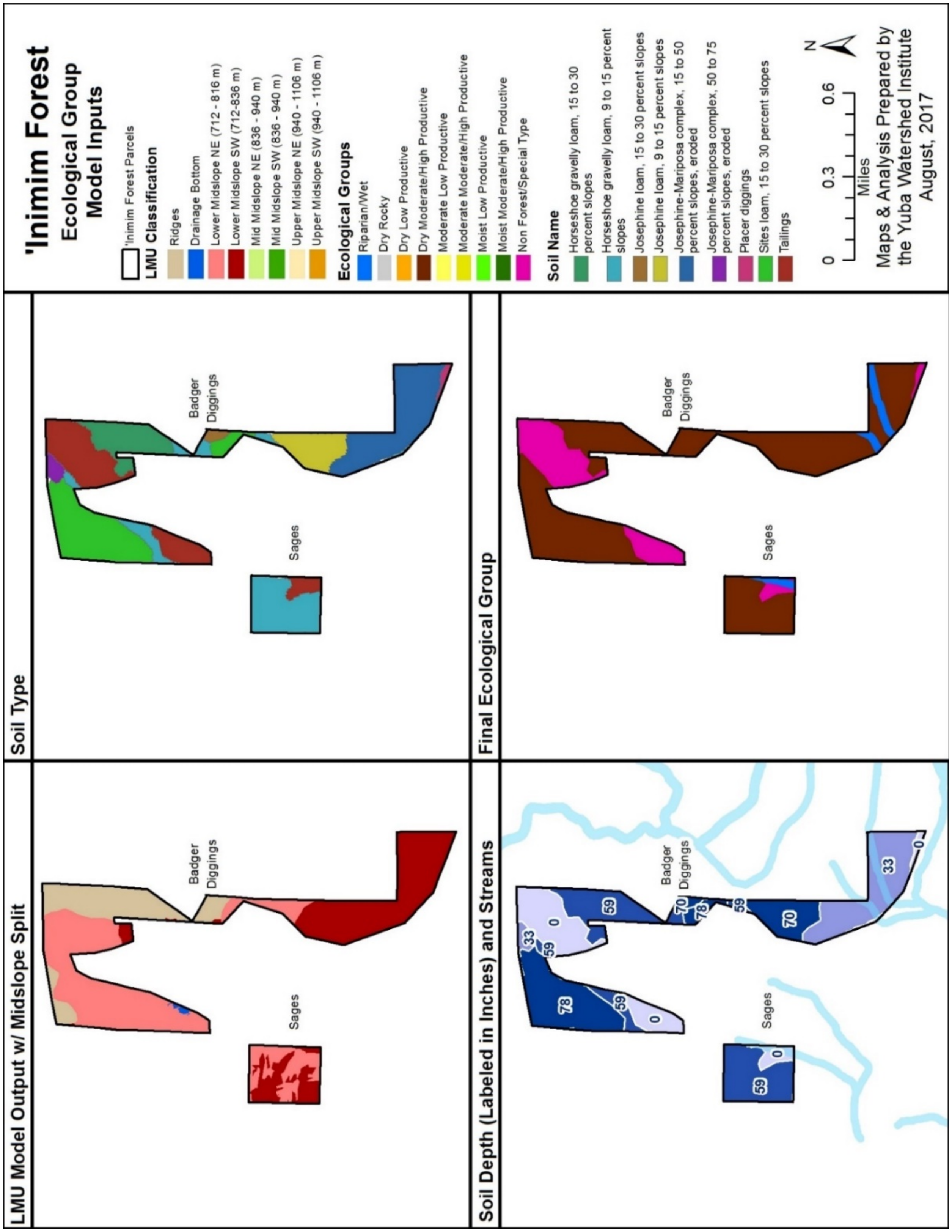

Figure 5. Ecological group model input layers and resulting ecological group map for the Sages and Badger Diggings Parcels.

2.2 FIELD PLOT SAMPLING

Field data was collected from June through August 2017. Two types of field plots were used to map and characterize the ecological groups:

1) **Quick plots –** used during reconnaissance or map validation to identify ecological group; and
2) **Detailed plots –** vegetation composition and structure to characterize ecological groups.

Quick plots were used for field validation of the ecological group maps and to document locations of past management or fine-scale environmental features (i.e., wetlands) important for management. Limited data was collected at each quick plot so that more time was available to survey more of the ‘Inimim Forest.

Detailed plots included a more comprehensive set of data observations and were used to describe the vegetation for the primary ecological groups. The primary ecological groups were defined as those that were most prevalent and were most likely to be managed.

2.2.1 Quick Plot Protocol

The quick plots were used to map locations of the ecological groups in the field. They were used during the initial phase of ecological group mapping, or reconnaissance, and the later phase, field validation. Other information on site history, current conditions (i.e., tree mortality), and special features (i.e., wetlands) was also collected at some sites. More comprehensive mapping of tree mortality, wetlands, uncommon plants (i.e., Indian manzanita, *Arctostaphylos mewukka*), past forest treatments, and existing access routes was documented in a separate data set and is described in Section 3. Over 140 quick plots were collected. The data collected included characteristics of:

1. Ecological group;
2. Plant association (Fites 1993) or vegetation type;
3. Indicator plant species;
4. Invasive plant species;
5. Vegetation Condition Class;
6. Old forest index, or late successional old growth forest (LSOG, Franklin and Fites-Kaufman 1996);
7. Disturbance/treatment history; and
8. Environmental features.

Not all of these characteristics were recorded at each site. The primary characteristics recorded were ecological group and/or plant association. The ecological group can be determined from the plant association. When only the plant association was recorded, the ecological group was added to the database later. The other fields were only entered some of the time. This is because the information was not central to the purpose of the quick plots in validating and improving the ecological group mapping and slowed down completion of the quick plots. For the ecological group map validation, it was more important to collect many quick plots across more of the ‘Inimim Forest than more detailed data.

Data was collected on paper field forms or using the Collector for ArcGIS mobile app on smartphones connected through Bluetooth to an antenna (Bad Elf GNSS Surveyor). The categories for each of the characteristics are described in the data dictionary used in the Collector app. The full dataset is located in the project geodatabase. The categories are also summarized in the subsections below (**Table 1**-**Table 8**).

2.2.1.1 Ecological Group

The ecological groups are described in the *Revised 'Inimim Forest Management Plan*, Appendix A. Ecological groups were based primarily on groupings of mixed conifer plant associations as described in Fites (1993). For vegetation types that are not mixed conifer forests, the groups were derived from the California Native Plant Society – California Department of Fish and Game (CNPS-CDFG) classification of the alliances and associations of the Northern Sierra Nevada Foothills, California (Klein et al. 2007). This included non-forested types such as: whiteleaf manzanita (*Arctostaphylos viscida*), blue oak (*Quercus douglasii)* woodlands, and MacNab cypress (*Hesperocyparis macnabiana).*

For the ecological group, plant association, indicator plants, and invasive plants, a common set of classes to describe the amount (percent cover or percent area) was used (**Table 1**). For the ecological groups, up to three types were recorded at each site. These were recorded in primary, secondary, and third ecological group fields. The first was the most prevalent, the second, the next most common, and the third the least common. The third type was rarely recorded and used when a contrasting group occurred in small amounts. For example, small amounts of wetlands within a mostly dry productive patch. This was to characterize the mosaic of ecological groups that often occurs in mixed conifer forests.

Table 1. Classes and codes used to describe the amount of a plant association or group or cover of indicator or invasive plants.

Classes	% of Area or Canopy Cover
Sparse (S)	Sparse
Low (L)	1 - 10%
Low Moderate (LM)	10 - 25%
Moderate (M)	25 - 40%
Moderate High (MH)	40 - 60%
High (H)	> 60%

Table 2. Ecological groups or vegetation types used in quick plots. Up to three groups/types were noted at each plot. This category also included less common vegetation types or habitats. The corresponding final names are shown to the right.

Ecological Group/Vegetation Type Categories in Quick Plot	Ecological Groups in *Revised 'Inimim Forest Management Plan*
moist mixed conifer	moist productive
dry mixed conifer	dry productive
moderate mixed conifer	moderate productive
dry rocky forest	dry low productive
moist rocky forest	moist low productive
meadow	wetland
riparian zone	riparian/moist productive
springs	wetland
seeps	wetland
rare plant community	MacNab cypress or not specified
invasive plant	n/a
other	Used for dry rocky or other non-mapped types with limited extent.

2.2.1.2 Plant Association or Vegetation Type

Plant associations are based on more detailed ecological classes than ecological groups. The definitions and relationships between plant associations and groups are described in the *Revised 'Inimim Forest Management Plan*.

Plant associations were identified and recorded based primarily on the classifications in Fites (1993) and Klein et al. (2007) (**Table 3**). Up to three types were recorded for each plot. They were recorded in order of extent. The dominant type, or that covering the majority of the area, was entered into the Plant Association Type 1 field. The second most common type was entered into the Plant Association Type 2 field. The third field was used for plant associations that were present but localized or occurring in low amounts. The second and especially third fields were only used when the additional plant associations were highly contrasting types or would warrant specific or specialized management. A mosaic of similar or contrasting plant associations often occur in the western Sierra Nevada landscapes.

Table 3. Mixed conifer plant associations & non-mixed conifer vegetation types. Up to three types were recorded for each plot. MCN is mixed conifer. A look-up table with scientific names is included in **Table 4** below. Manzanita is primarily whiteleaf manzanita but can also include Indian manzanita.

Plant Association/Vegetation Type Abbreviation	Name (common names)
PSME_MCN_ACMA_COCOC	Douglas-fir mcn – big-leaf maple/California hazelnut
PSME_MCN_ACMA_ADBI	Douglas-fir mcn - big-leaf maple /trailplant
PSME_MCN_CONU_COCOC	Douglas-fir mcn – mountain dogwood/California hazel
PSME_MCN_CONU_ADBI	Douglas-fir mcn – mountain dogwood/trailplant
PSME_MCN_COCOC	Douglas-fir mcn/California hazel
MCN_ADBI	Mcn/trailplant
moist_mcn_unknown	Moist mixed conifer, unknown type
PIPO_MCN_CHFO_GABO	Ponderosa pine mcn/bearclover/Bolander's bedstraw
PIPO_MCN_ARC_CHFO	Ponderosa pine mcn/manzanita -bearclover
PIPO_MCN_GABO_POCO	Ponderosa pine mcn/Bolander's bedstraw-milkwort
dry_mcn_unknown	Dry mixed conifer, unknown type
PSME_MCN_TRLA	Douglas-fir mcn/starflower
MCN_SMRA_DIHO	Mcn/false Solomon's seal - Hooker's fairybells
MCN_SYMO_KEGA	Mcn/snowberry/kellogia (ecologically equivalent to Douglas-fir – mixed conifer/hairy honeysuckle in quick and detailed plots)
mod_mcn_unknown	Douglas-fir mixed conifer, unknown type
CYPRESS	MacNab cypress
PIPO_MCN_QUCH_GABO	Ponderosa pine mcn-canyon live oak/Bolander's bedstraw
PIPO_MCN_QUCH_CHFO	Ponderosa pine mcn-canyon live oak/bearclover
PIPO_MCN_ARC	Ponderosa pine mcn/manzanita
dry_rocky_mcn_unknown	Ponderosa -mixed conifer, low productivity, unknown type
PSME_MCN_QUCH_POMU	Douglas-fir mcn - canyon live oak/sword fern
moist_rocky_mcn_unknown	Douglas-fir – mixed conifer, low productivity, unknown type
blue oak woodland	Blue oak
manzanita	Manzanita (primarily whiteleaf, rarely Indian manzanita)
chaparral_unknown	Chaparral (mixed shrub species including manzanita, wedgeleaf ceanothus)

Table 4. Look-up table of plant names and codes. The common names are based upon the Jepson Manual (Hickman 1993).

Common Name	Scientific Name	Abbreviation
bearclover	***Chamaebatia** foliolosa*	CHFO
big-leaf maple	*Acer macrophyllum*	ACMA
birch-leaf mountain-mahogany	*Cercocarpus betuloides*	CEBE
black oak	*Quercus kelloggii*	QUKE
blue oak	*Quercus douglasii*	QUDO
Bolander's bedstraw	*Galium bolanderi*	GABO
California hazelnut	*Corylus cornuta*	COCO or COCOC
California lilac	*Ceanothus species*	Ceanothus
canyon live oak	*Quercus chrysolepis*	QUCH
Douglas-fir	*Pseudotsuga menziesii*	PSME
false solomon’s seal	*Smilacina racemosa*	SMRA
hairy honeysuckle	*Lonicera hispidula*	LOHI
Hooker’s fairy bells	*Disporum hookeri*	DIHO
Indian manzanita	*Arctostaphylos mewukka*	ARMEW
kellogia	*Kelloggia galioides*	KEGA
madrone	*Arbutus menziesii*	ARME
milkwort	*Polygala cornuta*	POCO
MacNab Cypress	*Hesperocyparis macnabiana*	CUMA
mountain dogwood	*Cornus nuttallii*	CONU
ponderosa pine	*Pinus ponderosa*	PIPO
starflower	*Trientalis latifolia*	TRLA
swordfern	*Polystichum munitum*	POMU
trailplant	*Adenocaulon bicolor*	ADBI
wedgeleaf ceanothus	*Ceanothus cuneatus*	CECU
white fir	*Abies concolor*	ABCO
whiteleaf manzanita	*Arctostaphylos viscida*	ARVI

2.2.1.3 Indicator Plant Species

In plots where indicator plants were recorded, one to several indicator plants were entered into the database. Indicator plants are important in identification of ecological groups and plant associations. Indicator plants are those affiliated with certain environmental conditions, such as moist or dry soils. Indicator plants were identified based primarily on Fites (1993). Other indicator plants were identified based on experience of the author in mapping vegetation in the northern and central Sierra Nevada in similar landscapes. Indicator plants are described in the *Revised ‘Inimim Forest Management Plan*, Appendix A. The species names were listed as codes, common names, or scientific names as shown in **Table 4** and **Table 12**. Cover classes were assigned as shown in **Table 1**.

2.2.1.4 Invasive Plant Species

Invasive species were recorded similarly to the indicator plant species. The primary invasive species listed were perennial plants including scotch broom (*Cytisus scoparius*) and Himalayan blackberry (*Rubus armeniacus*).

2.2.1.5 Vegetation Condition Class

Vegetation Condition Class (VCC) is an index of the departure of vegetation structure and composition from NRV (**Table 5**). The VCC is from the national LANDFIRE (Landscape Fire and Resource Management Planning Tool) program, described in Rollins (2009) and LANDFIRE (2017). The determination of VCC was determined visually based on experience in vegetation condition and fire research.

Table 5. Vegetation condition class from the LANDFIRE (see detailed protocol below). NRV is the natural range of variability.

Vegetation Condition Class (VCC)	Description
1	Similar to NRV
2	Low departure from NRV
3	Moderate departure from NRV
4	High departure from NRV
5	Very high departure from NRV

2.2.1.6 Late Successional/Old Growth Forest (LSOG) Index

The Late Successional/Old Growth Forest (LSOG) index was developed by Franklin and Fites-Kaufman (1996). The index is based on describing old forests as a gradient of old forest structure rather than a dichotomous (yes or no) old forest classification (**Table 6**). Old forest structure primarily refers to the presence and density of large trees but can also include large snags and logs. What sizes comprise large trees are defined in Franklin and Fites-Kaufman (1996). What size is considered large varies with forest type (i.e., subalpine vs mixed conifer) and site productivity. For this area, on productive sites (i.e., deep soils), large refers to trees greater than 40 or 50 inches diameter or more at 4.5 feet height. Currently, trees this large are rare because of timber harvest and European settlement over the past 150 years or more (Franklin and Fites-Kaufman 1996). As a result, trees that are near 40 inches diameter in the near future are important old forest structure. For the original *'Inimim Forest Management Plan* and this *Revised 'Inimim Forest Management Plan,* trees greater than 30 inches are also considered old forest structure. They are assigned a lesser LSOG value than areas where trees greater than 40 inches diameter occur. As a result, sites meeting the criteria for high or very high LSOG ratings are rare and only occur in very small areas, within stands.

Table 6. Late Successional Old Forest (LSOG) Index (see detailed protocol below). Based on Franklin and Fites-Kaufman (1996).

LSOG	Description
0	No old forest structure present
1	Scattered old forest structure
2	Low amount of old forest structure
3	Moderate amount of old forest structure
4	High amount of old forest structure
5	Very high amount of old forest structure

2.2.1.7 Disturbance/Treatment History

The type and extent of the treatment was recorded for areas that had evidence of previous management or disturbance, especially timber harvest or mechanical vegetation treatment (**Table 7**). Timber harvest categories were subdivided into three categories based on extent of impact, from the CDFW-CNPS (2016) protocol. The “other” category was used to record non-timber harvest disturbances or past management such as camping. Additional information on management and overall site history was also recorded in the notes field. As the quick plot data forms evolved, non-harvest management, including mining, was added to the Environmental Feature Table in more detail.

Table 7. Vegetation management history, describing the intensity or level of management, especially harvest history.

Management History Type	Definition
Harvest Light	Less than 33% of stand is impacted
Harvest Moderate	Between 33 and 66% of the stand is impacted
Harvest Heavy	More than 66% of the stand is impacted
Other	Management other than harvest, such as camping. Category replaced with more specific, non-harvest management such as mining, in the environmental feature table.

For each of the Management History Types, a corresponding entry was made for the estimated time since the management activity had occurred (**Table 8**).

Table 8. Vegetation management history, the estimated time since the harvest or other management.

Management History, Time Elapsed
1 - 5 Year
5 - 10 Year
10 - 20 Years
20 - 50 Years
50 - 100 Years
Other

2.2.1.8 Environmental Features

The environmental features field was used to record observations on ecological characteristics or disturbances that have limited extent (**Table 9**). This included wetlands, rock outcrops, and non-timber harvest disturbances. They were based on observations in the immediate vicinity of the quick plots. These features were often described in the notes field with more detail, especially when the other category was selected.

Table 9. Presence of various environmental features including rock outcrops, wetlands, and disturbance other than timber harvest.

Environmental Feature
Rock
Water Features
Seeps/Springs
Streamside
Ephemeral Draw
Disturbed
Mining (High)
Mining (Medium)
Mining (Low)
Camping/Recreation
Other

2.2.2 Detailed Plot Protocol

Detailed plots were collected to develop descriptions of the primary ecological groups. Data collected included vegetation composition and structure, environment, and a more comprehensive suite of ecological characteristics in addition to those collected on the quick plots (i.e., wildlife habitat, potential restoration treatment types). Plots were placed in representative locations with a minimum of three detailed plots were sampled in each ecological group. More plots were collected in the widespread ecological groups. In the ‘Inimim Forest the dry productive ecological group occupies the majority of the area. For the more uncommon vegetation types that were not mapped and not likely to be a focus of restoration, such as blue oak, there were no plots collected. It was assumed for these less common types, that management would be based on site-specific examinations and not broader ecological characteristics provided by detailed plots in representative locations.

The data collected included:

1. Overall plot information including location (parcel, map coordinates), date, crew;
2. Environmental conditions (i.e. topography, aspect, vegetation condition class, site history);
3. Vegetation composition, wildlife habitat, old forest;
4. Restoration opportunities;
5. Forest structure (tree dbh - diameter at breast height, species, and, for some trees, height and canopy base height); and
6. Surface fuels (live and dead), including understory plant structure (shrub, herb, grass).

The following sections contain the detailed plot data forms and protocol.

The protocols were based largely on three sources:

1. US Forest Service Ecological Classification (Fites 1993);
2. California Native Plant Society-California Department of Fish and Wildlife Relevé Protocol (CNPS-CDFW 2016);
3. US Forest Service Fire Behavior and Assessment Team (FBAT 2017).

The descriptions of the data protocols below contain a summary of methods used from these sources. More detailed descriptions can be found in these source documents. The location and layout of plots for all types of data (i.e., vegetation composition, fuels, forest structure) was the same (Sections 2.2.2.1-2). The CDFW-CNPS (2016) protocol was used for plot location selection and plot layout methods.

2.2.2.1 Plot Location

Plots were located in areas that had similar species composition and vegetation structure, called “stands” in the CDFW-CNPS (2016) protocol. This is described in the excerpt below:

> *When sampling a stand of vegetation, the main point is to select a sample that, in as many ways as possible, is representative of that stand. This means that you are not randomly selecting a plot, on the contrary, you are actively using your best judgement to find a representative example of the stand.*

For this project, past treatment was also considered in locating plots. Some plots were located in areas treated differently to represent vegetation reflecting different types of treatments (i.e., thinning, mastication, burning) as well as untreated areas.

2.2.2.2 Plot Layout

At each detailed plot location, several different plot shapes were used sample different characteristics (i.e., vegetation composition, forest structure, fuels) (**Figure 6**). The data collected in each plot type are described in the following sections. This includes: ***relevé*** for vegetation composition, habitat, and environment; ***Brown's Planar*** Intercept transect for surface fuels; and ***tree plot*** for forest structure.

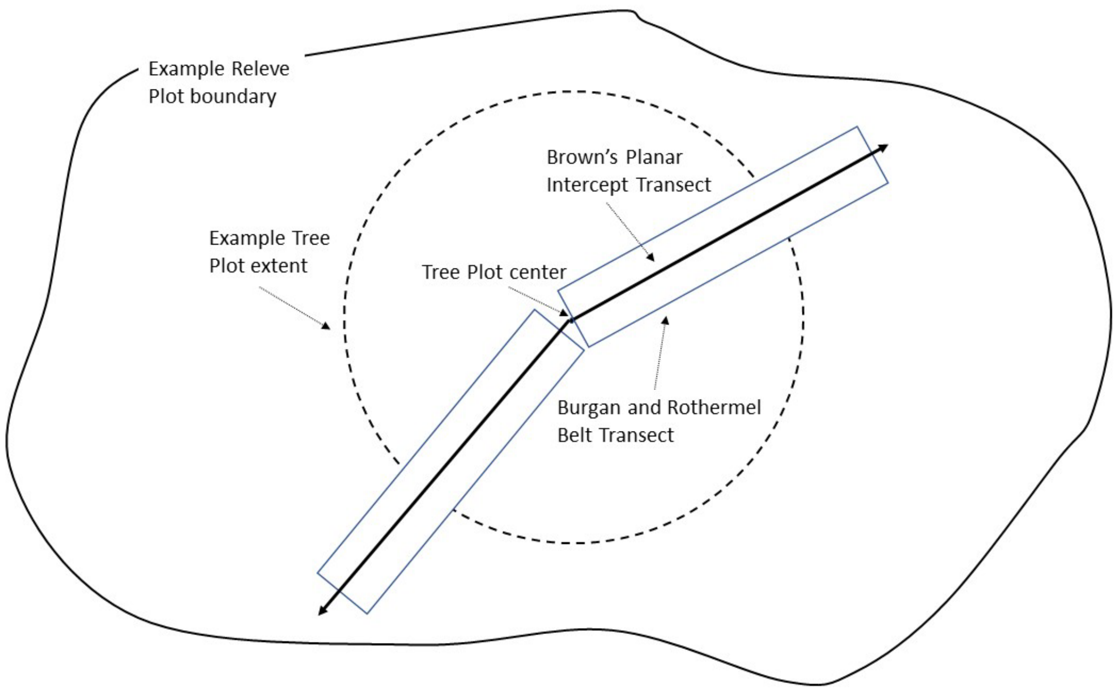

Figure 6. Diagram of shape, size, and location of vegetation composition (Relevé Plot), forest structure (Tree Plot), surface fuels (Brown's Planar Intercept Transect), and live understory live vegetation fuel (Burgan and Rothermel Transect).

2.2.2.3 Data and Collection Methods Overall

The ecological characteristics and data collection method are summarized in **Table 10**. More detail on each are found in the sections that follow.

Table 10. Summary of vegetation composition and condition, environment, history, and potential treatment data collected.

Ecological Characteristic	Metric	Collection Method	Source
Environmental Conditions			
Topography	Classes: ridge, upper 1/3 slope, mid 1/3 slope, lower 1/3 slope, bottom	Visual estimation of location of plot in relation to landscape (i.e. ridges or bottoms).	Fites (1993), North et al. (2012)
Plot Aspect	Degrees	Measured using a compass in a representative direction	FBAT (2017)
Shape	Classes: convex, flat, concave, undulating	Visual estimation of shape of land surface in plot area	Fites (1993)
VCC	Vegetation Condition Class from LANDFIRE (Landscape Fire and Resource Management Planning Tool)	Visual estimate	Rollins (2009), LANDFIRE (2017)
Plot Slope	Percent	Measured using a clinometer for a representative slope	FBAT (2017)
Size of Stand	Classes: < 1acre, 1-5 acres, > 5 acres	Visual estimate	CDFW-CNPS (2016)
Disturbance, Site history, stand age	Notes (for some sites, the CNPS codes)	Visual Estimate. CNPS codes were used on a couple of sites but did not fit conditions; thus, not used on most plots.	CDFW-CNPS (2016) and this project
Habitat and Vegetation Description			
Vegetation Cover by Layer	Foliar cover by physiognomic layer (overstory tree, regenerating trees, shrubs, herbaceous).	Visual estimate by classes. For dominant layers (i.e. overstory tree cover in forests), the class to the nearest 5-10 percent was often estimated.	CDFW-CNPS (2016)
Vegetation composition	Indicator and common species, up to 20 species in general. Indicator plants are primarily from Fites (1993). Shrub and tree composition and cover	Visual estimate of canopy cover by classes in representative area	CDFW-CNPS (2016)
Alliance	Northern Sierra Nevada Foothills Classification types	Visual estimate.	Klein et al. (2007)
Plant Association & Ecological Group	Dominant ecological group and plant associations in patch or “stand”	Visual identification or use of key from Fites (1993). For non-mixed conifer types, use of CNPS-CDFW types.	Fites (1993); Klein et al. (2007)
CWHR	California Wildlife Habitat Relationships (CWHR) cover type and size class	Visual estimate	Mayer and Laudenslayer (1988)
LSOG	Late Successional/Old Growth Index (LSOG)	Visual Estimate	Franklin and Fites-Kaufman (1996)
Environment, History, Potential Treatments			
Restoration options	Classes in the Revised ‘Inimim Forest Management Plan: mechanical thin, hand thin, pile, biomass, pile/burn, rx (prescribed burn), pull invasives (plants), variable dbh thin.	Visual estimate; professional judgement	This project
Evidence of wildlife	Notes	Visual observations of scat, trails, cavities, chewed cones or other signs of wildlife presence or use.	This project

Hardwoods	Presence in overstory or overstory, especially greater than 40%	Visual observation and professional judgement.	This project
Old Forest	Presence of large trees (>30 inches diameter at 4.5 feet height), snags and logs.	Visual observation.	Franklin and Fites-Kaufman (1996)
Heterogeneity	Variation in tree spacing and size	Visual observation	North (2009)

2.2.2.4 Overall Plot

At the top of each plot form (i.e., vegetation composition, fuels, tree) the parcel, crew, plot number, and date were recorded. These are described in **Table 11**.

Table 11. Description of overall plot data collected.

Data Field	**Description**
parcel	Name of ‘Inimim Forest Parcel: Badger Diggings, Bald Mountain, Big, Grizzly Hill, Poison Oak, Sages, Shady Grove, Shield’s Camp, Spring Creek, and Sugarloaf.
plot	Unique number assigned for this project.
crew	Initials of persons collecting data. Included: Jo Ann Fites-Kaufman (JFK), Rusty Fites-Kaufman (RFK), Nathaniel Van Order (NVO), Casey Fites-Kaufman (CFK), and Chris Friedel (CF).
date	Month, day, and year of data collection.

The location of the plot was recorded in the Collector for ArcGIS mobile app. It was optional to also write down data on the form. This data was recorded in the latitude (lat) and longitude (long) fields or as other coordinates in the GPS (global positioning system device) and system (map projection) fields.

2.2.2.5 Environment, Site History, Vegetation Composition and Type, and Potential Treatments

A combination of portions of the CDFW-CNPS (2016) protocol and protocols designed for this project were used to collect data on:

1. plot environment;
2. disturbance, site history, and age of stand;
3. vegetation composition;
4. vegetation type and habitat condition (VCC, CWHR, LSOG, alliance, ecological group, plant association); and
5. potential restoration (types, objectives, approaches).

The data form used to record data for these characteristics is shown in **Figure 7**.The descriptions of data collected generally follows the order on the data sheet below or groups of similar ecological characteristics (i.e., VCC and LSOG). The descriptions of the protocol for ecological characteristics are grouped by similarity in type of data.

Vegetation Composition and Typing					
Parcel:	**Crew:**			**GPS**	system (i.e. NAD 83)
Plot:	**Date:**			**lat:**___________________**long:**_________	

ENVIRONMENTAL CONDITIONS		
	Shape convex flat concave undulating	Plot aspect (deg):
VCC (veg condition class) 1(in NRV) 2(low depart) 3 (mod depart.) 4 (high departure) 5 (v. high departure)		Plot slope (%):
Type/Level of disturbance codes ____/__, ____/__, ____/__, ____/__, ____/__	**Size of Stand** < 1ac 1-5 acres >5 acres	
Site history, stand age, and comments		

HABITAT AND VEGETATION DESCRIPTION

Total veg % _____ **OS Tree cov%** _____ **HW cov%** ____ **Shrub cov%** __________ **US tree cov%** _______ **Herb cov%** _____ **Grass cov%** ____

Species (up to 20 major and indicator species and % cover)

% cover classes: ***t*** *= <1%,* ***1*** *=1-5%,* ***5*** *= 5-15%,* ***15*** *= 15-25%,* ***25*** *= 25-50%,* ***50*** *=50-75%,* ***75*** *= >75%*

Type: i= indicator spp (for ecological groups or plant associations); r= representative/common; inv=invasive

Type	Species	% cover class	Type	Species	% cover class

ALLIANCE (see list):

CWHR (California Wildlands Habitat Relations)	*choose size for dominant layer (i.e. tree for forests or shrub for chaparral)*
Circle: Tree Shrub Herb	**Tree size:** 1 (<1"dbh) 2 (1-6"dbh) 3(6-12"dbh) 4(12-24"dbh), 5 (>24" dbh), 6 (>24" dbh & multilayered)
Cover Type (see list): _____________	**Shrub size: s**1 (<3 yrs old), s2 (>3 yrs, <1% dead), s3 (1-25% dead), s4 (>25% dead)

ECOLOGICAL GROUP (circle): moist prod, moist rocky, mod prod, mod rocky, dry prod, dry rocky, chaparral, other

PLANT ASSOCIATION (see list): Name ____ **Code**______________

LATE SUCCESSIONAL/OLD FOREST INDEX *(LSOG)* **: 0** (no OF structure) **1** (scattered) **2** (low amt) **3** (mod amt) **4** (high amt) **5** (v high amt)

RESTORATION OPTIONS: mech thin hand thin pile biomass pile/burn rx burn pull invasives variable dbh thin
evidence of wildlife
hardwoods present in understory or midstory? Potential to increase cover in canopy to >40%?
old forest? Heterogeneity

Figure 7. Data form used to record vegetation composition, overall conditions, and recommended treatment for detailed plots. Definitions of LSOG are described in **Table 6** above.

The CDFW-CNPS (2016) relevé protocol was used to collect data on plant species composition and environmental conditions. A summary of this protocol is described in the following sections. More detail is found in the CDFW-CNPS (2016) document.

2.2.2.5.1.1 Relevé Plot Size and Shape

The size of relevé plots varied with vegetation type, based on CDFW-CNPS (2016) protocol guidelines:

- Herbaceous communities – 100 m^2 plot;
- Shrublands and riparian forest/woodlands – 400 m^2 plot;
- Upland forest and woodland communities – 1000 m^2 plot.

The relevé plots are not fixed area, meaning the plot size and shape is varied to represent conditions on each site (CDFW-CNPS 2016). Relevés have no fixed shape, but are based on selecting representative, homogenous areas. When a stand or patch of vegetation is linear, or elongated, such as along a riparian area, they may be rectangular. Most of the plots sampled for this project were circular.

2.2.2.5.2 Plot Environment

Data on environment data collected included aspect, slope, topography, shape, and size of the stand. The methods used are described in **Table 10** above.

2.2.2.5.3 Disturbance, Site History, Age of Stand

Evidence of disturbance, past management, and age of the stand were observed and recorded, mostly as comments. CDFW-CNPS (2016) disturbance codes were recorded but were more general than the comments. Evidence of logging, roads, mastication, burning, camping, mining or other past treatments or disturbances were recorded along with a general description of the amount of disturbance and an estimate of how long ago it occurred. Stand age, or age of dominant vegetation (i.e., forest or chaparral) was visually estimated.

2.2.2.5.4 Vegetation Composition

The CDFW-CNPS (2016) protocols for total vegetation cover, vegetation cover by layer, and species composition were used. The methods for each of these canopy cover data are described in the next sections. For all canopy cover measurements, cover was estimated visually and recorded primarily as cover classes (**Figure 7**). In some situations where useful, more specific estimates were made. For example, if tree cover was estimated to be in the class >75 percent but the estimated over was 90 percent, then the value of 90 percent was recorded. Canopy cover of 90 percent is substantially denser, often reflecting a greater departure from NRV, but this condition is not reflected in the CDFW-CNPS classes.

2.2.2.5.4.1 Total Vegetation Cover and Percent Cover by Layer

Total vegetation cover and cover by layer was estimated visually using the CDFW-CNPS (2016) protocol as described in the excerpt below:

> *Record a specific number for the total aerial cover of "bird's-eye view" looking from above for each category, estimating cover for the living plants only.*

The layers included the following:

- Overstory (OS) tree cover (cov) (percent);
- Hardwood (HW) tree cover (percent);
- Shrub cover (percent);
- Understory (US) tree cover (percent) – referring to seedlings and saplings (<1 inch dbh);
- Herb cover (percent);
- Grass cover (percent).

2.2.2.5.4.2 Species Composition

Individual plant species were listed for dominant or characteristic plants and percent canopy cover visually estimated for each plant. Species were selected based upon the CDFW-CNPS (2016) protocol as well as those that are indicator plants in Fites (1993) mixed conifer plant association classification. An excerpt of the CDFW-CNPS (2016) protocol on selection of plant species to list is shown below.

> *List up to 20 species that are dominant or that are characteristically consistent within the assessment area. These species may or may not be abundant, but they should be constant representatives in the survey. When different layers of vegetation occur, make sure to list species from each stratum. As a general guide, make sure to list at least 1-2 of the most abundant species per stratum.*

For this project, invasive species were always recorded in the species list as well as both understory and overstory tree cover for each species.

Species names were recorded using codes or abbreviations (**Table 12**). The codes were based on the scientific names. For most of the indicator plants, the system used by CNPS-CDFW (2016), FBAT (2017), and Fites (1993) was used. In this system, four letter codes are used with the first two letters from the first two letters of the genus and the second two letters are from the specific epithet. For common trees, abbreviations used by FVS (Dixon 2005) were often used, preceded with an O for overstory tree, or a U for understory tree. The FVS abbreviations were used for consistency with those on the tree plots.

Table 12. Abbreviations used for plant species composition data in the detailed and quick plots.

Abbreviations	Common Name	Scientific Name
ACMA, BM	big-leaf maple	*Acer macrophyllum*
ADBI	trailplant	*Adenocaulon bicolor*
APO	dogbane sp.	*Apocynum sp.*
AQFO	crimsome columbine	*Aquilegia formosa*
ARC	manzanita species	*Arctostaphylos*
ARME manzanita	Indian manzanita	*Arctostaphylos mewukka*

ARME, MA	madrone	*Arbutus menziesii*
ARMEW	Indian manzanita	*Arctostaphylos mewukka*
ARVI	whiteleaf manzanita	*Arctostaphylos viscida*
Aster sp.	Eaton's aster	*Symphyotrichum eatonii*
Azalea	western azalea	*Rhodendron occidentalis*
BM	big-leaf maple	*Acer macrophyllum*
BO	black oak	*Quercus kelloggii*
Brodiaea	brodiaea sp.	*Brodiaea sp.*
Bromus	bromegrass	*Bromus sp.*
CADE, IC	incense cedar	*Calocedrus decurrens*
CAMU	multi-stemmed sedge	*Carex multicaulis*
CAPR	harebell	*Campanula prenthanthiodes*
Carex	sedge species	*Carex sp.*
CEBU	birch leaf mountain mahogany	*Cercocarpus betuloides*
CECU, ceanothus	wedgeleaf ceanothus	*Ceanothus cuneatus*
CEIN	deer brush	*Ceinothus integerrimus*
CEPR	prostrate ceanothus	*Ceanothus prostratus*
CHFO	bearclover	*Chamaebatiafoliolosa*
CHME	little prince's pine	*Chimaphila menziesii*
CHMO	western prince's pine	*Chimaphila umbellata var. occidentalis*
Corallorhiza	coral-root orchid sp.	*Corallorhiza sp.*
CLO	canyon live oak	*Quercus chrysolepus*
COCOC, COCO	hazel	*Corylus cornuta*
Coffeeberry	Coffeeberry sp.	*Rhamnus sp.*
CONU	mountain dogwood	*Cornus nuttallii*
CUMA	MacNab Cypress	*Hesperocyparis macnabiana*
DF	Douglas-fir	*Pseudotsuga menziesii*
DIFO	bleeding heart	*Dicentra formosa*
dogbane	spreading dogbane or Indian hemp	*Apocynum androsaemifolium*
EAAS	Eaton's aster	*Symphyotrichum eatonii*
Festuca	fescue species	*Festuca sp.*
ELGL	blue wild ryegrass	*Elymus glaucus*
Elymus	wild ryegrass	*Elymus sp.*
FEOC	western fescue	*Festuca occidentalis*
FERU	red fescue	*Festuca rubra*
GAAP	cleavers	*Galium aparine*
GABO	Bolander's bedstraw	*Galium bolanderi*
GOOB	rattlensake-plantain orchid	*Goodyera oblongifolia*

Gooseberry	gooseberry sp.	*Ribes sp.*
HIAL	white-flowered hawkweed	*Hieracium albiflorum*
Horkelia	horkelia	*Horkelia sp.*
IC	incense cedar	*Calocedrus decurrens*
IRHA, Iris	Hartweg's iris	*Iris hartwegii*
Iris	iris sp.	*Iris sp.*
LANE	Sierra Nevada pea	*Lathyrus nevadensis*
LIDE	tanoak	*Notholithocarpus densiflorus, formerly Lithocarpus densiflous*
LO	live oak	*Quercus chrysolepus*
LOHI	hairy honeysuckle	*Lonicera hispidula*
LON	honeysuckle	*Lonicera sp.*
Lonicera	honeysuckle	*Lonicera sp.*
Lotus	lotus	*Lotus sp.*
Lupinus	lupine sp.	*Lupinus sp.*
MA	madrone	*Arbutus menziesii*
MacNab cypress	MacNab Cypress	*Hesperocyparis macnabiana*
Melica	melic	*Melica sp.*
Penstemon	penstemon sp. or beardtongue	*Penstemon sp.*
Philadelphus	mock orange	*Philadelphus lewisii*
PHLE	mock orange	*Philadelphus lewisii*
PILA, SP	sugar pine	*Pinus lambertiana*
POCO	milkwort	*Polygala cornuta*
POMU	swordfern	*Polystichum munitum*
PP	ponderosa pine	*Pinus ponderosa*
PSME, DF	Douglas-fir	*Pseudotsuga menziesii*
PTAQL	bracken fern	*Pteridium aquilinum var. pubescens*
QUCH	canyon live oak	*Quercus chrysolepus*
QUGA	Oregon white oak	*Quercus garryana var. semota*
QUKE, BO	black oak	*Quercus kelloggii*
Ribes	gooseberry sp.	*Ribes sp.*
RIRO	Sierra gooseberry	*Ribes roezlii*
ROGY	wood rose	*Rosa gymnocarpa*
Rosa	Rose sp.	*Rosa sp.*
RUAR	Himalayan blackberry	*Rubus americus*
Rubus	raspberry, likely glaucous-leaved sp.	*Rubus sp., likely R. glaucifolius*
Rye	rye	*Elymus sp.*
Sanicle	sanicle	*Sanicula sp.*
Scotch broom	Scotch broom	*Cytisus scoparius*

SMRA	false Solomon's seal	*Smilacina racemosa*
soap plant	soap plant	*Chlorogalum pomeridianum*
SP	sugar pine	*Pinus lambertiana*
Stephanomeria	stephanomeria	*Stephanomeria lactucina*
TODI	poison oak	*Toxicodendron diversiloba*
TRLA	starflower	*Trientalis latifolia*
VILO	pine violet	*Viola lobata*
WF	white fir	*Abies concolor*
Yerba Santa	yerba santa	*Eriodictyon californicum*

2.2.2.5.5 Vegetation and Habitat Condition

Several different vegetation type classifications, habitat condition classifications, and an old forest index were used to record information on vegetation structure and plant community composition. A variety of classifications and systems were used because each represents different information that collectively provides a comprehensive overview of habitat, broad-level biodiversity, and restoration opportunities. The data collected included:

1. Alliance (CDFW and CNPS dominant species-based vegetation classification);
2. California Wildlife Habitat Relations (CWHR);
3. Ecological Groups (described in *Revised 'Inimim Forest Management Plan*);
4. Plant Association (subset of ecological groups, see above);
5. Vegetation Condition Class (national fire classification, LANDFIRE 2017); and
6. LSOG (old forest index, see above under quick plots).

Each of these are described briefly below.

2.2.2.5.5.1 Alliance

Alliances are a classification of vegetation based on existing dominant species developed by CNPS and CDFG (Sawyer and Keeler-Wolf 2007). The alliances used for the 'Inimim Forest were from the Klein et al. (2007) classification for the northern Sierra Nevada foothills and Sawyer and Keeler-Wolf (2007) Manual of California Vegetation. The dominant alliance for each plot was recorded. In some cases, more than one alliance was recorded where vegetation dominance was varied. In mixed conifer forests, varying mixtures of conifer species occur at a fine-scale, making selection of a single forest alliance difficult and sometimes arbitrary.

Below is a list of the alliances that were sampled in the detailed plots (**Table 13**). Additional alliances are found in other parts of the 'Inimim Forest and were not recorded on the detailed data plot forms. The additional forest, woodland and shrub alliances that were observed but not sampled are also listed for use in other future analyses or reports. Additional alliances that are non-forested or found in wetlands and riparian areas were not observed in detail and are not listed here.

Table 13. List of alliances sampled in detailed plots or observed in the ‘Inimim Forest.

Vegetation Category	Alliance	Sampled in Detailed Plots
Forest/Woodland	big-leaf maple	x
	birch-leaf mountain mahogany	
	black oak	x
	blue oak	
	canyon live oak	x
	Douglas-fir	x
	gray pine (*Pinus sabiniana*) woodland	
	incense cedar	
	MacNab cypress	x
	madrone	x
	ponderosa pine	x
	Ponderosa pine – Douglas-fir	x
	Ponderosa pine - incense cedar	x
	sugar pine	
Shrubland/Vine	Scotch broom	
	Himalayan blackberry brambles	x
	shrubby Oregon white oak	
	wedgeleaf ceanothus	
	whiteleaf manzanita	x

2.2.2.5.5.2 California Wildlife Habitat Relationships

The CHWR data was collected according to the CDFW-CNPS (2016) protocol. This included cover type, size class, and density (canopy cover). The CWHR cover types were recorded based on Mayer and Laudenslayer (1988). Cover types refer to the dominant species, similar to the alliances described above but are often more general. For example, instead of black oak (alliance), the CWHR classification has a montane hardwood type. Only forest and shrublands were sampled for this project. The tree type was selected when tree cover was greater than 10 percent. Otherwise, the plot was considered a shrub type. Size class was determined based on a visual estimate of the tree dbh and shrub size classes. The size classes and means for estimating them are described below in the excerpts from the CDFW-CNPS (2016) protocol.

> ***Tree Size Class -*** *Circle on of the tree size classes provided when the tree canopy closure exceeds 10% of the total cover, or if young tree density indicates imminent tree dominance. Size class is based on the average diameter at breast height of each trunk (standard breast height is 4.5 ft or 137 cm). When marking the main size class, make sure to estimate the mean diameter of all trees over the entire stand, and weight the mean toward the large tree dbh’s.*

> ***Shrub Size Class –*** *Circle one of the shrub size classes provided when shrub canopy closure exceeds 10 percent (except in desert types) by recording which class is predominant in the survey. Shrub size class is based on the average amount of crown decadence (dead standing vegetation on live shrubs when looking across the crowns of the shrubs).*

In the protocol, either the tree size or shrub size class are recorded, depending on whether the vegetation is considered a forest or shrub type. For this project, shrub size class was also recorded for forests because the shrub size classes provide useful information for fuel evaluation and fire behavior modeling. The shrub size classes include information on the relative age of the shrubs, based on the amount of dead canopy or branches. The number of dead branches increases flammability, fire intensity, and rate of spread.

2.2.2.5.5.3 Ecological Groups

Data collected for ecological groups was mostly the same as in the quick plots (Section 2.2.1.1). The names of the ecological groups are slightly different than those described in the *Revised 'Inimim Forest Management Plan* but the definitions are the same.The names evolved with the mapping process, with the final names and types in the *Revised 'Inimim Forest Management Plan*. Ecological group definitions and descriptions are also in the *Revised 'Inimim Forest Management Plan*. A cross-walk of the names on the data forms and those in the revised plan is shown below (**Table 14**).

Table 14. Cross-walk of ecological group names in the Revised 'Inimim Forest Management Plan and on the detailed plot data forms.

Ecological Groups in *Revised 'Inimim Forest Management Plan*	**Ecological Groups on the Detailed Plot Forms**
Moist Productive	moist productive (prod)
Moist Low Productive	moist rocky
Moderate Productive	moderate (mod) productive (prod)
Moderate Low Productive	moderate (mod) rocky
Dry Productive	dry productive (prod)
Dry Low Productive	dry rocky
Dry rocky	chaparral
Dry rocky	other and chaparral (both identified)
Riparian	other and moist productive (both identified)

In some plots, more than one ecological group was selected. This included where broad transitions between ecological groups occurred, such as between moderate and dry groups on hillsides. Plots in riparian areas with moist productive plant associations (i.e., Douglas-fir – mixed conifer – big leaf maple/California hazel) were recorded as both riparian and moist productive ecological groups.

2.2.2.5.5.4 Plant Association
Plant associations representing the relevé area were identified and recorded as in the quick plots (Section 2.2.1.2). For mixed conifer forests, plant association names were based on Fites (1993). For other vegetation, they were based upon the CDFW-CNPS associations (Klein et al. 2007). The plant associations used are listed in **Table 3** above.

2.2.2.5.5.5 Vegetation Condition Class (VCC)
Vegetation condition classes were visually identified using classes and method as described for the quick plots (Section 1.1.1.1).

2.2.2.5.5.6 Late Successional/Old Forest Index (LSOG)
Late successional/old growth forest index was assigned as described for the quick plots (Section 1.1.1.2).

2.2.2.5.6 Potential Restoration

A visual evaluation of restoration options was made for the plot and surrounding stand. The surrounding stand was included because larger areas are more likely to be restored. Five different aspects of potential restoration were evaluated:

1. Restoration options;
2. evidence of wildlife;
3. hardwood potential;
4. old forest; and
5. heterogeneity.

2.2.2.5.6.1 Restoration Options
Restoration options were recorded both as treatment type categories and comments. The treatment type categories were an earlier version of those described in the *Revised 'Inimim Forest Management Plan*. A cross-walk of treatment types in the revised plan and on the data sheet, and definitions are shown in **Table 15**. Types are listed in order of their appearance on the data sheet.

One or more treatment types were chosen, circled on the form, and briefly described for each sampled area.

Table 15. Cross-walk of restoration options on the detailed plot form and in the Revised ‘Inimim Forest Management Plan. Definitions of the treatments are summarized from those in the Revised ‘Inimim Forest Management Plan.

Treatment Types on Data Forms	**Treatment Types in *Revised ‘Inimim Forest Management Plan***	**Definition Summary**
mechanical thin (mech thin)	mechanical thin	Cut trees and/or shrubs using mechanical equipment such as chainsaws, feller-bunchers, skidders, and tractors.
hand thin	hand thin or hand cut	Cut shrubs and/or small diameter trees using chainsaws, handsaws, axes, and or loppers.
pile	pile	Pile cut trees or shrubs, and sometimes surrounding dead surface fuels (small logs or large branches).
biomass	thin (where thinned vegetation is processed at biomass plant as whole pieces or chips)	Refers to cutting to reduce density of trees or shrubs. Removed trees and shrubs may be utilized for biomass, biochar, timber, or other uses.
pile/burn	pile and burn	Pile cut trees or shrubs, and sometimes surface fuels. Planned burn of piles.
prescribed area burn (rx burn)	prescribed burn, area burn	A planned fire across an area (generally tens of acres or more).
pull invasives	hand pull, pile and burn remove invasive plants	Pull out invasive plants (i.e. scotch broom, Himalayan blackberry, star-thistle) from the ground, including the roots by hand or using hand-tools. Pulled material is piled and burned or removed to avoid seed spread.
variable dbh thin	Variable diameter and density thin	Mechanically thin small, medium and large trees to achieve heterogeneity and desired forest densities and species composition, may include some hand thinning of smaller trees. May also be applied to shrubs.
n/a, not recommended	mastication	Use of mechanical equipment (including grinder, mower, specialized masticator) to chop up shrubs and/or small diameter trees.
described in narrative only	cut hazard or dead trees	Cut hazard or dead trees with chainsaws or mechanical equipment. Trees may be left as downed trees, burned in pieces or removed using mechanical equipment.

2.2.2.6 Forest and Understory Vegetation, and Fuels

Data on forest and understory vegetation and fuels was collected using the Fire Behavior Assessment Team (FBAT) protocol (Fites et al. 2006, Lydersen et al. 2014, Valliant et al. 2014, Ewell et al. 2015, FBAT 2017). Plot transect data collection methods were based on the FBAT protocol. Data included forest structure and composition, dead surface fuels, and understory structure and composition.

2.2.2.6.1 Forest Structure and Composition

Forest structure data collection methods are based on the national Forest Inventory and Analysis (FIA) protocol (USDA 2017). FIA data is collected across all of the USA and provides input data for analysis in the national Forest Vegetation Simulator (FVS) (Dixon 2002, Crookston and Dixon 2005). For each tree (>= 1-inch dbh) measurements were made on dbh, height (all or representative sample), and height to live crown (**Figure 9**). Species and status (dead or alive) were recorded for each tree. For the MacNab cypress site a different protocol was used specific to MacNab cypress (Mallek 2009).

Forest structure and composition were sampled by measuring individual trees within a plot. Trees in variable radius plots were identified with a relaskop (slope-correcting tree prism) (Avery and Burkhart 1983). A prism factor was selected to include between 5 and 10 trees for each plot. A different prism factor was selected for pole-sized (>2.5 to 5.9 inch dbh and overstory (>6 inch dbh) trees. Tree height and height to live crown measurements were completed with a laser rangefinder. Dbh was measured with a diameter tape or Biltmore stick.

Descriptions of the data fields (**Table 16**) and data form (**Figure 8**) are below. For both the pole and overstory tree plots, the prism factor was recorded (circled on form).

Table 16. Description of the data fields on the Forest Structure Data collection form (Figure 8).

Tree Characteristic	metric	Units and significance levels	Source
Tree number (#)	Unique number	Recorded in order from north to south from plot center.	FBAT (2017)
Species	code		FVS (Crookston and Dixon 2005)
Distance	n.a	Used for post-fire data collection	
Dead/Alive	Dead or alive		USDA (2017)
Signs of beetles	Yes or no. Presence of pitch tubes, sloughed and tunneled bark, recently dead trees	Recorded where there was a sign of beetles (yes).	FBAT (2017)
Diameter at breast height (dbh)	Bole diameter at 4 ½ feet height.	Inches, to the nearest ½ inch.	USDA (2017)
Total height	Distance from ground to top of tree.	Feet, to the nearest 1 foot.	USDA (2017)
Height to live crown	Distance from ground to lower tree crown	Feet, to the nearest 1 foot.	FBAT (2017), USDA (2017)

Parcel:						**Crew:**				
Plot:						**Date:**				Prism factor (circle)
Pole Trees: > 1 in (2.5cm) DBH, but <5.9 in. (14.9cm) DBH										**5, 10**
Tree #	Species	***Distance (ft)**	Dead/ Live	signs of beetles	DBH (in)	Total height (ft)	Height to live crown (ft)			Tree Codes
1										BO = Black Oak
2										BM=Big leaf maple
3										MD=Madrone
4										LO=Live Oak
5										DW= Dogwood
6										BL = Blue Oak
7										BU = Buckeye
8										
9										
10										DF= Douglas Fir
11										IC = Incense Cedar
12										PP = Ponderosa pine
13										SP = Sugar pine
14										WF = White fir
15										

* OK to estimate these data, they are not used in data analysis, only to aid in finding trees for post-fire measurements

First White Bar=5 factor
White+Black=10 factor
White+Black+White=20 factor
White+Black+White+Black=40 factor

Start at North and go clockwise when recording trees? Y/N

Parcel:						**Crew:**		
Plot:						**Date:**		Prism factor (circle)
Overstory Trees: ≥6 in. (15 cm) DBH								**20, 40**
Tree #	Species	***Distance (ft)**	Dead/ Live	signs of beetles	DBH (in)	Total height (ft)	Height to live crown (ft)	Notes (only obvious and key--i.e. fire scar or witches broom, nests or white wash from birds)
1								
2								
3								
4								
5								
6								
7								

Figure 8. Form used to collect information on forest structure. Includes data on individual trees within each plot.

The FVS species codes used are listed in **Table 17** below.

Table 17. Tree species codes used on forest structure data form and associated common names. Table used with permission from FBAT.

Code	Common Name		Code	Common Name		Code	Common Name
LP	Lodgepole pine		IC	Incense cedar		TO	Tanoak
PP	Ponderosa pine		WF	White fir		BO	Black oak
JP	Jeffrey pine		RF	Red fir		WO	White oak
SP	Sugar pine		DF	Douglas fir		IL	Interior live oak
GP	Grey pine		MA	Madrone		CL	Canyon live oak
BCP	Bristlecone pine		BM	Bigleaf maple		WJ	Western juniper
KP	Knobcone pine		MD	Mountain dogwood		ES	Engelmann spruce
WBP	Whitebark pine		QA	Quaking aspen		MH	Mountain hemlock
CP	Coulter pine		WA	White alder		RW	Redwood
WP	Western white pine		RA	Red alder		GS	Giant sequoia
US	Unknown softwood		AS	Ash		PY	Pacific yew
UH	Unknown hardwd.		CL	California laurel		CB	California buckeye

Measurement of height to live crown followed the FBAT (2017). The FBAT protocol is based on the FIA protocol (USDA 2017) but with more specific definitions. The FBAT definition for height to live crown includes having enough crown to fill an estimated 30-degree wedge (**Figure 9**).

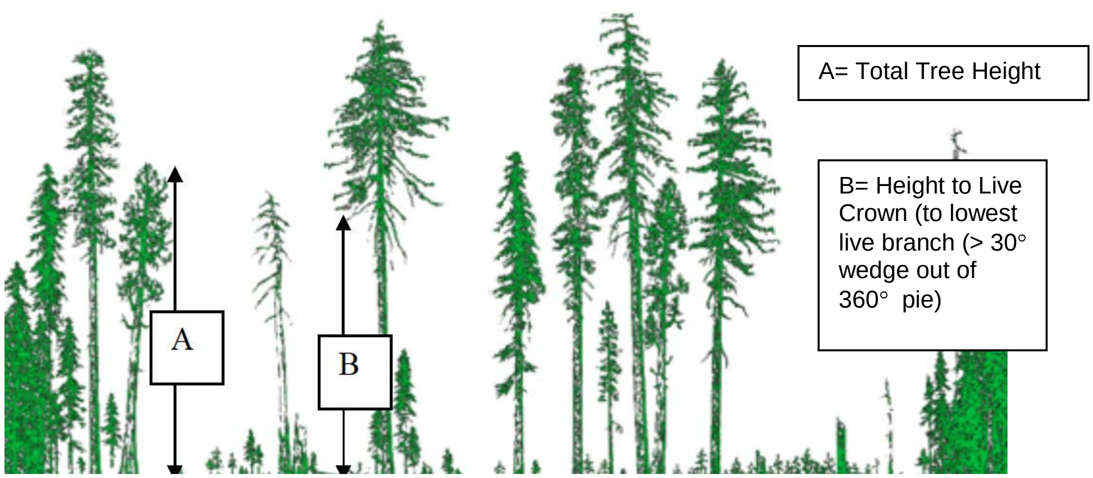

Figure 9. Diagram of a forest cross-section with location and explanation of total tree height and height to live crown measurements. Figure used by permission of FBAT.

2.2.2.6.2 Understory Vegetation and Fuels

Understory vegetation and fuels were measured using the FBAT (2017) protocol based on standard fuels protocols. In each tree plot fuels transects were sampled including one or two Brown's Planar Intercept transects (Brown 1974) and understory vegetation belt transects

(Burgan and Rothermel 1984). The Brown's Planar intercept measures dead surface fuels, including litter, duff, down sticks, and logs. The Burgan and Rothermel belt transects measure live understory vegetation fuels, including species, canopy cover, density, fuel type, and height. There are detailed protocol handbooks for both of these plot types. For detail on these protocols refer to Brown (1974) and Burgan and Rothermel (1984). The FBAT (2017) plot layout methods were followed.

One or two transects were laid out from the tree plot center. Either a random bearing or a representative direction was selected for each transect. Random direction was obtain using a random number generator on a digital device (phone or computer) or spinning a compass ring for a random period, at which time the ending bearing was used. The end of each transect was placed at plot center. The transect origin was located away from plot center to avoid trampling that would compact fuels or crush vegetation. A summary of the data collected, and codes are described below for the dead surface fuels and live understory vegetation fuels. The live understory vegetation fuel protocol also provides vegetation structure, which is also described below.

2.2.2.6.2.1 Dead Surface Fuels

Data on dead surface fuels was collected using the Brown's Planar Intercept Method (Brown 1974), the standard national approach (Lutes and Keane 2017). An excerpt from the FBAT protocol (Ewell et al. 2015) describes measurements:

> *Surface and ground fuels were measured along the same three 50-foot transects as the understory vegetation at each plot. Surface fuel loadings (litter, 1-hr, 10-hr, 100-hr and 1000-hr time lag fuel classes and fuel height) were measured using the line intercept method (Brown 1974, Van Wagner 1968). One and 10-hr fuels were tallied from 0 to 6 ft, 100-hr from 0 to 12 ft and 1000-hr from 0 to 50 ft. Maximum fuel height was recorded from 0 to 6 ft, 6 to 12 ft and 12 to 18 ft. Litter and duff depths were measured at 1 and 6 ft.*

The surface fuels data form in **Figure 10**, from FBAT (2017) used with full permission. The associated definitions for the data fields are in **Table 18**.

Plot information & Fuels data (3, 50ft transects)										
Parcel:			**Crew:**				**Post crew:**			
Plot:			**Date:**				**Post date:**			
transect slope (%):										
				Dead and down count			**Depth nearest 1/2 inch**			
Transect 50-0	Status	Slope (%)	Aspect (deg)	1hr (0-6ft)	10hr (0-6ft)	100hr (0-12ft)	Duff 1ft	Litter 1ft	Duff 6ft	Litter 6ft
1 Azimuth=	Pre									
2 Azimuth=	Pre									
3 Azimuth=	Pre									

1000 hr fuels (0-50 ft)									
Transect	Species	Rotten/ sound	Pre diam (1/2 in)	Post diam (1/2 in)	Transect	Species	Rotten/ sound	Pre diam (1/2 in)	Post diam (1/2 in)

Max fuel height nearest 1/2 inch			Notes: (natural or cut etc)	picture checklist	
0-6 ft	6-12 ft	12-18 ft		0-50	50-0?

Directions or roads to plot:

Figure 10. Data form used to collect dead surface fuel information. Used with full permission of FBAT.

Table 18. Description of data fields in the fuels data form (Figure 10). Detailed definitions and methods are from Brown (1974).

Data Field	Description
Transect slope	Slope steepness along transect (percent)
Transect aximuth	Direction of transect, from origin to end (plot center), in degrees
status	Refers to pre or post fire or other disturbance
slope	Slope steepness of plot overall (along direction plot is facing)
aspect	Direction plot overall faces, in degrees
1-hour	Count of pieces of dead fuels on the forest floor, < ¼ inch diameter, that cross the transect line, excluding litter and duff
10-hour	Count of pieces of dead fuels on the forest floor, ¼ to 1-inch diameter, that cross the transect line
100-hour	Fuels on the forest floor, 1 to 3-inch diameter (includes cones) (tons/acre)
duff	Partially decomposed litter (leaves and needles) on forest floor (tons/acre)
litter	Undecomposed litter (leaves and needles) on the forest floor (tons/acre)

transect	Unique number assigned to each Brown's Planar Intercept transect
species	Species of each piece of 1000-hour fuel intersecting the transect, recorded as tree codes (see Table 16)
Rotten/sound	Condition of 1000-hour fuel piece, rotten is soft and partially decomposed, hard is little to no evidence of decomposition
Pre-diameter (diam)	Diameter, defined as cross-section of 1000-hour piece of fuel
Post-diameter	*n/a (used for post-fire measurements)*
Maximum fuel height (max)	Height of tallest dead surface fuels along the transect, measured along three distance intervals (0 to 6 feet, 6 to 12 feet, and 12 to 18 feet)
Picture checklist	Box marked to note whether picture was taken along transect, from origin to end (0 to 50 feet) and/or end to origin (50 to 0 feet)
Directions or roads to plot	Comments used to note location. Used primarily for plots on wildfires. Not used for this project

2.2.2.6.2.2 Understory Vegetation and Live Fuels

Understory vegetation and live fuels data includes: the plant species, canopy cover, branch density, height, and proportion of dead branches and leaves. For quantifying understory vegetation and live fuels, the FBAT protocol (FBAT 2017) was used. The method for characterizing vegetation within the belt transect is according to Burgan and Rothermel (1984). A summary of the protocol is described below. For more detailed protocol description refer to the Burgan and Rothermel (1984) handbook.

The Burgan and Rothermel (1984) method is based on visual estimates of shrub, herb, and grass cover, density, and live fuel type within a belt transect. Fuel types and density are assigned using photo series from the handbook. The categories vary with leaf type (i.e. needles, evergreen, or soft broad leaves) and density with the compactness and amount of leaves and branches (i.e. sparse to dense). The FBAT protocol uses a belt transect along the Brown's planar intercept transect. The "belt" transect is a long, narrow rectangle-shaped plot that is approximately one yard in width. The width is determined visually, using a measuring device (tape, yardstick or Biltmore stick) in one to several places to calibrate visual estimates of the boundary. Within this belt transect, individual species or lifeform is identified and recorded. For each of the species, the percent cover, representative height, and density class (using Burgan and Rothermel 1984 classes) are recorded. The species are assigned a live vegetation fuel type using a photo-series in Burgan and Rothermel (1984). The fuel type assignments from FBAT (2017) were used.

The data form used is shown in **Figure 11**, and description of the data fields in **Table 19**.

Parcel:	Crew:	Post crew:
Plot:	Date:	Post date:

Herb/Grass: Collected within 3 (1yd x 50 ft) belt transects

Transect	life form: grass, herb, species	% cover estimate	*grass type 1-4, shrub 1-5?	density class 1-6 (low-high)	average height (in)	% alive	% foliage scorched	% foliage consumed
			This is done at the office.					

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*functional type note: if herb has leathery or big leaves & stems=shrub; if fine foliage & stems=grass

Comments/notes: invasive weeds?

plants observed and not captured in transects?

% cover	class
<1	1
1-9'	10
10-24	25
25-49	50

Parcel:	Crew:	Post crew:
Plot:	Date:	Post date:

Shrub/Seedling: Collected within 3 (1yd x 50 ft) belt transects

Transect	life form: shrub, seedling, species	% cover estimate	shrub type 1-5?	density class 1-6	average height (in)	% alive	% foliage scorch	% foliage consum
			This is done at the office.					

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Figure 11. Data form used to collect information on understory vegetation composition, structure, and fuels. Data form is used by permission from FBAT (2017).

Table 19. Data fields and description on the understory vegetation and live fuels form (Figure 11). Cover class values are in Table 20.

Data Field	**Description**
Transect	Unique number corresponding with associated dead surface fuel transect
Life form (grass, herb, species)	Species if known (recorded as codes, Table 11), or if unknown as lifeform (annual grass, perennial grass, herb, shrub, fern, hardwood tree seedlings, conifer tree seedling)
% cover estimate	Visual estimate of canopy cover in percent. Includes cover of plants not rooted in plot but with canopy over plot. Recorded as canopy cover classes (Table 19) or estimated cover to nearest 5 percent
Grass or shrub fuel type	Classes from Burgan and Rothermel (1984), assigned by species if possible using the FBAT (2017) species specific fuel type assignments
Density class	Classes from Burgan and Rothermel (1984)
Average height (inches)	Representative height (to nearest inch) of species within belt transect, average or average of 75^{th} percentile
% alive	Visual estimate of the proportion (percent) of the foliage and branches that are alive
% foliage scorch	Visual estimate of the proportion (percent) of the foliage and branches that were killed and turned brown, but not consumed (burned away) by fire; *n/a for this project*
% foliage consumption (consum)	Visual estimate of the proportion (percent) of the foliage and branches that were consumed (burned away) by fire; *n/a for this project*

Table 20. Cover classes used for understory shrub, herb, and grass cover in belt transects.

Code	**% Cover Classes for each Species**
1	<1%
10	1-10%
25	10-25%
50	25-50%
75	50-75%
100	75-100%

2.3 Analysis Methodology Summary

The methods used to analyze data are described in this section. Standard methodology including existing spreadsheets and modeling software were used.

For all analysis, data was entered into Excel spreadsheets. Most of the vegetation structure and all the fuels data were entered into and processed using FBAT (2017) spreadsheets. Other data, such as canopy cover by layer, were summarized in new spreadsheets, developed for this project.

The NEXUS model (Scott and Reinhardt 2004) was used to predict potential fire behavior. The analysis for each data type is described briefly in **Table 21** below.

Table 21. Summary of analysis methods for each of the major types of data collected in the detailed plots.

Data	Analysis Tool	Comments
Tree Structure	FBAT (2017) tree spreadsheet	Calculates tree list for input into FVS (trees per acre and basal area for tree list, Avery and Burkhart 1983)
Dead surface fuels	FBAT (2017) fuels spreadsheet	Calculates tons per acre by fuel size class (Brown 1974)
Live understory vegetation and fuels	FBAT (2017) live understory fuels spreadsheet	Calculates tons per acre of shrub, grass, and herb fuels (Burgan and Rothermel 1984)
Vegetation Cover by layer	Excel	Entered as recorded in observations. For data recorded as classes, the mid-point was entered
Fire Behavior	NEXUS	Predictions of fire behavior for representative sites by forest condition and treatment types. Data inputs based on plot data and research data on fuels and fire behavior.

The FBAT (2017) fuels spreadsheets incorporate standard methodology for calculating fuels. Excerpts from FBAT (2017) on fuels computations are included below:

> *The [fuel] measurements were used to calculate surface and ground fuel loading with basal area weighted species-specific coefficients (van Wagtendonk et al. 1996; 1998).*
>
> *Biomass of live woody fuels (shrubs and seedlings) and live herbaceous fuels (grasses, herbs, subshrubs) were estimated using coefficients developed for the Behave Fuel Subsystem (Burgan and Rothermel 1984).*

Analysis of dead surface fuels data was based on Brown (1974). Fuel loads and summary statistics were calculated using a spreadsheet.

Summary statistics included the median and range values. Forests and other vegetation do not typically occur in an “average” condition in the landscape but are variable. The median combined with the range (low and high), provide better representations of the variation in vegetation and fuels. In addition, the median is more appropriate than the average for vegetation in most of the Sierra Nevada because the data are usually not normally distributed (required statistical assumption).

Each ecological group is represented by 3 to 12 plots. Most of the plots were located in areas that were likely to receive treatment. This number of plots is a relatively low sample size but since the plots were placed in representative locations that were likely to be treated, they provide a reasonable description of conditions for the revised plan.

The number of plots sampled in each ecological group is roughly proportional to their extent in the ‘Inimim Forest. The most plots were placed in the dry productive group followed by the moderate productive group. There are no plots representing moist or moderate low productive because these were very limited in the ‘Inimim Forest.

A total of 29 plots were sampled. The number of plots collected by ecological group were:

- Dry Productive – 12 plots
- Dry Low Productive – 6 plots
- Moderate Productive – 5 plots
- Moist Productive – 3
- Dry Rocky – 3

The classification of each plot was straightforward but there were some ecological group assignments that varied. One of the moderate plots was classified as moderate low productive but was combined with the moderate productive plots because they were highly similar in vegetation and there was only one of these plots. The moderate low productive ecological group occupied little area in the analysis area.

The moist productive group included two plots that were within 75 feet of intermittent stream channels. There is similarity in the vegetation found in moist productive and riparian areas. These areas tend to have similar composition and indicator plants, such as mountain dogwood and big-leaf maple. In the results sections below, the moist productive data are representative of both the moist productive group and areas mapped as the riparian group.

The dry rocky group results included one plot in MacNab cypress and two in whiteleaf manzanita vegetation types. The MacNab cypress site also has high whiteleaf manzanita cover.

2.4 RESULTS SUMMARY- DETAILED PLOTS

Results for the vegetation data are summarized by ecological groups. The emphasis of the summaries is on the characteristics described numerically in the desired conditions in the *Revised ‘Inimim Forest Management Plan*.

The data includes:

1) Vegetation cover by layer - tree, hardwood, shrub, herb, and grass;
2) Forest structure - tree density, basal area, large tree density, large snag density;
3) Fuels - live and dead surface fuel load.

The data summarized here corresponds with conditions quantified in the desired conditions. This allows for a comparison of the existing vegetation conditions for representative areas with the desired conditions described in the plan. This comparison provides insight into the types and extent of restoration needed to implement the *Revised ‘Inimim Forest Management Plan*. It does not provide a spatial comparison of existing conditions, which require maps of existing vegetation. Existing vegetation maps are not sufficiently detailed for this type of analysis.

Other characteristics used for the ecological group descriptions in the *Revised 'Inimim Forest Management Plan*, but not summarized here include: plant species composition; California Wildland Habitat Relations (CWHR) types; vegetation condition class (VCC); late successional and old forest index (LSOG); description of site history; heterogeneity; potential for hardwood cover; and recommended treatment types. These data are described using narrative (vs. numbers) in the ecological group descriptions or desired conditions.

In the findings below, there are statements comparing the findings with the NRV (natural range of variability). The sources for NRV conditions are the same used for the desired conditions in the *Revised 'Inimim Forest Management Plan*:

- Fites-Kaufman. 2007. Montane and subalpine vegetation of the Sierra Nevada and Cascade ranges. In *Terrestrial Vegetation of California*, pp. 456-501.
- Franklin & Fites-Kaufmann 1996. Assessment of late-successional forests of the Sierra Nevada. In *Sierra Nevada ecosystem project, final report to Congress*, Vol. 2, pp. 627-662.
- Long et al. 2014. *Science synthesis to support socioecological resilience in the Sierra Nevada and southern Cascade Range* (PSW-GTR-247).
- North et al. 2009. *An ecosystem management strategy for Sierran mixed-conifer forests* (PSW-GTR-220).
- North 2012. *Managing Sierra Nevada forests* (PSW-GTR-237).
- Safford & Stevens 2017. *Natural range of variation for yellow pine and mixed-conifer forests in the Sierra Nevada, southern Cascades, and Modoc and Inyo National Forests, California, USA* (PSW-GTR-256).
- van Wagtendonk & Fites-Kaufman 2006. Sierra Nevada bioregion. In *Fire in California's ecosystems*, pp. 264-294.

The emphasis of the results section is a summary of the primary findings by ecological group. More detailed analysis or interpretation of the data would vary by individual project or other uses and is not included.

2.4.1 Vegetation Cover

Vegetation cover for all vegetation and by layer (i.e., overstory trees, seedlings) was analyzed (**Table 22**). There are more similarities than differences in vegetation cover among the ecological groups.

Total vegetation cover was high in all ecological groups, especially the productive groups. Total vegetation cover was mostly greater than 60 percent. All groups also had relatively high seedling and sapling cover (5-10%) compared to NRV. This is a reflection of both fire suppression and the overall high productivity of these sites. Under a natural fire regime, many seedlings would be killed periodically by fire, with few surviving. Productive sites generally have high seedling establishment and survival because of favorable growing conditions.

Overstory tree cover varied more than total vegetation cover, in both the median and range values (**Table 22**). Median values ranged from 42 to 70 percent cover. The range was highly varied, from 5 to 95 percent. The lowest levels of overstory tree cover (0 and 5 percent) reflect sites with high tree mortality. In the dry productive group, median overstory tree cover was 42 percent. This reflects the prevalence of ponderosa pine-mixed conifer/bearclover type within the dry productive group. It has dense shrub cover but tree cover is moderate because the bearclover suppresses tree regeneration. Compared to NRV, overstory tree cover is much greater now, except where black oak is or was prevalent (i.e., co-dominant or dominant).

Shrub cover was greatest in the dry groups, especially the dry productive group. This was due to the prevalence of bearclover. Other dry sites had high whiteleaf manzanita cover. Moist sites and dry rocky sites had the highest herb and grass cover. Moderate to high levels of California hazel, other deciduous shrubs occurred in the moist and riparian sites. Less specific information is available on NRV of understory plants. Moist sites mostly had a diverse cover of shade-tolerant, understory flowering plants and grasses. Shrub cover on moist sites was also likely higher and patchier. Dry rocky sites typically have and had a diverse cover of understory flowering plants and grasses that prefer sunny openings. Shrub cover in whiteleaf chaparral and forests with bearclover is likely similar to historic levels. On other sites, Similarly, herbs and grasses are sparse now compared to NRV conditions under a natural fire due to more open overstory canopy. Many native grasses and understory flowering plants are adapted to fire and have increased reproduction, flowering, and vigor following fire.

Table 22. Vegetation cover by ecological group. The rows are the median and range (low to high) values for each ecological group.

Value	Total Vegetation Cover (%)	Overstory Tree Cover (%)	Hardwood Cover (%)	Shrub Cover (%)	Seedling /Sapling Tree Cover (%)	Herb Cover (%)	Grass Cover (%)	number of plots
Dry Productive								
median	90	42	10	63	10	3	1	12
range	50 to 98	5 to 95	1 to 65	0 to 95	1 to 60	1 to 5	0 to 10	
Dry Low Productive								
median	60	50	23	33	7	1	1	6
range	40 to 70	0 to 80	2 to 60	1 to 70	5 to 30	0 to 5	0 to 5	
Moderate Productive								
median	80	60	5	15	25	5	1	5
range	75 to 95	40 to 80	0 to 20	0 to 50	10 to 70	1 to 50	0 to 50	
Moist Productive								
median	75	70	35	15	5	25	5	3
range	75 to 90	50 to 70	25 to 50	1 to 60	2 to 50	20 to 50	5 to 5	
Dry Rocky								
median	75	70	35	15	5	25	5	3
range	75 to 90	50 to 70	25 to 50	1 to 60	2 to 50	20 to 50	5 to 5	

The dry productive ecological group was sampled more than other groups because it was the most prevalent in the landscape. The dry productive group was separated into three variants for analysis (**Table 23**) to reflect differences in vegetation:

- ***Hardwood–mixed conifer*** **–** dominated or co-dominated by black oak, madrone and /or canyon live oak;
- ***High tree mortality*** – dry areas where more than 80 percent of the trees died recently;
- ***Ponderosa pine-mixed conifer*** **–** remainder of the dry productive group.

The greatest differences between the three variants was in overstory tree and hardwood tree cover. Forest sites with high tree mortality had very low tree cover, less than 15 percent. Forest sites with high hardwood cover had the greatest median tree cover, at 60 percent. The hardwood variant also had the highest median hardwood cover, although it varied widely. Seedling/sapling tree cover was also highly variable. However, the median and high range of seedling/sapling tree cover were the highest in the hardwood variant. Most of this regeneration was conifers, especially incense cedar. More conifer regeneration is a continuation of a trend that started with fire suppression. Conifers increase with fire suppression and then shade out oaks. Compared to NRV, hardwood cover (especially black oak) is lower. More areas in the ‘Inimim Forest landscape would have structure similar to the hardwood-mixed conifer sites described above.

Table 23. Vegetation cover for three variants of the dry productive group. These include: high tree mortality, high hardwood, and remaining plots. For each type, the first row is the median and the second row is the range (low to high) values.

Value	Total Vegetation Cover (%)	Overstory Tree Cover (%)	Hardwood Cover (%)	Shrub Cover (%)	Seedling/Sapling Tree Cover (%)	Herb Cover (%)	Grass Cover (%)	number of plots
Ponderosa Pine – Mixed Conifer								
median	60	40	5	40	1	1	0	5
range	50 to 95	30 to 95	1 to 5	0 to 95	1 to 5	1 to 5	0 to 10	
Hardwood – Mixed Conifer								
median	90	60	30	75	25	5	5	5
range	90 to 95	40 to 65	15 to 65	40 to 90	5 to 60	2 to 5	0 to 5	
High Tree Mortality								
range	95 to 98	5 to 15	5 to 40	75 to 90	15 to 30	1 to 5	1 to 10	2

2.4.2 Forest Structure

Forest structure characteristics analyzed include the size, density and arrangement of live and dead trees. The forest structure metrics, or measurements, used were:

1. **Live tree density** – number of live trees per acre greater than 1-inch dbh (diameter at 4.5 feet height);
2. **Dead tree density –** number of dead trees per acre greater than 1-inch dbh;
3. **Live tree basal area** – total cross-sectional area of live tree boles greater than 1-inch dbh per acre;
4. **Dead tree basal area –** total cross-sectional area of dead tree boles greater than 1-inch dbh per acre;

5. **Large tree densities –** number of live trees per acre greater than 20, 30, and 40 inches dbh;
6. **Large snags –** number of dead trees per acre greater than 20 inches dbh.

2.4.2.1 By Ecological Groups

This section primarily describes forest structure results for the productive and low productive ecological groups comprised of mixed conifer and hardwoods (i.e., black oak). Results from the one forest plot sampled in the dry rocky group, in a MacNab cypress stand, are also briefly described.

Although the data on forest structure is limited due to the small number of plots, there are some interesting findings (**Table 24**). First, median and maximum live tree densities were high to very high compared to NRV. The high median values in the dry and moderate ecological groups were especially high compared to NRV. The maximum levels measured were very high, often described as "dog-hair" thickets. While dog-hair thickets do not occur everywhere, they are common throughout the 'Inimim Forest. These or other forest patches or stands with dense structure have very low resilience to drought, climate change, fire, and insects and pathogen outbreaks. Small pockets or clumps of dense forest may be within NRV but entire stands with this structure were considered rare. The forest structure data were consistent with general observations across the 'Inimim Forest.

Table 24. Summary of forest structure data by ecological group. Abbreviations: no is number; ac is acre. Dry rocky types are not included since they are dominated by chaparral.

Value	Live Tree Density (no/acre >1"dbh)	Dead Tree Density (no/ acre, >1"dbh)	Live Tree Basal Area (square feet/ ac)	Dead Tree Basal Area (square feet/ ac)	Large Trees >20"dbh (no/ac)	Large Trees >30"dbh (no/ac)	Large Trees >40"dbh (no/ac)	Large Snags >20"dbh (no/ac)
Dry Productive								
median	175	0	200	0	14	5	0	0
min	25	0	45	0	0	0	0	0
max	2673	102	400	260	67	41	7	50
Dry Low Productive								
median	209	88.5	150	15	4.5	0	0	0
min	75	0	20	0	0	0	0	0
max	749	226	375	80	54	14	3	0
Moderate Productive								
median	429	192	295	25	27	3	0	0
min	120	0	145	0	2	0	0	0
max	1088	253	360	40	64	29	4	0
Moist Productive								
median	64	191	245	5	38	27.5	5	0
min	30	173	240	5	30	25	0	0
max	98	208	250	5	46	30	10	0

The median tree densities on moist productive sites were lower than on the dry and moderate sites, but the maximum was still high compared to NRV. There were fewer moist productive plots sampled than the dry and moderate productive type, so the moist site data may not be as representative of the ‘Inimim Forest. For example, dense forests were observed at number of moist sites in much of the Poison Oak Parcel.

Tree densities in the MacNab cypress plots were comparable to research on MacNab cypress (Mallek 2009), at 9,000 stems per acre. This is at the higher end of stem densities Mallek (2009) found at different sites across California.

Basal areas were also high, especially in the moderate and moist productive sites. When multiple large (>30 inch dbh) trees are present, basal area is generally higher than when large trees are absent. Almost all the plots had few large trees in the sampled moist and moderate group plots. This means that high basal areas measured reflect high densities of small and medium trees. Compared to NRV, basal areas were higher in most areas.

The median basal area on dry productive sites was lower than for all other productive ecological groups (moderate and moist). This is mostly because dry productive plots included two sites with high tree mortality. Several other plot sites had high bearclover cover and lower tree densities. Basal area on the dry low productive sites were the lowest of all ecological groups because of lower site productivity and harsher growing conditions. However, the levels were not as low as thought to occur historically, under NRV conditions.

The large tree density data from plots along with observations made during quick plot sampling are interesting in two ways. First, the presence of any large trees, greater than 30 or 40 inches dbh is uncommon given the extensive logging and mining history in the northern Sierra Nevada. However, these levels were far lower compared to historic, NRV large tree densities. There were moderate densities of trees 20 to 30 inches dbh, with a number of these trees nearly 30 inches dbh. This is similar to forest descriptions in the original *‘Inimim Forest Timber Harvest Implementation Plan* (YWI 2000). The YWI (2000) old growth forest map and description identified some areas with “near old growth” forest.

Since the previous inventory (YWI, 2000), there have evidently been a number of trees that have grown larger than 30 inches dbh and a few that have grown larger than 40 inches dbh, based on collected data and observations. Most of the large trees observed looked relatively young, based on branch size, bark plate size, and canopy architecture. High soil productivity and higher than average precipitation for the Sierra Nevada result in high tree growth rates. Large trees grow relatively fast in these favorable conditions. Old forest structure is recovering relatively fast based on field observations. The growth rates will increase, with more of the large tree centered restoration that the YWI has been conducting as volunteers. This included thinning small trees around large ones, freeing up water and nutrients for the large trees.

Tree sizes in the MacNab cypress plot were much smaller, reflecting the harsh growing site and slow growth. The largest trees were 10 to 12 inches dbh. Of the eight stems greater than 6 inches dbh measured, six stems were in clumps. The smaller stems ranged in diameter from 0.3 to 1-inch dbh.

2.4.2.2 Dry Productive Group - Variants

The forest structure data for the dry productive group was subdivided into three variants, as with vegetation cover data (**Table 25**). Snag density was substantially greater in the high mortality sites, compared to all other sites, as expected. There was a corresponding drop in live tree basal area in these areas. The hardwood-conifer sites had the greatest density of trees greater than 30 and 40 inches in diameter. The greatest live tree density and basal area were found on the hardwood-conifer sites. Forest structure was variable in the ponderosa pine mixed conifer sites. The basal area and density of large trees was lower than the hardwood – conifer type.

Table 25. Summary of forest structure for three variants of the dry productive ecological group.

Value	Live Tree Density (no/acre >1"dbh)	Dead Tree Density (no/ acre, >1"dbh)	Live Tree Basal Area (square feet/ac)	Dead Tree Basal Area (square feet/ac)	Large Trees >20"dbh (no/ac)	Large Trees >30"dbh (no/ac)	Large Trees >40"dbh (no/ac)	Large Snags >20"dbh (no/ac)
High Mortality								
median	165	47	68	210	3	3	0	34
min	25	18	45	160	0	0	0	18
max	304	76	90	260	6	6	0	50
Hardwood-Conifer								
median	144	0	256	0	30	11.5	1	0
min	88	0	120	0	20	5	0	0
max	2673	102	400	40	67	41	3	0
Ponderosa Pine-Mixed Conifer								
median	194	0	200	0	0	0	0	0
min	84	0	110	0	0	0	0	0
max	606	2	280	20	28	28	7	12

2.4.3 Surface Fuels

Surface fuels were sampled and calculated using methods from the Fire Behavior Assessment Team (Vaillant et al. 2014). The fuel characteristics summarized here are shown in **Table 26** below. This includes live and dead surface fuels broken out by different type or size.

The categories of dead surface fuels are described in terms of 1-hour, 10-hour, 100-hour or 1000-hour. These correspond to the amount of time it takes each size of fuel to equilibrate to ambient air humidity. For example, the 1-hour fuels are small sticks, less than ¼ inch in diameter. They will equilibrate to ambient humidity within 1 hour. These different classes are used as inputs to fire behavior models.

Table 26. Surface fuel characteristics and descriptions.

Surface Fuel Characteristic	**Definition**
Grass/Herb	grass and herb fuels (tons/acre)
Seedling	tree seedling (< 1-inch diameter at 4.5 feet) fuels (tons/acre)
Shrub	Shrub fuels (tons/acre)
All Live	Sum of grass, herb, tree seedling, and shrub fuels (tons/acre)
1-hour	Fuels on the forest floor, < ¼ inch diameter, excluding litter and duff (tons/acre)
10-hour	Fuels on the forest floor, ¼ to 1-inch diameter (tons/acre)
100-hour	Fuels on the forest floor, 1 to 3-inch diameter (includes cones) (tons/acre)
1-100 hour	Sum of 1-hour, 10-hour, and 100-hour fuels (tons/acre)
duff	Partially decomposed litter (leaves and needles) on forest floor (tons/acre)
litter	Undecomposed litter (leaves and needles) on the forest floor (tons/acre)
duff and litter	Sum of duff and litter
1000 hour	Fuels on the forest floor greater than 3" diameter, including logs (tons/acre)
1-1000 hour	Sum of 1-100 hour and 1000 hour (tons/acre)
all surface	Sum of 1-1000 hour and duff and litter (tons/acre)

Table 27. Summary of surface fuels from the detailed plots. Abbreviations: ac for acre; hr for hour; min for minimum; max for maximum. Definitions of categories in Table 5. Individual plots are shown for the dry rocky types, since they vary widely and include two vegetation types (ARVI or whiteleaf manzanita and MacNab Cypress).

Value	Tree seed-ling (tons/ac)	Shrub (tons/ ac)	Grass /herb (tons/ ac)	all live (tons/ ac)	1-hr (tons/ ac)	10-hr (tons/ ac)	100-hr (tons/ ac)	1 to 100-hr (tons/ ac)	Duff (tons/ ac)	Litter (tons/ ac)	1000-hr (tons/ac)	all dead	all surface (dead and live)	fuel height (ft)
							dry productive							
median	0.0	4.6	0.01	7.7	0.2	1.3	3.1	4.1	36.2	12.7	0.8	61.9	67.3	1.0
min	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.4	6.5	0.5	0.0	12.8	25.1	0.2
max	37.5	75.7	0.27	75.7	0.8	4.2	20.1	24.8	64.1	26.8	12.0	85.3	112.2	2.3
							dry low productive							
median	0.5	4.6	0.01	5.1	0.6	4.1	1.6	7.8	22.8	6.3	1.5	39.0	47.4	0.7
min	0.0	0.6	0.00	2.0	0.1	2.4	1.1	6.4	0.0	0.0	1.1	9.8	14.9	0.5
max	1.4	13.1	0.01	13.1	0.7	6.1	6.3	8.9	31.0	6.6	2.0	45.4	52.2	1.0
							moderate productive							
median	0.1	0.1	0.01	0.6	0.5	2.9	7.1	10.5	38.1	11.2	4.3	66.8	67.4	1.2
min	0.0	0.0	0.00	0.0	0.3	2.1	1.8	4.3	14.3	7.2	1.4	53.5	53.5	0.6
max	1.3	0.4	0.65	1.4	0.8	15.0	45.8	61.7	40.5	16.5	12.1	99.1	100.5	1.6
							moist productive							
median	1.3	1.3	0.02	4.3	0.2	1.6	1.5	2.3	44.8	11.6	3.6	64.8	70.6	0.5
min	0.2	0.7	0.01	1.5	0.1	0.6	0.0	1.7	22.7	0.8	0.5	42.9	44.4	0.5
max	6.0	3.0	0.06	6.8	0.4	2.5	1.5	4.3	46.7	17.4	17.5	66.3	71.5	26.3
							dry rocky							
ARVI	0.0	228.6	0.00	228.6	0	0	0	0.0	0.0	0.1	0.0	0.1	228.7	22.0
ARVI	0.0	107.5	0.00	107.5	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	107.9	10.0
MacNab Cypress	113.0	25.0	0.02	138.0	1.0	0.7	4.1	5.8	17.5	0.0	0.0	23.3	23.3	10.0

There was high variability fuel loading for all fuel categories (**Table 27**). Compared to NRV, total dead surface fuel loading was high to very high (median values were 39 to over 60 tons per acre), in all but the low productive types. Median levels of combined 1 to 100-hour fuels were less than 10 tons per acre, but litter and duff loadings were very high. The high litter and duff fuel loads reflect both fire suppression and the high productivity of the sites. Productive sites have higher tree and vegetation densities, with more litter and duff production. Litter and duff are deep throughout most of the ‘Inimim Forest. In very dry fire weather conditions, litter and duff contribute more to fire intensity, spread, and severity. Total litter and duff consumption have become more common with warmer winters and longer, hotter summers, as well as frequent drought.

Live fuels, including shrubs and seedlings, had high loading in numerous areas. The understory live fuel loading reflects the higher seedling densities. The age of shrubs affects their flammability. Older shrubs have higher levels of dead branches or decadence, making them more flammable. Most of the shrubs sampled in the detailed plots and observed were older and decadent, including bearclover and whiteleaf manzanita. This resulted in high to very high live fuel loadings. In chaparral, these high loadings are not outside of NRV, but historically there was more of a mosaic of different ages and sizes and less uniform older chaparral.

3 Additional Data Collection

In addition to the data collected on ecological groups and forest conditions summarized in section 2, more comprehensive mapping of wetlands, uncommon plants, existing access routes, past forest treatments, and tree mortality was conducted from June to August 2017. This data was used during development of priority treatment areas. The scopes and methodologies for each category of data collected is summarized below.

3.1 WETLANDS

‘Inimim Forest parcels were surveyed for the wetland features. Data was collected using the Collector for ArcGIS app on an Apple iPhone SE using a wirelessly connected Bluetooth GPS antenna (Bad Elf GNSS Surveyor). Focus was placed on collecting features that were not mapped on existing data layers, such as major streams. The number and type of features collected for each parcel is summarized in **Table 28**. Four of the parcels (Sages, Badger Diggings, Poison Oak, and Shady Grove) were not surveyed. The data were stored in the project geodatabase.

These data were not meant to be comprehensive. A reasonable effort was made to map all large, easily identifiable features, including meadows, ponds, and perennial streams. Other features (seeps, springs, ephemeral streams, and ephemeral pools) were mapped as they were observed but were not searched for in a systematic way. Therefore, there is a high probability that the results of this survey underrepresent these features, especially on the parcels not surveyed.

Table 28. Wetland features collected during field surveys. Grey rows represent parcels that were not surveyed.

PARCEL	POINT		LINE		POLYGON		
	Seep	Spring	Ephemeral Stream	Perennial Stream	Meadow	Pond	Ephemeral Pool
Sages							
Badger Diggings							
Sugarloaf			2				
Grizzly Hill							
Poison Oak							
Shady Grove							
Big Parcel		1	1	1		7	
Bald Mountain					1		
Bear Tree							
Shady Creek							
Shield’s Camp	1		4	1	8	4	
Long View							

3.2 UNCOMMON PLANTS

‘Inimim Forest parcels were surveyed for occurrences of three uncommon plant species: Indian manzanita, Oregon white oak, and MacNab cypress. Data was collected using the Collector for ArcGIS app on an Apple iPhone SE using a wirelessly connected Bluetooth GPS antenna (Bad Elf GNSS Surveyor). These populations may be managed differently than more common plant associations. For example, the Indian manzanita or Oregon white oak may be left uncut because of their uncommon status even though a prescription calls for the removal of shrubs and small diameter trees in the area where they are growing. The mapped occurrences are summarized below in **Table 29**. The data were stored in the project geodatabase.

Table 29. Rare plant occurrences by 'Inimim Forest parcel.

PARCEL	Indian manzanita			Oregon white oak			MacNab cypress		
	Points	Polygons	Acres	Points	Polygons	Acres	Points	Polygons	Acres
Bald Mountain			-	41		-	1	1	13.8
Shield’s Camp		2	1.6	28		-			-
Long View	1		-			-			-
TOTAL AC.			1.6			-			13.8

Again, for this data collection effort, the following parcels were not surveyed (Sages, Badger Diggings, Poison Oak, and Shady Grove). Also, these plant occurrences were not collected in a systematic way; rather, known populations were visited and assessed. There is a low probability that other populations of these species exist elsewhere in the ‘Inimim Forest and were not mapped.

3.3 ACCESS ROUTES

Access routes not shown on existing maps were mapped during field surveys. Data was collected using the Collector for ArcGIS app on an Apple iPhone SE using a wirelessly connected Bluetooth GPS antenna (Bad Elf GNSS Surveyor). A total of 52 line features were collected on 7 parcels (Sugarloaf, Grizzly Hill, Big Parcel, Bald Mountain, Bear Tree, Shield’s Camp, and Long View). The data were stored in the project geodatabase.

Each line feature was identified as one of three types: skid trail, walking trail, or abandoned road. These access routes will be used to plan treatment area boundaries and skid trail and landing locations. Again, these data are not meant to be comprehensive; they were collected as observed in the field during other surveys. If needed, additional surveys should be conducted to map additional routes, especially on parcels not surveyed.

3.4 PAST FOREST TREATMENTS

Information on past treatments was collected from: paperwork (maps and project descriptions) located in YWI’s storage files; interviews with long-time forest residents and YWI affiliates (Bob Erickson and Jerry Tecklin); and field mapping of obvious treatment areas observed during parcel surveys. Field data was collected using the Collector for ArcGIS app on an Apple iPhone

SE using a wirelessly connected Bluetooth GPS antenna (Bad Elf GNSS Surveyor). Digitization of hand drawn maps and printed paper maps was done using ArcGIS software. The information found on past forest treatments is summarized in **Table 30**. Spatial data is stored in the project geodatabase.

Table 30. Summary of past 'Inimim Forest management actions (treatments). CWF is Chris Friedel.

Parcel	Type	Year	Notes	Area (sq m)	Area (acres)
Big Parcel	Plantation	1964	Machine planted ponderosa pine following clearing of manzanita brushfield with tractor. Digitized from project maps.	288740	71.3
Bald Mountain	Plantation	1964	Ponderosa pine planted March 1964. Machine planting following clearing of manzanita brushfield with tractors. Digitized from project maps	58454	14.4
Shield's Camp	Salvage Logging	1978	Logged by Jerry Tecklin. Digitized from verbal accounts.	82783	20.5
Shield's Camp	Salvage Logging	1985	Logged by Jerry Tecklin. Exact year unknown. Digitized from verbal accounts.	28371	7.0
Shield's Camp	Prescribed Burn	1996	Digitized from hand-drawn map.	144508	35.7
Bald Mountain	Mastication	1996	Mapped by CWF in field. Commercial thin plus mastication. Lots of pine mortality here.	942	0.2
Bald Mountain	Mastication	1996	Mapped by CWF in field.	67897	16.8
Shield's Camp	Mastication	1997	Digitized from verbal accounts (Jerry Tecklin, Bob Erickson). Boundaries are approximate.	62422	15.4
Shield's Camp	Mastication	1997	Digitized from verbal accounts (Jerry Tecklin, Bob Erickson). Boundaries are approximate .	46023	11.4
Shield's Camp	Salvage Logging	1997	Logged by Jerry Tecklin. Digititized from verbal accounts.	40246	9.9
Shield's Camp	Prescribed Burn	1997	Digitized from verbal accounts (Jerry Tecklin). Very light burn. Fuel conditions were not favorable.	112742	27.9
Big Parcel	Mastication	2001	7 units. Digitized from YWI solicitation (paper map)		183.0
Bald Mountain	Mastication	2001	Digitized from YWI solicitation (paper map)		80.0
Big Parcel	Thinning (Commercial)	2004	Silverthorn commerical and pre-commercial thin. Digitized from BLM map (Ed Bollinger)	174782	43.2
Shield's Camp	Thinning (Commercial)	2005	Mapped by CWF in field. Commercial thin plus mastication. Lots of pine mortality here.	33044	8.2
Spring Creek	Thinning (Stand)	2005	Digitized from verbal accounts (Jerry Tecklin & Bob Erickson)	41784	10.3
Shield's Camp	Understory Fuels Reduction	2010	Mapped by CWF in field	92122	22.8
Shield's Camp	Understory Fuels Reduction	2010	Mapped by CWF in field	111771	27.6
Bald Mountain	Meadow Restoration	2010	Digitized from hand-drawn map	4773	1.2
Big Parcel	Understory Fuels Reduction	2010	Digitized from hand-drawn map of work around Long Ravine trail	313850	77.6
Sugarloaf	Mastication	n/a	Mapped by CWF in field. Manzanita has grown back 2-5 ft. This may also be old BLM clearcut.	25915	6.4
Grizzly Hill	Mastication	n/a	Mapped by CWF in field.	27789	6.9
Grizzly Hill	Mastication	n/a	Mapped by CWF in field.	44127	10.9
Grizzly Hill	Mastication	n/a	Mapped by CWF in field.	36680	9.1
Bald Mountain	Mastication	n/a	Mapped by CWF in field.	36779	9.1
Bald Mountain	Mastication	n/a	Mapped by CWF in field. 2-6 ft regrowth of manzanita.	92464	22.8
				Treatments since 1995	**636.29**

3.5 TREE MORTALITY

An effort was made to quantify the spatial extent and distribution of tree mortality in the ‘Inimim Forest. The levels of tree mortality in the ‘Inimim Forest, and in the Sierra Nevada range generally, increased substantially between 2015 and 2017, due to a combination of prolonged drought stress and bark beetle attack. In the ‘Inimim Forest, ponderosa pines have been the predominant tree species that has died, although sugar pines have also been affected. Future management efforts may target removal of dead trees, especially near roads or other infrastructure, and knowing the location and extent of dead stands will aid in planning and prioritizing treatments.

Individual dead tree and stands were mapped during field surveys using the Collector for ArcGIS app on an Apple iPhone SE using a wirelessly connected Bluetooth GPS antenna (Bad Elf GNSS Surveyor). Additional polygons were added later in ArcGIS by tracing obvious patches of mortality from a basemap aerial photograph (dated 9/30/2016). The first method was not a comprehensive survey of the ‘Inimim Forest; mortality patches and dead individuals were mapped opportunistically during surveys for other features. The desktop method did not allow for mapping of current extent of mortality since the aerial photograph was from the previous year. However, taken together, these two methods yielded a reasonable minimum extent of tree mortality (about 57.4 acres). **Figure 12** shows the spatial distribution of mortality. Spatial data is stored in the project geodatabase.

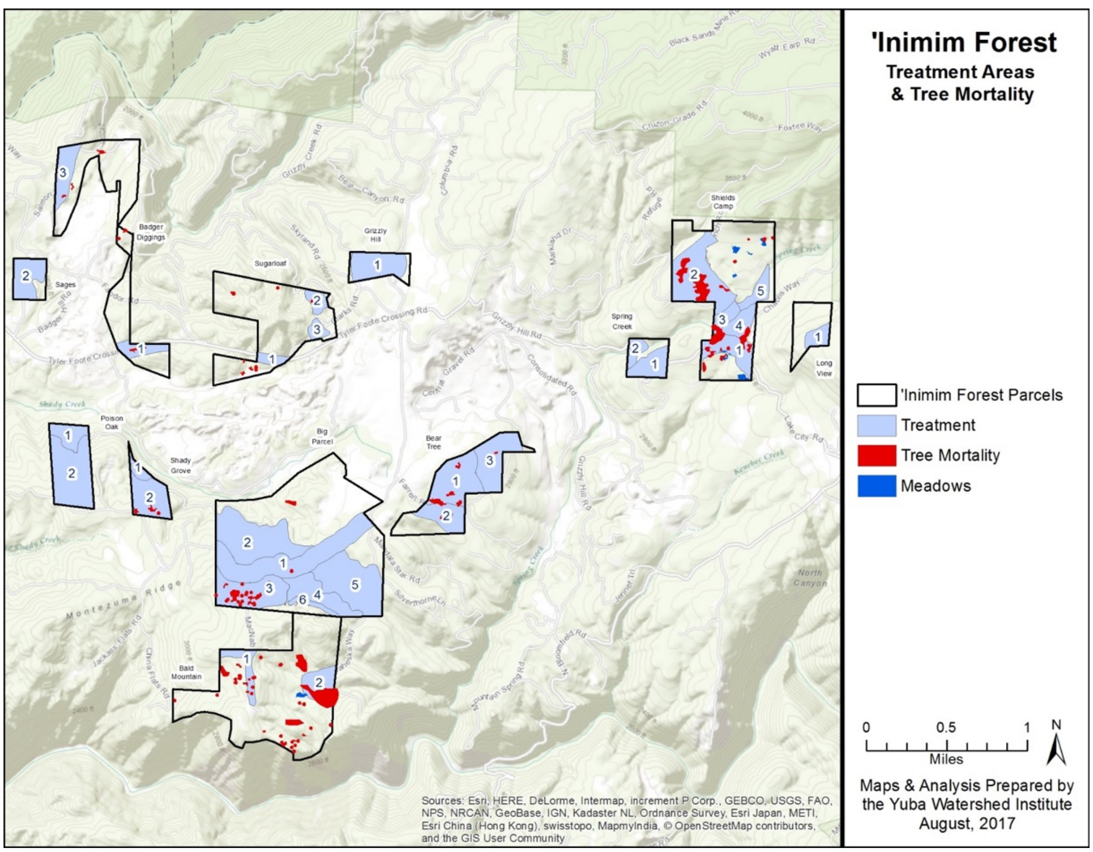


Figure 12. Extent of tree mortality in the 'Inimim Forest. Please note that treatment area boundaries have been revised since the map was produced.

4 Treatment Limitations

Treatment limitations are a key part of the *Revised 'Inimim Forest Management Plan*. The limitations were included as a map in the revised plan (Section 5.2, Figure 7). This section contains a description of the methods and data used to develop the limitations map.

Treatment limitations were mapped using criteria similar to that in the original *'Inimim Forest Management Plan*. The primary difference in treatment limitation maps between the original and this plan, is how old forests are addressed. In the original 'Inimim Forest Timber Harvest Implementation Plan (YWI 2000), old forest areas were excluded from treatment. In the *Revised 'Inimim Forest Management Plan*, old forest locations are not excluded from treatment.

The treatment limitation map was constructed from the following input layers:

1) Slope steepness;
2) Distance from existing road or skid trails;
3) Soil sensitivity; and
4) Proximity to perennial stream, seep or meadow.

Each of these map layers was categorized into no, low, moderate or high limitations based upon quantitative criteria (**Table 31**).

Table 31. Management limitation rating criteria by characteristic, used as inputs to the Management Limitations Map.

Input Layer	Low Limitation	Moderate Limitation	High Limitation
Slope Steepness	<35%	35 to 55%	>55%
Distance from roads/skids	<1,000 feet from existing roads or mapped skid trails	Same as low	>1,000 feet from existing roads or mapped skid trails
Soil Sensitivity to Management	Not in moderate or high limitation	Granitic & slopes >35%; Horseshoe gravelly loam; Medium to rapid runoff and slopes >35%	Eroded and slopes >35%; Slopes >50%; Rapid runoff and slopes > 35%; Hydraulically mined tailings
Proximity to Wetlands	>100 feet from perennial streams; >75 feet from intermittent streams or meadows	< 100 feet from perennial streams; <75 feet from intermittent streams	n/a

The criteria for the soil sensitivity rating is shown in more detail in Appendix F of the revised management plan (Soil Survey Information). This includes a summary of soil map unit characteristics from the Nevada County Soil Survey (Brittan 1975).

5 Recommended Treatment Priorities

Each recommended treatment area was assigned a priority level. This is important because it may not be possible to treat all recommended areas at once, and choices will need to be made about what to treat first. Areas were assigned to 1st, 2nd, or 3rd priority levels. The approach to assign the priority levels was both quantitative and qualitative.

The first step was to create a map of priority criteria using several input map layers. The input layers and criteria included:

1. **High** - 300-foot buffer from major fire access roads (Tyler Foote, Lake City, Jackass Flats, Sages);
2. **Moderate** - old forest mapped from original *'Inimim Forest Management Plan*;
3. **Low** - areas that are not high or moderate that are either <35% slope or previously treated (<20 years).

Each area was assigned one of three priority levels from low to high using a Python Script in ArcGIS. The mapping process is included as a Python Script in the project geodatabase (YWI 2017).

The old forest map from the original *'Inimim Forest Timber Harvest Implementation Plan* (YWI 2000) was used for the old forest map for this analysis (**Figure 13**). This map was intensively ground-truthed for the original plan. According to field observations and plots for the current *Revised 'Inimim Forest Management Plan*, the map remains a good representation of old forest structure. In addition, there is no other available map that incorporates large tree presence and density to identify old forest. Areas mapped as mature forest with multi-canopy layers from the map were not included for this analysis.

The next step in the mapping process was to modify some priority assignment levels to make the total area in each priority categories roughly equal. There was less area assigned to the first priority category. Some areas rated as second priority were changed to first priority. Most of the first priority areas are along important fire access and evacuation routes. Additional areas assigned moderate were added to the first priority group to increase the area. Add areas included old forest in the Bear Tree Parcel, and high quality older hardwood stands in the Shield's Camp Parcel. Other areas with some old forest or adjacent to human habitation were assigned to the second priority. This included the Grizzly Hill parcel adjacent to the school and the fuel break along the ridge in the Bald Mountain Parcel. The remaining areas were assigned to the third priority level.

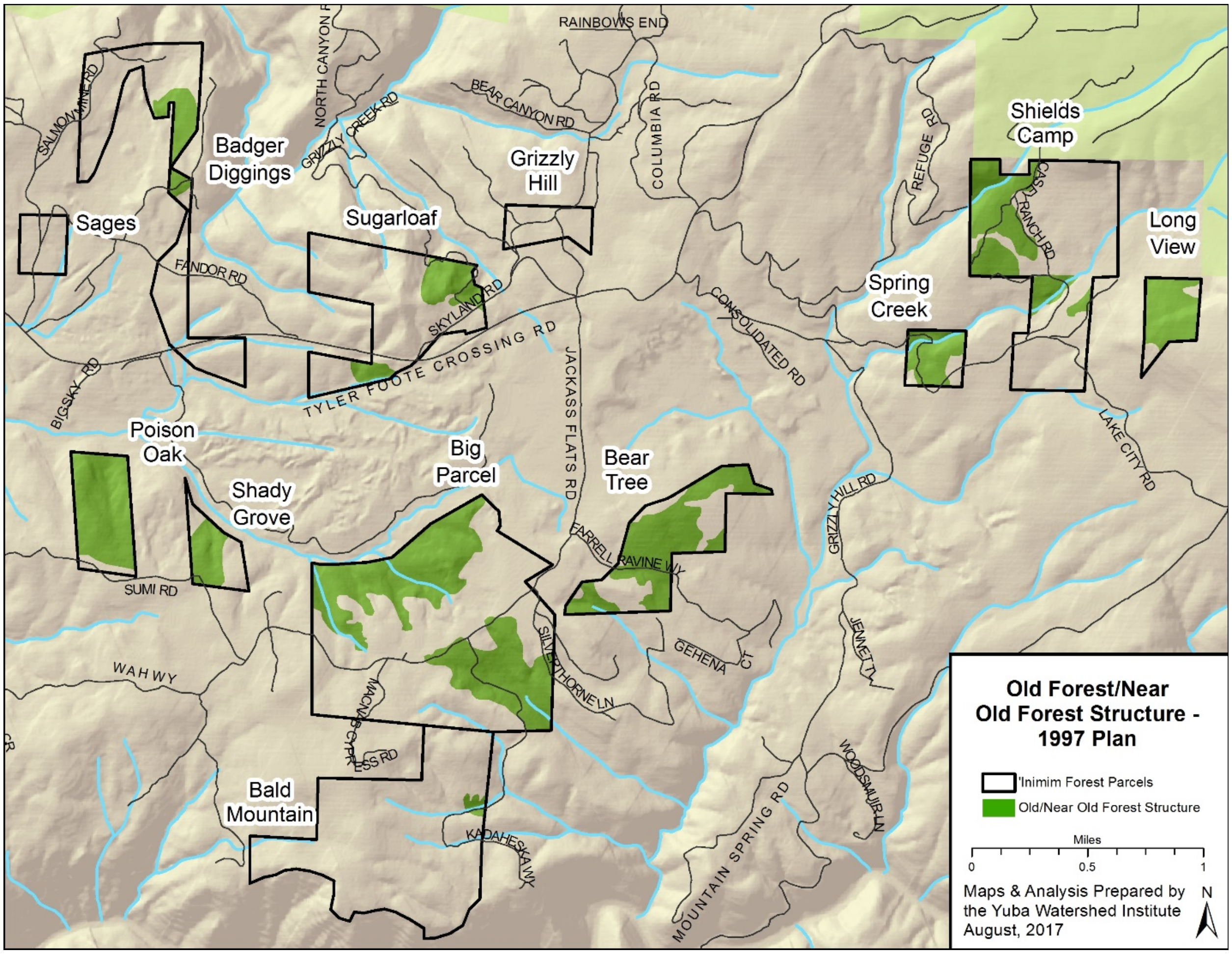


Figure 13. Map of old forest structure from the original '*Inimim Forest Management Plan*. These are areas with trees greater than 30 or 40 inches diameter at 4.5 feet height. Large trees may be present in other areas but are highly scattered. Some areas have trees that have grown larger and now meet the criteria but are not shown in the map.

6 Fire Behavior Modeling

Fire behavior modeling is the use of scientific models to predict what kind of fire would result from different fuel, vegetation, weather, and topographic conditions. Commonly used fire behavior characteristics used for land management planning include:

- **Fire type** – surface, crown, groups of trees torching;
- **Fire intensity** – flame length, the distance from base to tip of the longest flame;
- **Rate of spread –** the speed that the fire moves.

All of the commonly used fire behavior models in the USA are based upon the same underlying algorithms, or equations. There are two basic types of these models: spatial and non-spatial.

For this project, a non-spatial model was used for several reasons. The available, existing spatial input fuel model layers for the area are very coarse and do not reflect variation in fuels. Over 80 percent of the area is mapped as one fuel type. The available spatial fuel models do not portray changes or differences from different treatments, such as mastication, prescribed burning or pile burning. It was beyond the scope of this project to undertake a detailed modification of the spatial fuel layer. As a result, a non-spatial approach, the NEXUS fire behavior model (Scott & Reinhardt 2004), was used.

There are several important input assumptions to the fire behavior models, including fuel moisture and weather. The fuel moisture and weather conditions were selected to represent peak fire season conditions during a dry year. While peak fire conditions only occur for part of the year, these are the fires that are difficult to control and result in the most undesirable fire effects. These are when higher tree mortality and soil heating are most likely. The effects of these types of fires can be long-lasting, over centuries. This analysis reflects peak conditions.

6.1 METHODOLOGY

6.1.1 Fuel Moisture and Weather Inputs and Assumptions

Dead surface fuels were assumed to be very dry, varying from 3 to 5 percent moisture content. Live understory vegetation, including shrubs and large herbs, was assumed to have a low moisture content of 60 percent. During extreme drought years in chaparral, shrub foliar moistures can go lower than 60 percent. These extreme drought conditions were not modeled. Tree crown foliar moisture content was assumed to be low, at 100 percent. During extreme drought, tree crown foliar moisture can drop down to 70 percent. Values less than 100 percent were not used because the threshold for crown fire is typically reached at 100 percent anyway.

It was assumed that winds were moderate, at 10 miles per hour. In addition, flame length was graphed at low to very high windspeeds.

Fire behavior increases on slopes. The steeper the slope, the greater the intensity, speed, and likelihood of crown fire are. For this modeling, a slope of 20 percent was assumed. Slope steepness varies in the analysis area but many of the areas have low to moderate slope. For areas with steeper slopes, it can be inferred that fire behavior would increase at least proportional to the increase in slope. Fire can also increase and accelerate dramatically in ravines, canyons, and chimneys, even small ones. These topographic features occur throughout the ‘Inimim Forest. This modeling does not represent accelerated fire in those topographic features.

6.1.2 Fuel Model Selections and Fire Behavior Model Calibration

The fuel model selections were based upon data collected in the detailed plots and research on fuels and fire behavior (i.e. Vaillant et al. 2009a, 2009b, Reiner et al. 2009, Reiner et al. 2012, Vaillant et al. 2015). The fuel models and fire behavior model assumptions were calibrated with fire behavior data collected by the Fire Behavior Assessment Team (FBAT) during active wildfires (i.e. Fites et al. 2006, Ewell et al. 2014, Reiner et al. 2014, Valliant et al. 2014, Ewell et al. 2015, Reiner et al. 2016). These data can be found on the FBAT website, under the fire behavior heading:

https://www.fs.fed.us/adaptivemanagement/publications.php

Fire behavior data from FBAT sites with similar vegetation and fuels were compared with the modeled outputs to gauge whether they were reasonable.

6.2 Results Summary

This section includes a description of the modeled fire behavior characteristics, treatment and vegetation condition scenarios, and a summary of the findings.

6.2.1 Modeled Fire Behavior Characteristics

Fire predictions included fire type, flame length, crowning index and rate of spread. Definitions of these fire characteristics and input fuel models are described in **Table 32**.

Table 32. Definitions for fire model characteristics shown in **Table 33**.

Fire Model Characteristic	**Definition**
Fuel model	Surface fuel models from Scott and Burgan (2005). Characterizes the type and amount of surface fuel.
Canopy Bulk Density (kg/m3)	Amount of tree crown fuel, expressed as weight per volume. Based on Wagner (1977), Scott and Reinhardt (2001), Reinhardt et al. (2006). Also applies to shrub fuels in chaparral.
Canopy Base Height (feet)	Base to live tree crown. Calculated according to Scott and Reinhardt (2001).
Fire type	Category of fire type. Surface fire is below the crowns of most trees or shrubs in chaparral. Crown fire is where the fire is spreading through the crowns of the upper trees, usually has high intensity surface fire at the same time. Torching, or passive crown fire, is where the fire goes into the crowns of trees in groups, not necessarily traveling from tree to tree.
Flame length (feet)	The length of flame. This is usually longer than the height of a flame, since flames are usually leaning. Categories used for fire suppression methods based on flame length: <4 foot, use fire hand tools; 4-8 feet, use bulldozer or mechanical fire equipment; 8-12 foot, use aircraft; >12 foot, fire resists suppression. (Andrews and Rothermel 1981).
Crowning Index (windspeed mph)	This represents the windspeed at which surface fire transitions to crown fire.
Rate of Spread (chains /hour)	The speed at which fire moves. Expressed in chains per hour because these are the units of measure used by firefighters. Each chain is equivalent to 66 feet.

6.2.2 Treatment and Vegetation Condition Scenarios

There several different types of scenarios that were modeled. One was by major forest condition including ecological groups, and representative vegetation and fuels. A range of scenarios was developed to depict the range of conditions by:

- Vegetation type;
- Fuel load (i.e., high or moderate); and
- Post-treatment (by varied treatment types);

Multiple treatment types simulated were based on past or recommended types. The definitions of the treatments were the same as in the *Revised ‘Inimim Forest Management Plan* (Section 5.2). Here, it is assumed that thinning where there is no piling is mechanical and where there is piling it is hand thinning. The types and their assumed effect on different fuel conditions included:

- **Untreated** – current conditions, both high and moderate fuel load levels;
- **Thin only** – reduced canopy bulk density, increased canopy base height, increased surface fuels;
- **Burn only** – reduced surface fuels, increase canopy base height;
- **Thin and burn** – reduced canopy bulk density, increased canopy base height, decreased surface fuels;

- **Thin and pile –** some reduction in canopy base height, some reduction in surface fuels;
- **Pile and burn –** moderate reduction in surface fuels;
- **Thin, pile, and burn –** reduction in canopy bulk density, increased canopy base height, moderate decrease in surface fuel;
- **Pile –** some decrease in surface fuels; and
- **Mastication –** increased surface fuels, increase in canopy base height, no change in canopy bulk density.

Fires were modeled with two fire type assumptions. For most scenarios, it was assumed that crown fire was possible. When crown fire is predicted, the model output flamelengths are often taller than the trees. These are called crown and surface fire runs. In order to assess the role of surface fuels in increased fire intensity, some scenarios were also run without a crown fire option. These are called surface fire only runs.

For the tree mortality scenarios, it was assumed that most or all of the dead trees had fallen. Where there were no live trees remaining, the fires were surface fires because there were no crowns to burn. Where there were live trees, crown fire was predicted.

6.2.3 Summary of Findings

The fire modeling results for the primary fire characteristics are listed in **Table 33**. The results of the fire behavior modeling were not surprising. Since weather inputs were for late fire season during dry years, crown fire was predicted in most of the untreated scenarios. This is classified as passive or active crown fire in the model. Here the term torching is used instead of passive crown fire. Torching is when individual trees or groups of trees burn in the crowns.

For these predictions, slope was set at 20 percent for all model runs and winds at 10 miles per hour. These are not extreme and relatively moderate conditions for fire behavior. However, the likelihood of crown fire and speed of fire would increase considerably on steeper slopes or with higher winds. Slopes steeper than 20 percent occur on much of the ‘Inimim Forest.

Table 33. Results from fire behavior modeling. Assumes very high fire weather conditions including: fine dead fuel moistures of 3 to 5%; live understory fuel moistures of 60%; and tree foliar moisture of 100%. Winds and slope were assumed to be 10 miles per hour and 20% respectively. Vegetation type abbreviations: pp is ponderosa pine; mcn is mixed conifer; chfo is bearclover; dh is dry herb; df is Douglas-fir; and arc is manzanita. Fuel models are from Scott and Burgan (2005).

Vegetation Type	Scenario	Fuel model	Canopy Bulk Density (kg/m3)	Canopy Base Height (feet)	Fire type	Flame length (feet)	Crowning Index (windspeed mph)	Rate of Spread (chains /hour)
pp-mcn/chfo	thin	TU5	0.05	12	torch	31	34	17
pp-mcn/chfo	high load	TU5	0.33	3	crown	75	9	32
pp-mcn/chfo	thin & burn	SH2	0.05	12	surface	2.4	34	1.4
pp-mcn/chfo	moderate load	SH2	0.33	3	crown	55	9	32
pp-mcn/chfo	burn							
pp-mcn/chfo	surface run – thin	TU5	0.05			15		9.5
pp-mcn/chfo	surface run – high load	TU5	0.33			12		7
pp-mcn/chfo	surface run – thin & burn	SH2	0.05			2.4		1.4
pp-mcn/chfo	surface run – moderate load	SH2	0.33			7		4
pp-mcn/dh	high load	TL9	0.33	3	crown	58	9	32
pp-mcn/dh	mastication	TL5	0.15	3	torch	30	16	20
pp-mcn/dh	thin	TL9	0.05	12	torch	16	34	14
pp-mcn/dh	thin & burn	TL3	0.05	12	surface	0.6	34	0.4
df-mcn	moderate load	TL4	0.15	3	torch	10 to 12	16	13
df-mcn	high load	TU5	0.33	3	crown	49	9	32
df-mcn	thin	TU5	0.05	12	torch	26	34	15
df-mcn	thin & burn	TL1	0.05	12	surface	0.3	34	0.2
df-mcn	surface run - moderate load	TL4	0.15	3		7		2.5
df-mcn	surface run - high load	TU5	0.33	3		12		7
df-mcn	surface run - thin	TU5	0.05	12		15		10
df-mcn	surface run - thin & burn	TL1	0.05	12		0.3		0.2
mcn	high load	TL9	0.33	3	crown	58	9	32
mcn	moderate load	TL3	0.15	3	torch	7	16	6.7
mcn	thin & pile	TL9	0.05	12	torch	16	34	14
mcn	thin, pile & burn	TL3	0.05	12	surface	0.6	34	0.4
pp mortality	surface run: high mortality, fallen trees	SB4	0		surface	15		10
pp mortality	surface run: pile	SB2	0		surface	8		3.4
pp mortality	mixed live & dead forest	SB1	0.07	3	torch	24	27	13
pp mortality	mixed live & dead forest	SB1	0.07	3	torch	3.6	27	2
manzanita	high load chaparral	SH7	1		crown	18	11	8.4
manzanita	moderate load chaparral	SH5	0.5		crown	13	14	12
pp/arc	moderate load	SH5	0.1	3	torch	13	21	19
pp/arc	moderate load: pile & burn or burn	SH2	0.05	12	surface	2.4	34	1.4

Graphs of changes in flame length with windspeed are included in **Figure 14** below, and in the Detailed Findings (Section 2.2.2.2). These graphs are useful for seeing the acceleration of fire with wind. Similar trends would occur with increasing slope.

In forests with high tree mortality, other fire outputs are important. This includes heat per unit area, a measure of how much soil heating is predicted. Predicted heat outputs are included in Tables 29 through 36 in the detailed results below in Section 5.2.2.2. The high tree mortality scenarios resulted in high heat per unit area predictions, consistent with findings from recent measurements during active wildfires (i.e., Ewell et al. 2014 and 2015, Reiner 2014). While ember production was not modeled here, the FBAT team has documented increased ember production and fire spread from spotting in areas with many dead standing trees (Reiner et al. 2016).

The differences between treatment scenarios vary with windspeed. For each of the scenarios, graphs of changes in flamelength with windspeed were generated. An example of these graphs is shown in **Figure 14** for treatment scenarios in the ponderosa pine – mixed conifer/bearclover (pp-mcn/chfo) type.

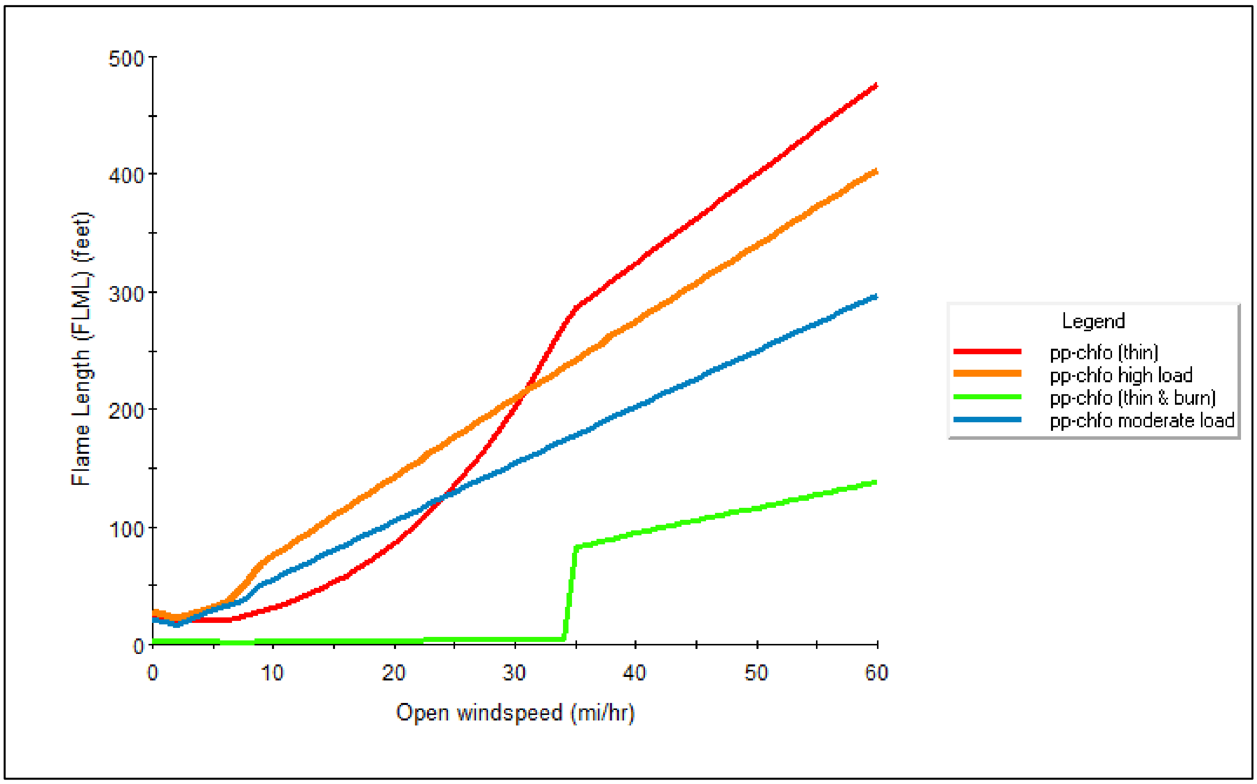


Figure 14. Outputs from NEXUS fire behavior modeling for four fuel load and treatment type scenarios in the ponderosa pine – mixed conifer/bear clover type. The high load scenario represents forests with heavy dead surface fuel and especially tall, dense, old bearclover. The moderate load scenario represents mid-aged, or shorter bearclover. The thin scenario has mostly small but also medium diameter trees removed to desired condition density levels. The thin and burn scenario is the same as the thin scenario but also includes prescribed fire, as an area burn.

At windspeeds of less than 15 miles per hour, the two untreated scenarios have the greatest predicted flame lengths (**Figure 14**). As displayed in **Table 33.** Results from fire behavior modeling. Assumes very high fire weather conditions including: fine dead fuel moistures of 3 to 5%; live understory fuel moistures of 60%; and tree foliar moisture of 100%. Winds and slope were assumed to be 10 miles per hour and 20% respectively. Vegetation type abbreviations: pp is ponderosa pine; mcn is mixed conifer; chfo is bearclover; dh is dry herb; df is Douglas-fir; and arc is manzanita. Fuel models are from Scott and Burgan (2005)., the two untreated stands would burn as crown fires. The thinned stand would have torching of individual trees or groups of trees. This is because thinning adds to surface fuels because branches and tops of trees are moved from the tree crowns to the ground (i.e., Vaillant et al. 2009). At winds of 30 miles per hour, all of these burn as crown fire. In contrast, the thin and burn scenario burns as a surface fire, with low flame lengths until winds reach 34 miles per hour. Similar results are found for the scenarios in other forest or vegetation types. Similar graphs for all of the scenarios are found in the Detailed Findings section, immediately following.

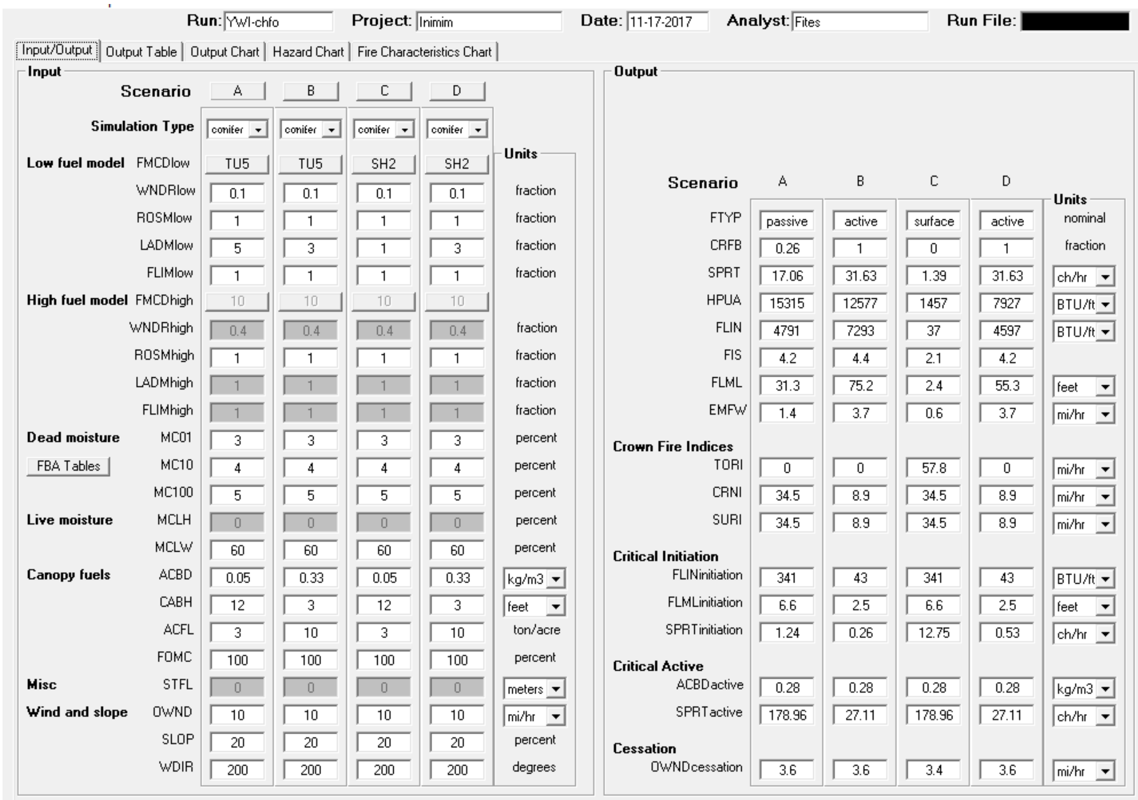
6.2.3.1 Detailed Findings

The scenario inputs and outputs are shown below, grouped by vegetation type. They are screen shots from the NEXUS program. The corresponding digital data is on file with the Yuba Watershed Institute.

6.2.3.1.1 Ponderosa pine – mixed conifer/bear clover (pp-mcn/chfo)

6.2.3.1.1.1 Surface and Crown Fire Option

Table 34. NEXUS runs representing potential crown fire in ponderosa-pine – mixed conifer/bear clover: A=thin; B=high load; C=thin and burn; and D=moderate load. Abbreviations in Scott and Reinhardt (2004).


Run: YWI-chfo Project: Inimim Date: 11-17-2017 Analyst: Fites Run File: [redacted]

Input/Output | Output Table | Output Chart | Hazard Chart | Fire Characteristics Chart

Input

		A	B	C	D	Units
Simulation Type		conifer	conifer	conifer	conifer	
Low fuel model	FMCDlow	TU5	TU5	SH2	SH2	
	WNDRlow	0.1	0.1	0.1	0.1	fraction
	ROSMlow	1	1	1	1	fraction
	LADMlow	5	3	1	3	fraction
	FLIMlow	1	1	1	1	fraction
High fuel model	FMCDhigh	10	10	10	10	
	WNDRhigh	0.4	0.4	0.4	0.4	fraction
	ROSMhigh	1	1	1	1	fraction
	LADMhigh	1	1	1	1	fraction
	FLIMhigh	1	1	1	1	fraction
Dead moisture	MC01	3	3	3	3	percent
FBA Tables	MC10	4	4	4	4	percent
	MC100	5	5	5	5	percent
Live moisture	MCLH	0	0	0	0	percent
	MCLW	60	60	60	60	percent
Canopy fuels	ACBD	0.05	0.33	0.05	0.33	kg/m3
	CABH	12	3	12	3	feet
	ACFL	3	10	3	10	ton/acre
	FOMC	100	100	100	100	percent
Misc	STFL	0	0	0	0	meters
Wind and slope	OWND	10	10	10	10	mi/hr
	SLOP	20	20	20	20	percent
	WDIR	200	200	200	200	degrees

Output

Scenario	A	B	C	D	Units
FTYP	passive	active	surface	active	nominal
CRFB	0.26	1	0	1	fraction
SPRT	17.06	31.63	1.39	31.63	ch/hr
HPUA	15315	12577	1457	7927	BTU/ft
FLIN	4791	7293	37	4597	BTU/ft
FIS	4.2	4.4	2.1	4.2	
FLML	31.3	75.2	2.4	55.3	feet
EMFW	1.4	3.7	0.6	3.7	mi/hr
Crown Fire Indices					
TORI	0	0	57.8	0	mi/hr
CRNI	34.5	8.9	34.5	8.9	mi/hr
SURI	34.5	8.9	34.5	8.9	mi/hr
Critical Initiation					
FLINinitiation	341	43	341	43	BTU/ft
FLMLinitiation	6.6	2.5	6.6	2.5	feet
SPRTinitiation	1.24	0.26	12.75	0.53	ch/hr
Critical Active					
ACBDactive	0.28	0.28	0.28	0.28	kg/m3
SPRTactive	178.96	27.11	178.96	27.11	ch/hr
Cessation					
OWNDcessation	3.6	3.6	3.4	3.6	mi/hr

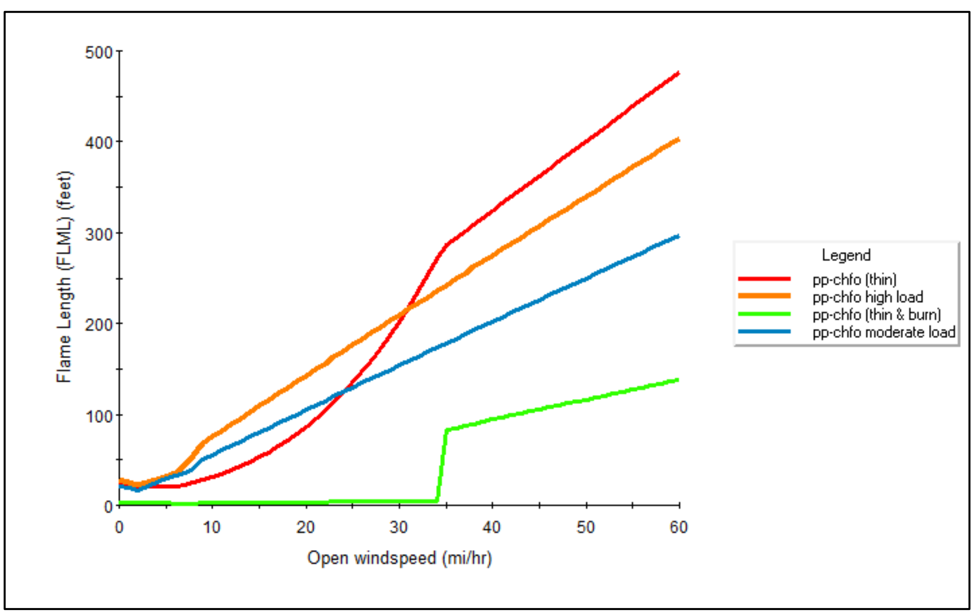
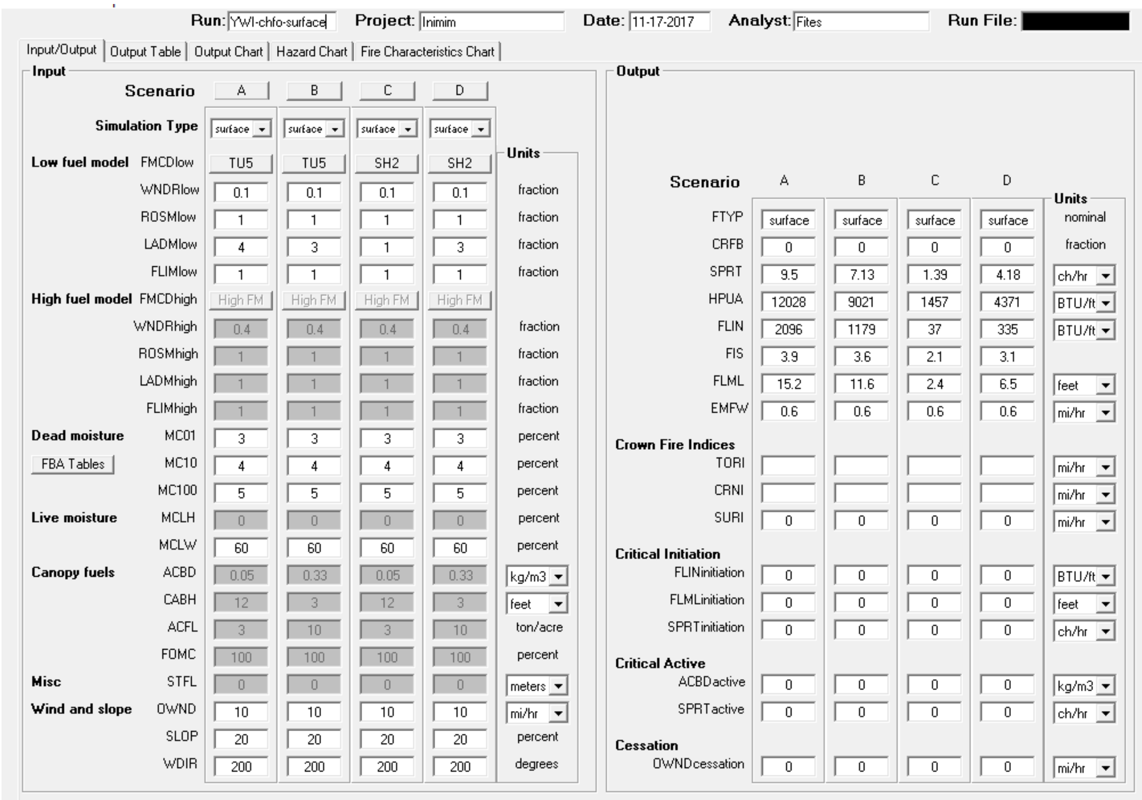


Figure 15. Graph of NEXUS model runs representing ponderosa-pine – mixed conifer/bear clover: A=thin; B=high load; C=thin and burn; and D=moderate load. Load is fuel load.

6.2.3.1.2 Ponderosa pine – mixed conifer/bear clover (pp-mcn/chfo)

6.2.3.1.2.1 Surface Fire Option

Table 35. NEXUS model runs representing surface fire only in ponderosa-pine – mixed conifer/bear clover: A=thin; B=high load; C=thin and burn; and D=moderate load. Abbreviations in Scott and Reinhardt (2004).



Run: YWI-chfo-surface Project: Inimim Date: 11-17-2017 Analyst: Fites Run File: [redacted]

Input/Output | Output Table | Output Chart | Hazard Chart | Fire Characteristics Chart

Input

		A	B	C	D	Units
Scenario		A	B	C	D	
Simulation Type		surface	surface	surface	surface	
Low fuel model	FMCDlow	TU5	TU5	SH2	SH2	
	WNDRlow	0.1	0.1	0.1	0.1	fraction
	ROSMlow	1	1	1	1	fraction
	LADMlow	4	3	1	3	fraction
	FLIMlow	1	1	1	1	fraction
High fuel model	FMCDhigh	High FM	High FM	High FM	High FM	
	WNDRhigh	0.4	0.4	0.4	0.4	fraction
	ROSMhigh	1	1	1	1	fraction
	LADMhigh	1	1	1	1	fraction
	FLIMhigh	1	1	1	1	fraction
Dead moisture	MC01	3	3	3	3	percent
FBA Tables	MC10	4	4	4	4	percent
	MC100	5	5	5	5	percent
Live moisture	MCLH	0	0	0	0	percent
	MCLW	60	60	60	60	percent
Canopy fuels	ACBD	0.05	0.33	0.05	0.33	kg/m3
	CABH	12	3	12	3	feet
	ACFL	3	10	3	10	ton/acre
	FOMC	100	100	100	100	percent
Misc	STFL	0	0	0	0	meters
Wind and slope	OWND	10	10	10	10	mi/hr
	SLOP	20	20	20	20	percent
	WDIR	200	200	200	200	degrees

Output

		A	B	C	D	Units
Scenario		A	B	C	D	
	FTYP	surface	surface	surface	surface	nominal
	CRFB	0	0	0	0	fraction
	SPRT	9.5	7.13	1.39	4.18	ch/hr
	HPUA	12028	9021	1457	4371	BTU/ft
	FLIN	2096	1179	37	335	BTU/ft
	FIS	3.9	3.6	2.1	3.1	
	FLML	15.2	11.6	2.4	6.5	feet
	EMFW	0.6	0.6	0.6	0.6	mi/hr
Crown Fire Indices	TORI					mi/hr
	CRNI					mi/hr
	SURI	0	0	0	0	mi/hr
Critical Initiation	FLINinitiation	0	0	0	0	BTU/ft
	FLMLinitiation	0	0	0	0	feet
	SPRTinitiation	0	0	0	0	ch/hr
Critical Active	ACBDactive	0	0	0	0	kg/m3
	SPRTactive	0	0	0	0	ch/hr
Cessation	OWNDcessation	0	0	0	0	mi/hr

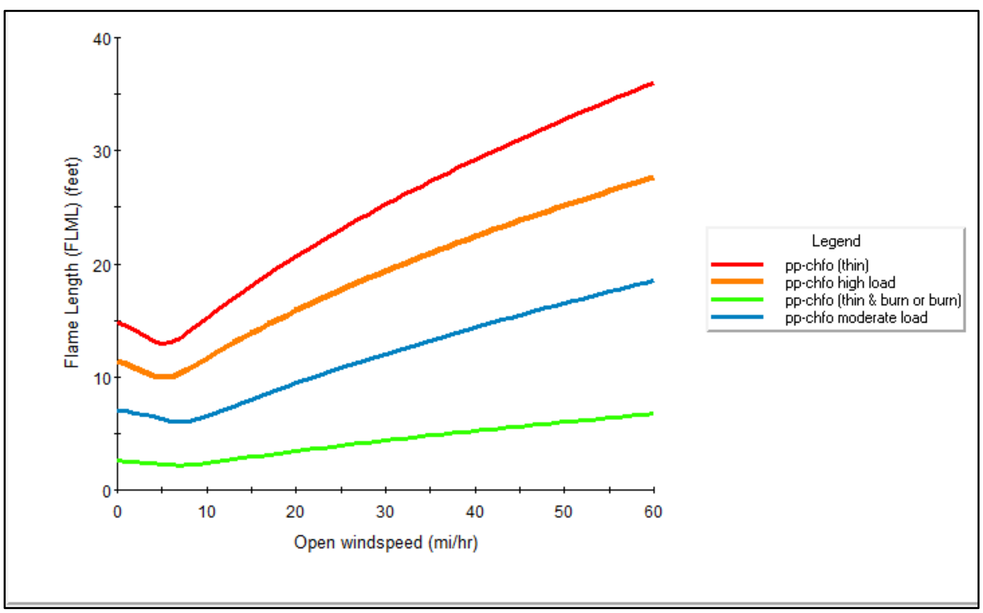
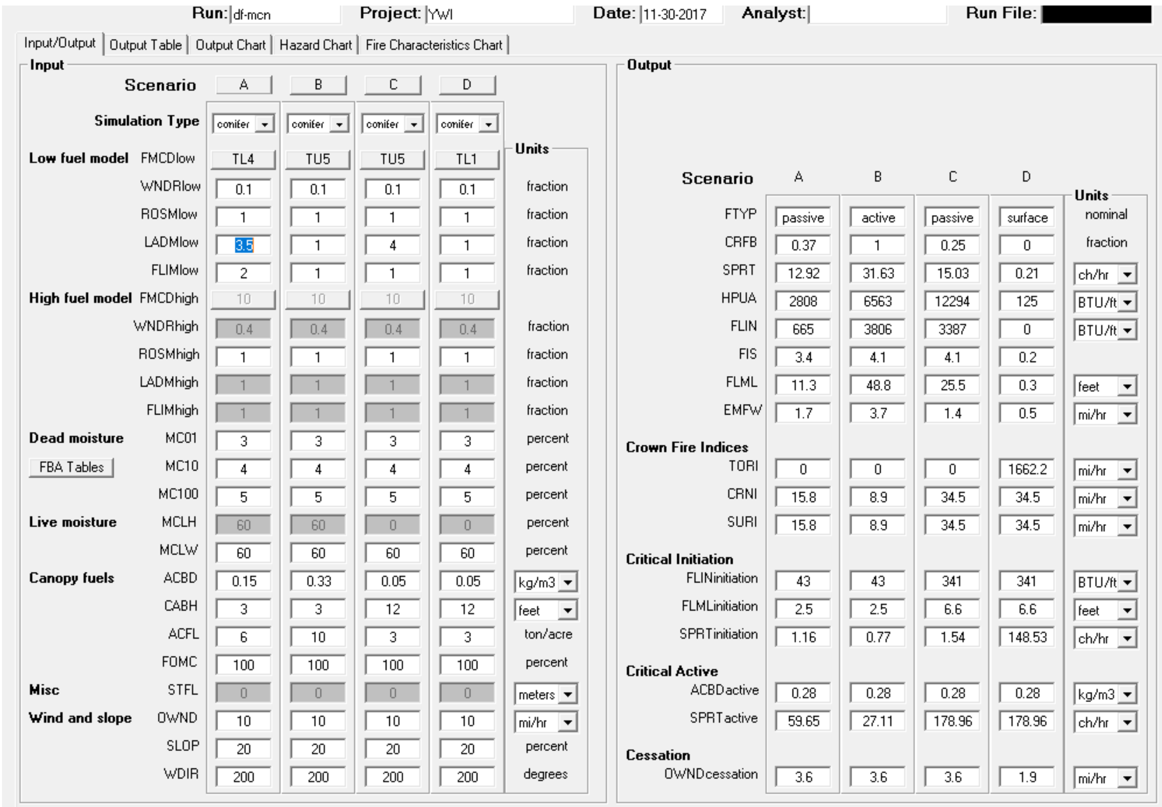


Figure 16. Graph of NEXUS model runs representing surface fire only ponderosa-pine – mixed conifer/bear clover: A=thin; B=high load; C=thin and burn; and D=moderate load.

6.2.3.1.3 Douglas fir – mixed conifer

6.2.3.1.3.1 Surface and Crown Fire Option

Table 36. NEXUS runs representing potential crown fire in Douglas-fir – mixed conifer. Scenarios: A=moderate load; B=high load; C=thin; and D=thin and burn. Abbreviations in Scott and Reinhardt (2004).



Run: df-mcn Project: YWI Date: 11-30-2017 Analyst: Run File: [redacted]

Input/Output | Output Table | Output Chart | Hazard Chart | Fire Characteristics Chart

Input

		A	B	C	D	Units
	Scenario	A	B	C	D	
	Simulation Type	conifer	conifer	conifer	conifer	
Low fuel model	FMCDlow	TL4	TU5	TU5	TL1	
	WNDRlow	0.1	0.1	0.1	0.1	fraction
	ROSMlow	1	1	1	1	fraction
	LADMlow	3.5	1	4	1	fraction
	FLIMlow	2	1	1	1	fraction
High fuel model	FMCDhigh	10	10	10	10	
	WNDRhigh	0.4	0.4	0.4	0.4	fraction
	ROSMhigh	1	1	1	1	fraction
	LADMhigh	1	1	1	1	fraction
	FLIMhigh	1	1	1	1	fraction
Dead moisture	MC01	3	3	3	3	percent
FBA Tables	MC10	4	4	4	4	percent
	MC100	5	5	5	5	percent
Live moisture	MCLH	60	60	0	0	percent
	MCLW	60	60	60	60	percent
Canopy fuels	ACBD	0.15	0.33	0.05	0.05	kg/m3
	CABH	3	3	12	12	feet
	ACFL	6	10	3	3	ton/acre
	FOMC	100	100	100	100	percent
Misc	STFL	0	0	0	0	meters
Wind and slope	OWND	10	10	10	10	mi/hr
	SLOP	20	20	20	20	percent
	WDIR	200	200	200	200	degrees

Output

Scenario	A	B	C	D	Units
FTYP	passive	active	passive	surface	nominal
CRFB	0.37	1	0.25	0	fraction
SPRT	12.92	31.63	15.03	0.21	ch/hr
HPUA	2808	6563	12294	125	BTU/ft
FLIN	665	3806	3387	0	BTU/ft
FIS	3.4	4.1	4.1	0.2	
FLML	11.3	48.8	25.5	0.3	feet
EMFW	1.7	3.7	1.4	0.5	mi/hr
Crown Fire Indices					
TORI	0	0	0	1662.2	mi/hr
CRNI	15.8	8.9	34.5	34.5	mi/hr
SURI	15.8	8.9	34.5	34.5	mi/hr
Critical Initiation					
FLINinitiation	43	43	341	341	BTU/ft
FLMLinitiation	2.5	2.5	6.6	6.6	feet
SPRTinitiation	1.16	0.77	1.54	148.53	ch/hr
Critical Active					
ACBDactive	0.28	0.28	0.28	0.28	kg/m3
SPRTactive	59.65	27.11	178.96	178.96	ch/hr
Cessation					
OWNDcessation	3.6	3.6	3.6	1.9	mi/hr

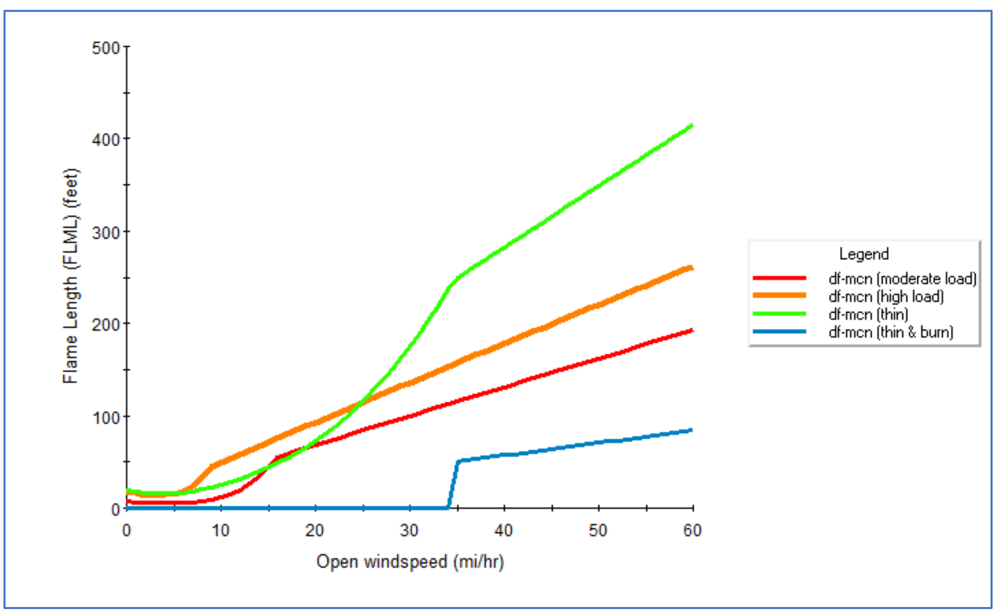
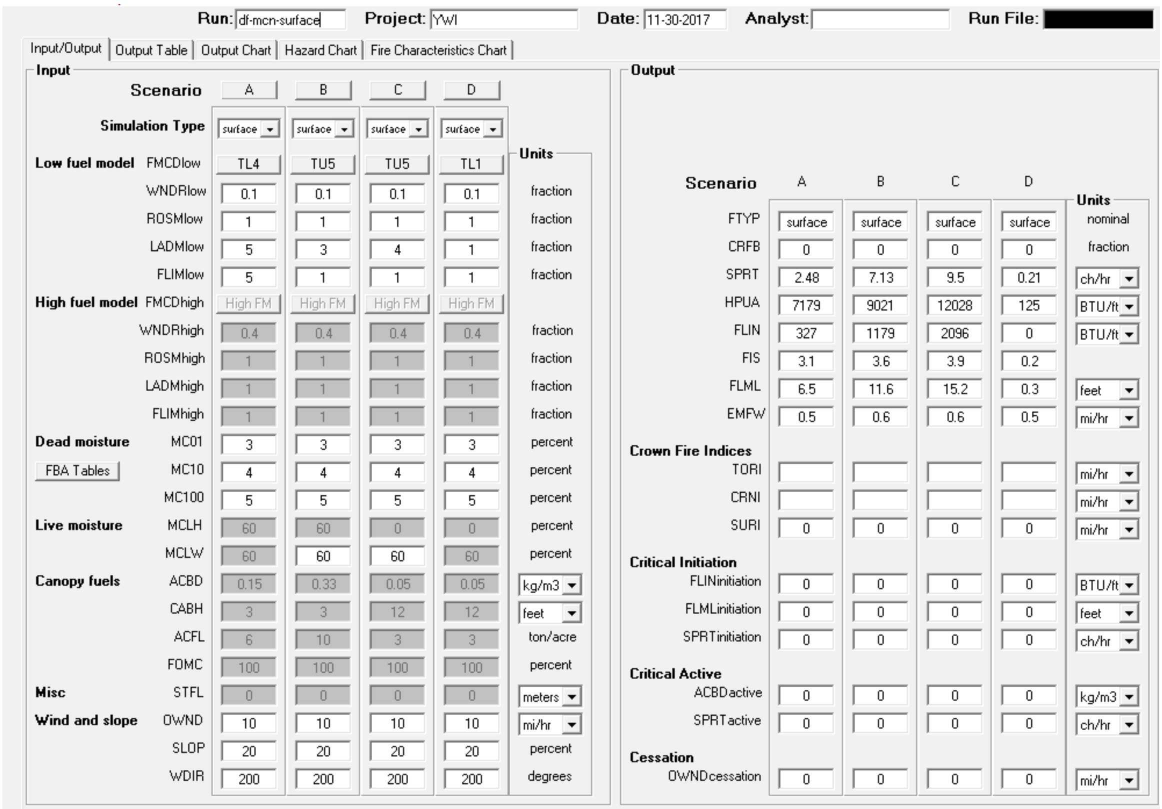


Figure 17. Graph of NEXUS model runs representing Douglas-fir – mixed conifer: A=thin; B=high load; C=thin and burn; and D=moderate load.

6.2.3.1.4 Douglas fir – mixed conifer

6.2.3.1.4.1 Surface Fire Option

Table 37. NEXUS runs representing surface fire only in Douglas-fir – mixed conifer: A=thin; B=high load; C=thin and burn; and D=moderate load. Abbreviations in Scott and Reinhardt (2004).



Run: df-mcn-surface Project: YWI Date: 11-30-2017 Analyst: Run File: [redacted]

Input/Output | Output Table | Output Chart | Hazard Chart | Fire Characteristics Chart

Input

		A	B	C	D	Units
Simulation Type		surface	surface	surface	surface	
Low fuel model	FMCDlow	TL4	TU5	TU5	TL1	
	WNDRlow	0.1	0.1	0.1	0.1	fraction
	ROSMlow	1	1	1	1	fraction
	LADMlow	5	3	4	1	fraction
	FLIMlow	5	1	1	1	fraction
High fuel model	FMCDhigh	High FM	High FM	High FM	High FM	
	WNDRhigh	0.4	0.4	0.4	0.4	fraction
	ROSMhigh	1	1	1	1	fraction
	LADMhigh	1	1	1	1	fraction
	FLIMhigh	1	1	1	1	fraction
Dead moisture	MC01	3	3	3	3	percent
FBA Tables	MC10	4	4	4	4	percent
	MC100	5	5	5	5	percent
Live moisture	MCLH	60	60	0	0	percent
	MCLW	60	60	60	60	percent
Canopy fuels	ACBD	0.15	0.33	0.05	0.05	kg/m3
	CABH	3	3	12	12	feet
	ACFL	6	10	3	3	ton/acre
	FOMC	100	100	100	100	percent
Misc	STFL	0	0	0	0	meters
Wind and slope	OWND	10	10	10	10	mi/hr
	SLOP	20	20	20	20	percent
	WDIR	200	200	200	200	degrees

Output

Scenario	A	B	C	D	Units
FTYP	surface	surface	surface	surface	nominal
CRFB	0	0	0	0	fraction
SPRT	2.48	7.13	9.5	0.21	ch/hr
HPUA	7179	9021	12028	125	BTU/ft
FLIN	327	1179	2096	0	BTU/ft
FIS	3.1	3.6	3.9	0.2	
FLML	6.5	11.6	15.2	0.3	feet
EMFW	0.5	0.6	0.6	0.5	mi/hr
Crown Fire Indices					
TORI					mi/hr
CRNI					mi/hr
SURI	0	0	0	0	mi/hr
Critical Initiation					
FLINinitiation	0	0	0	0	BTU/ft
FLMLinitiation	0	0	0	0	feet
SPRTinitiation	0	0	0	0	ch/hr
Critical Active					
ACBDactive	0	0	0	0	kg/m3
SPRTactive	0	0	0	0	ch/hr
Cessation					
OWNDcessation	0	0	0	0	mi/hr

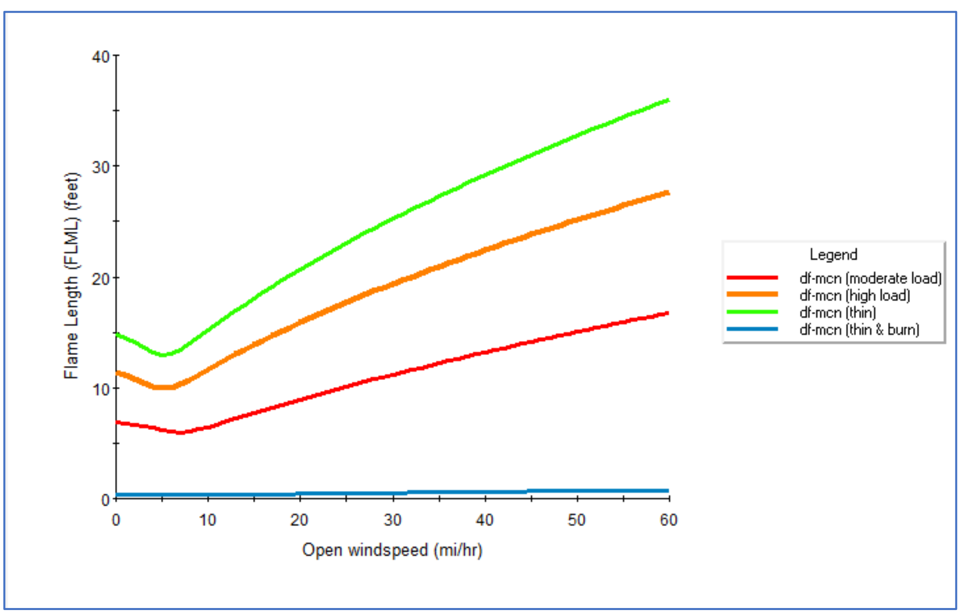


Figure 18. Graph of NEXUS model runs representing surface fire only in Douglas-fir – mixed conifer: A=thin; B=high load; C=thin and burn; and D=moderate load.

6.2.3.1.5 Mixed Conifer Pile and Burn Scenarios

6.2.3.1.5.1 Surface and Crown Fire Option

Table 38. NEXUS runs representing potential crown fire in mixed conifer: A=high load; B=moderate load; C=thin and pile; and D=pile and burn. Abbreviations in Scott and Reinhardt (2004).

Run: pp pile and burn Project: YWI Date: 12-4-17 Analyst: Fites Run File: [redacted]

Input/Output | Output Table | Output Chart | Hazard Chart | Fire Characteristics Chart

Input

		A	B	C	D	Units
Scenario		A	B	C	D	
Simulation Type		conifer	conifer	conifer	conifer	
Low fuel model	FMCDlow	TL9	TL3	TL9	TL3	
	WNDRlow	0.1	0.1	0.1	0.1	fraction
	ROSMlow	1	1	1	1	fraction
	LADMlow	4	3.5	5	1	fraction
	FLIMlow	1	2.5	1	1	fraction
High fuel model	FMCDhigh	10	10	10	10	
	WNDRhigh	0.1	0.1	0.1	0.1	fraction
	ROSMhigh	1	1	1	1	fraction
	LADMhigh	1	1	1	1	fraction
	FLIMhigh	1	1	1	1	fraction
Dead moisture	MC01	3	3	3	3	percent
FBA Tables	MC10	4	4	4	4	percent
	MC100	5	5	5	5	percent
Live moisture	MCLH					percent
	MCLW	60	60	60	60	percent
Canopy fuels	ACBD	0.33	0.15	0.1	0.05	kg/m3
	CABH	3	3	12	12	feet
	ACFL	10	6	4	3	ton/acre
	FOMC	100	100	100	100	percent
Misc	STFL					meters
Wind and slope	OWND	10	10	10	10	mi/hr
	SLOP	20	20	20	20	percent
	WDIR	200	200	200	200	degrees

Output

		A	B	C	D	Units
Scenario		A	B	C	D	
	FTYP	active	passive	passive	surface	nominal
	CRFB	1	0.18	0.39	0	fraction
	SPRT	31.63	6.77	17.83	0.37	ch/hr
	HPUA	8483	2446	6707	235	BTU/ft
	FLIN	4919	304	2192	2	BTU/ft
	FIS	4.2	3	3.9	0.7	
	FLML	57.8	6.7	22.5	0.6	feet
	EMFW	3.7	1.1	1.8	0.5	mi/hr
Crown Fire Indices	TORI	0	8.2	0	777	mi/hr
	CRNI	8.9	15.8	21.1	34.5	mi/hr
	SURI	8.9	15.8	21.1	34.5	mi/hr
Critical Initiation	FLINinitiation	43	43	341	341	BTU/ft
	FLMLinitiation	2.5	2.5	6.6	6.6	feet
	SPRTinitiation	0.47	1.13	3.02	78.92	ch/hr
Critical Active	ACBDactive	0.28	0.28	0.28	0.28	kg/m3
	SPRTactive	27.11	59.65	89.48	178.96	ch/hr
Cessation	OWNDcessation	3.6	3.6	3.6	2.6	mi/hr

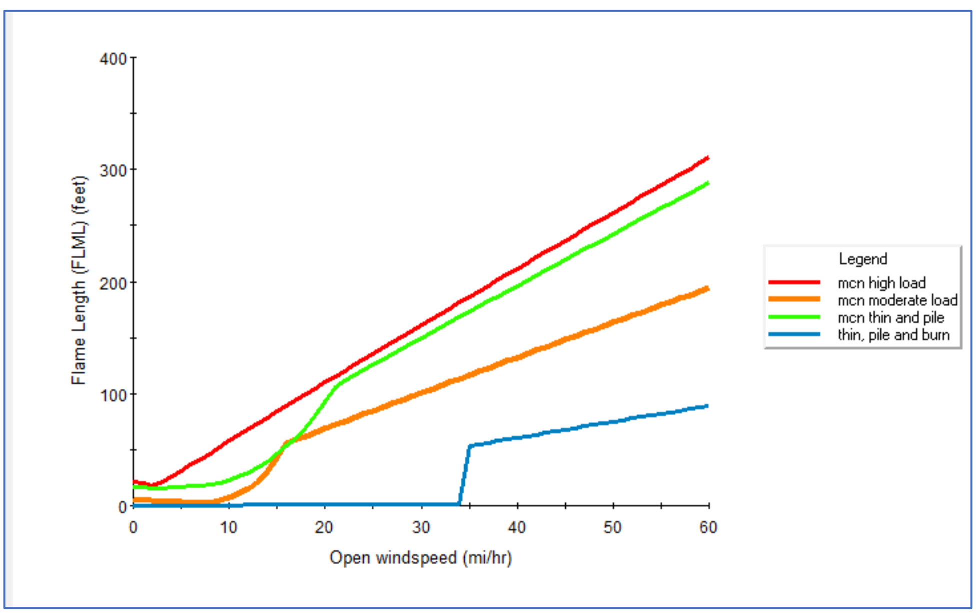
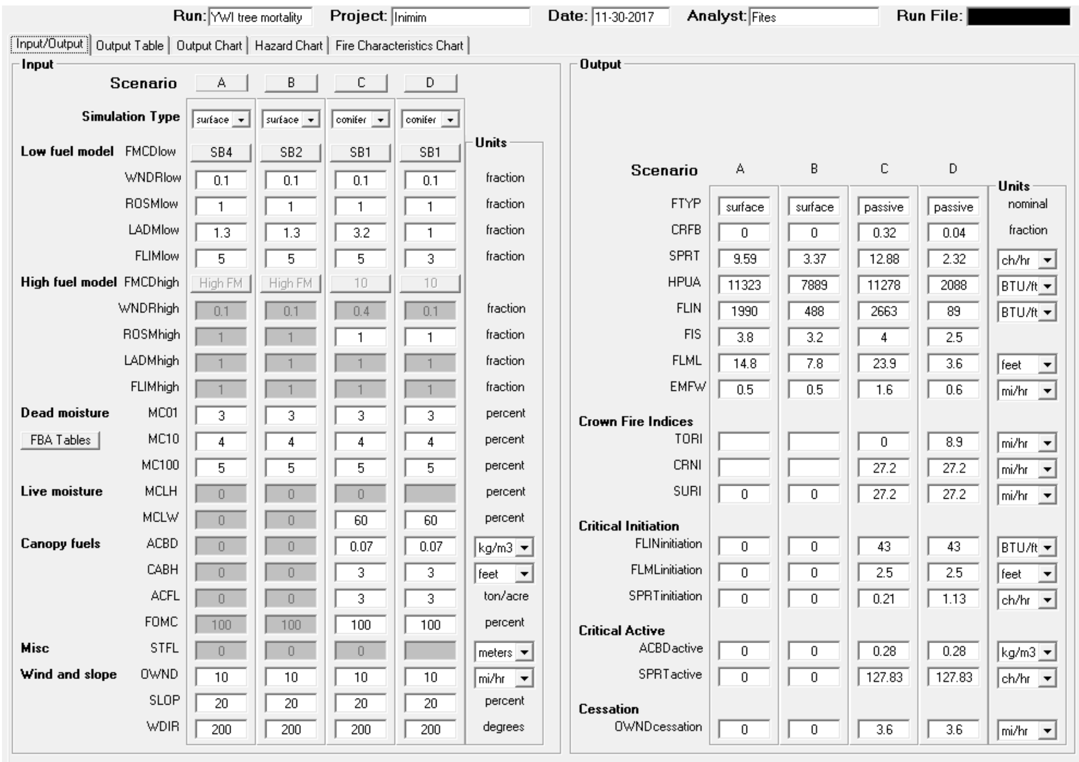


Figure 19. Graph of NEXUS runs representing potential crown fire in mixed conifer: A=high load; B=moderate load; C=thin and pile; and D=pile and burn..

6.2.3.1.6 Tree mortality (Dead Trees Fallen Down)

6.2.3.1.6.1 Surface Fire for all Dead; Surface and Crown Fire for Some Live Trees Remaining

Table 39. NEXUS runs representing potential crown fire in mixed conifer with tree mortality. Scenarios: A=high mortality, high load; B=high mortality, down material mostly piled; C=moderate mortality with mix of live and dead trees; and D=high mortality with dead trees removed, and remaining pieces piled and burned. Abbreviations in Scott and Reinhardt (2004).



Run: YWI tree mortality Project: Inimim Date: 11-30-2017 Analyst: Fites Run File: [redacted]

Input/Output | Output Table | Output Chart | Hazard Chart | Fire Characteristics Chart

Input

		A	B	C	D	Units
Scenario		A	B	C	D	
Simulation Type		surface	surface	conifer	conifer	
Low fuel model	FMCDlow	SB4	SB2	SB1	SB1	
	WNDRlow	0.1	0.1	0.1	0.1	fraction
	ROSMlow	1	1	1	1	fraction
	LADMlow	1.3	1.3	3.2	1	fraction
	FLIMlow	5	5	5	3	fraction
High fuel model	FMCDhigh	High FM	High FM	10	10	
	WNDRhigh	0.1	0.1	0.4	0.1	fraction
	ROSMhigh	1	1	1	1	fraction
	LADMhigh	1	1	1	1	fraction
	FLIMhigh	1	1	1	1	fraction
Dead moisture	MC01	3	3	3	3	percent
FBA Tables	MC10	4	4	4	4	percent
	MC100	5	5	5	5	percent
Live moisture	MCLH	0	0	0		percent
	MCLW	0	0	60	60	percent
Canopy fuels	ACBD	0	0	0.07	0.07	kg/m3
	CABH	0	0	3	3	feet
	ACFL	0	0	3	3	ton/acre
	FOMC	100	100	100	100	percent
Misc	STFL	0	0	0		meters
Wind and slope	OWND	10	10	10	10	mi/hr
	SLOP	20	20	20	20	percent
	WDIR	200	200	200	200	degrees

Output

Scenario	A	B	C	D	Units
FTYP	surface	surface	passive	passive	nominal
CRFB	0	0	0.32	0.04	fraction
SPRT	9.59	3.37	12.88	2.32	ch/hr
HPUA	11323	7889	11278	2088	BTU/ft
FLIN	1990	488	2663	89	BTU/ft
FIS	3.8	3.2	4	2.5	
FLML	14.8	7.8	23.9	3.6	feet
EMFW	0.5	0.5	1.6	0.6	mi/hr
Crown Fire Indices					
TORI			0	8.9	mi/hr
CRNI			27.2	27.2	mi/hr
SURI	0	0	27.2	27.2	mi/hr
Critical Initiation					
FLINinitiation	0	0	43	43	BTU/ft
FLMLinitiation	0	0	2.5	2.5	feet
SPRTinitiation	0	0	0.21	1.13	ch/hr
Critical Active					
ACBDactive	0	0	0.28	0.28	kg/m3
SPRTactive	0	0	127.83	127.83	ch/hr
Cessation					
OWNDcessation	0	0	3.6	3.6	mi/hr

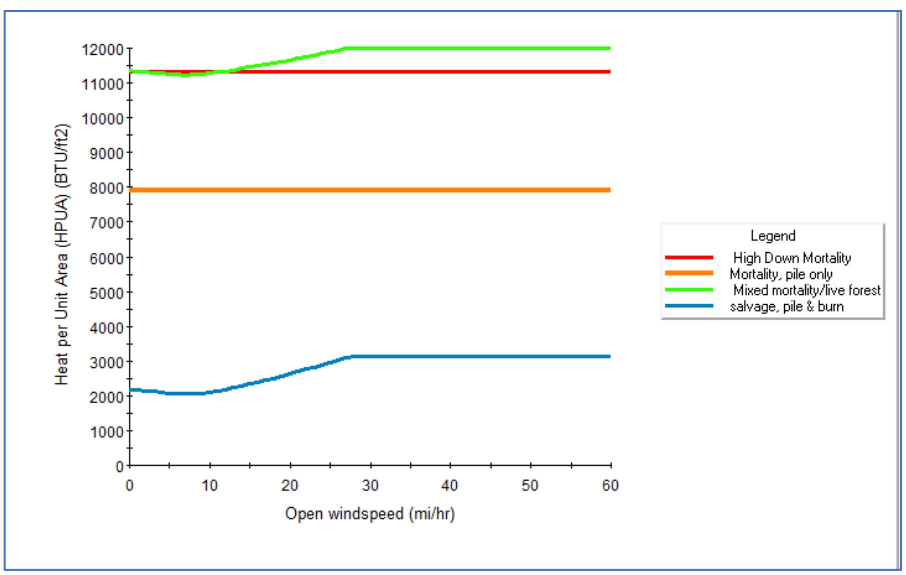


Figure 20. Graph of NEXUS runs representing potential crown fire in mixed conifer with tree mortality. Scenarios: A=high mortality, high load; B=high mortality, down material mostly piled; C=moderate mortality with mix of live and dead trees; and D=high mortality with dead trees removed, and remaining pieces piled and burned.

6.2.3.1.7 Manzanita and Open Pine/Manzanita

6.2.3.1.7.1 Crown Fire Option

Table 40. NEXUS runs representing potential crown fire in manzanita chaparral or pine forest. clover: A=manzanita, high load; B=manzanita moderate load; C=dense manzanita under open pine; and D=pile and burn dense manzanita under open pine. Abbreviations in Scott and Reinhardt (2004).

Run: manzanita Project: Inimim Date: 12-4-2017 Analyst: Fites Run File: [redacted]

Input/Output | Output Table | Output Chart | Hazard Chart | Fire Characteristics Chart

Input

		A	B	C	D	Units
Scenario		A	B	C	D	
Simulation Type		shrub	shrub	conifer	conifer	
Low fuel model	FMCDlow	SH7	SH5	SH5	SH2	
	WNDRlow	0.1	0.1	0.1	0.1	fraction
	ROSMlow	1	1	1	1	fraction
	LADMlow	1	1	1	1	fraction
	FLIMlow	4	1	1	1	fraction
High fuel model	FMCDhigh	SH7	SH5	10	10	
	WNDRhigh	0.1	0.1	0.4	0.1	fraction
	ROSMhigh	1	1	1	1	fraction
	LADMhigh	1	1	1	1	fraction
	FLIMhigh	4	4	1	1	fraction
Dead moisture	MC01	3	3	3	3	percent
FBA Tables	MC10	4	4	4	4	percent
	MC100	5	5	5	5	percent
Live moisture	MCLH	0	0	0		percent
	MCLW	60	60	60	60	percent
Canopy fuels	ACBD	1	0.5	0.1	0.05	kg/m3
	CABH	0	0	3	12	feet
	ACFL	0	0	3	3	ton/acre
	FOMC	100	100	100	100	percent
Misc	STFL	0	0	0		meters
Wind and slope	OWND	10	10	10	10	mi/hr
	SLOP	20	20	20	20	percent
	WDIR	200	200	200	200	degrees

Output

		A	B	C	D	Units
Scenario		A	B	C	D	
	FTYP	passive	passive	passive	surface	nominal
	CRFB	0.93	0.68	0.37	0	fraction
	SPRT	8.37	12.14	19.39	1.39	ch/hr
	HPUA	19694	6997	2282	1457	BTU/ft
	FLIN	3020	1557	811	37	BTU/ft
	FIS	4	3.7	3.4	2.1	
	FLML	17.9	13.2	12.6	2.4	feet
	EMFW	0.7	0.7	1.8	0.6	mi/hr
Crown Fire Indices	TORI	0	0	0	57.8	mi/hr
	CRNI	10.6	13.7	21.1	34.5	mi/hr
	SURI	10.6	13.7	21.1	34.5	mi/hr
Critical Initiation	FLINinitiation	0	0	43	341	BTU/ft
	FLMLinitiation	0	0	2.5	6.6	feet
	SPRTinitiation	0	0	1.23	12.75	ch/hr
Critical Active	ACBDactive	1.07	0.74	0.28	0.28	kg/m3
	SPRTactive	8.95	17.9	89.48	178.96	ch/hr
Cessation	OWNDcessation	7.1	6.3	3.6	3.4	mi/hr

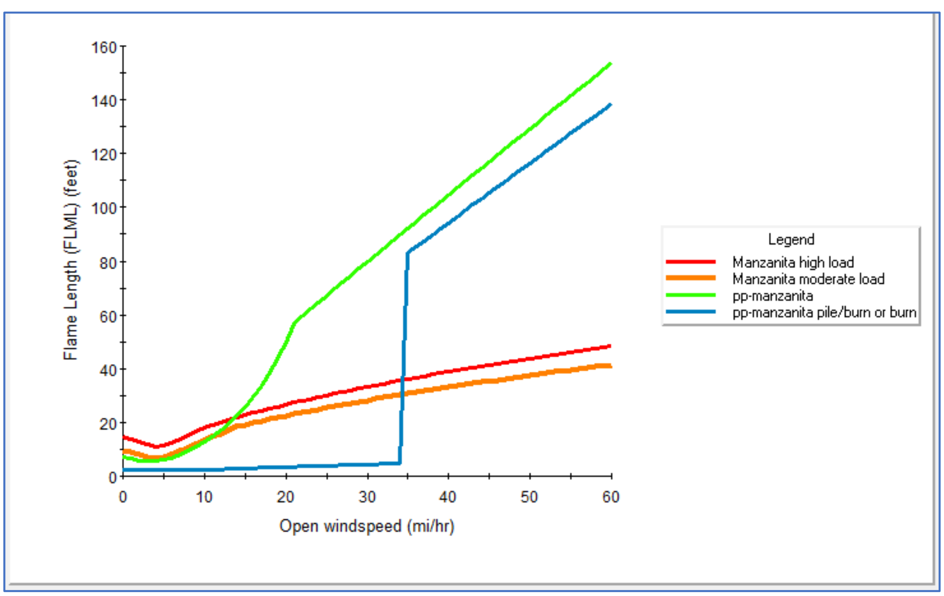


Figure 21. Graph of NEXUS runs representing potential crown fire in manzanita chaparral or pine forest. clover: A=manzanita, high load; B=manzanita moderate load; C=dense manzanita under open pine; and D=pile and burn dense manzanita under open pine.

6.2.3.1.8 Ponderosa Pine – Mixed Conifer/Dry Herb, Includes Mastication

6.2.3.1.8.1 Surface and Crown Fire Option

Table 41. NEXUS runs representing potential crown fire in ponderosa-pine – mixed conifer/dry herb: A=high load; B=masticated; C=thin; and D=thin and burn. Abbreviations in Scott and Reinhardt (2004).

Run: pp mastication Project: Inimim Date: 11-30-2017 Analyst: Fites Run File: [redacted]

Input/Output | Output Table | Output Chart | Hazard Chart | Fire Characteristics Chart

Input

	Scenario	A	B	C	D	Units
	Simulation Type	conifer	conifer	conifer	conifer	
Low fuel model	FMCDlow	TL9	TL5	TL9	TL3	
	WNDRlow	0.1	0.1	0.1	0.1	fraction
	ROSMlow	1	1	1	1	fraction
	LADMlow	4	3	5	1	fraction
	FLIMlow	1	5	1	1	fraction
High fuel model	FMCDhigh	10	10	10	10	
	WNDRhigh	0.1	0.1	0.1	0.1	fraction
	ROSMhigh	1	1	1	1	fraction
	LADMhigh	1	1	1	1	fraction
	FLIMhigh	1	1	1	1	fraction
Dead moisture	MC01	3	3	3	3	percent
FBA Tables	MC10	4	4	4	4	percent
	MC100	5	5	5	5	percent
Live moisture	MCLH					percent
	MCLW	60	60	60	60	percent
Canopy fuels	ACBD	0.33	0.15	0.05	0.05	kg/m3
	CABH	3	3	12	12	feet
	ACFL	10	6	3	3	ton/acre
	FOMC	100	100	100	100	percent
Misc	STFL					meters
Wind and slope	OWND	10	10	10	10	mi/hr
	SLOP	20	20	20	20	percent
	WDIR	200	200	200	200	degrees

Output

	Scenario	A	B	C	D	Units
	FTYP	active	passive	passive	surface	nominal
	CRFB	1	0.59	0.19	0	fraction
	SPRT	31.63	19.69	13.53	0.37	ch/hr
	HPUA	8483	7549	6366	235	BTU/ft
	FLIN	4919	2726	1579	2	BTU/ft
	FIS	4.2	4	3.7	0.7	
	FLML	57.8	30.1	16	0.6	feet
	EMFW	3.7	2.4	1.1	0.5	mi/hr
Crown Fire Indices	TORI	0	0	0	777	mi/hr
	CRNI	8.9	15.8	34.5	34.5	mi/hr
	SURI	8.9	15.8	34.5	34.5	mi/hr
Critical Initiation	FLINinitiation	43	43	341	341	BTU/ft
	FLMLinitiation	2.5	2.5	6.6	6.6	feet
	SPRTinitiation	0.47	0.37	3.02	78.92	ch/hr
Critical Active	ACBDactive	0.28	0.28	0.28	0.28	kg/m3
	SPRTactive	27.11	59.65	178.96	178.96	ch/hr
Cessation	OWNDcessation	3.6	3.6	3.6	2.6	mi/hr

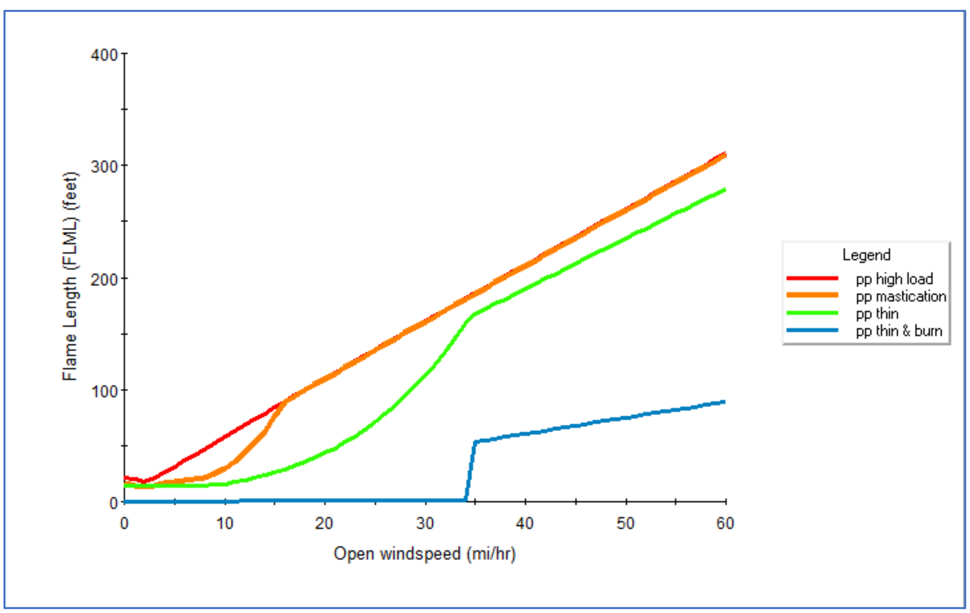


Figure 22. Graph of NEXUS runs representing potential crown fire in ponderosa-pine – mixed conifer/dry herb: A=high load; B=masticated; C=thin; and D=thin and burn. Abbreviations in Scott and Reinhardt (2004).

7 Literature Cited

Andrews, P. L., & Rothermel, R. C. (1982). Charts for interpreting wildland fire behavior characteristics. GTR-INT-13. US Forest Service, Intermountain Forest and Range Extension Station, Ogden, Utah.

Avery, T. E. and Burkhart, H. E. (1983). Forest Measurements, 3rd ed. McGraw-Hill, New York.

Brittan, L. A. (1975). *Soil survey of Nevada County Area, California*. U.S. Department of Agriculture, Soil Conservation Service and Forest Service. Retrieved from https://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/california/CA619/0/nevada_a.pdf.

Brown, J. K. (1974). *Handbook for inventorying downed woody material*. USDA For. Serv. Gen. Tech. Rep. INT-16, 24 p. Intermountain Forest and Range Exp. Station., Ogden, Utah.

Burgan, R. E., & Rothermel, R. C. (1984). BEHAVE: fire behavior prediction and fuel modeling system--FUEL subsystem. USDA Forest Service, Intermountain Forest and Range Experiment Station, 126 pp.

CDFW-CNPS (2016). California Department of Fish and Wildlife and California Native Plant Society protocol for the combined vegetation rapid assessment and relevé field form. Retrieved https://www.cnps.org/cnps/vegetation/pdf/protocol-combined-2016.pdf

Crookston, N.L., Dixon, G.E. (2005). The forest vegetation simulator: a review of its structure, content, and applications. *Computers and Electronics in Agriculture, 49,* 60-80.

Dixon, G. E. (2002). Essential FVS: A user's guide to the Forest Vegetation Simulator. *Fort Collins, CO: USDA-Forest Service, Forest Management Service Center*.

Environmental Systems Research Institute (ESRI). (2017). *ArcGIS Desktop Release 10.5.1*. Redlands, CA.

Ewell, C., Hilden, M., Greene, S., Boatman, B., Reiner, A., Robinson, K., Vaillant, N. (2014). *2013 Aspen Fire Sierra National Forest, Fire Behavior Assessment Team Summary Report*. Unpublished document on file. Retrieved on January 24, 2018 from https://www.fs.fed.us/adaptivemanagement/projects_main_fbat.php.

Ewell, C., Courson, M., Reiner, A., Dickinson, Morgan, C., Norman, T., Blackburn, K., Sohl, Z., Key, H., Napier, K., Butler, B. (2015). *2014 French Fire Sierra National Forest, Fire Behavior Assessment Team Summary Report.* Unpublished document on file. Retrieved on January 24, 2018 from https://www.fs.fed.us/adaptivemanagement/projects_main_fbat.php.

FBAT, Fire Behavior Assessment Team. (2017). Personnel communication with principle members of the FBAT team (Ewell, C., Reiner, A., and Vallaint, N.). Communications between July and December 2017.

FIREMON, Fire Effects Monitoring and Inventory System. 2017. Fuel Load, Sampling System. Obtained from website on January 8, 2018) at https://www.frames.gov/partner-sites/firemon/sampling-methods/

Fites, J. A. (1993). *Ecological guide to mixed conifer plant associations: Northern Sierra Nevada and Southern Cascades: Lassen, Plumas, Tahoe, and Eldorado National Forests*, R5-ECOL-TP-001. Vallejo, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region.

Fites-Kaufman, J. A., Rundel, P., Stephenson, N., & Weixelman, D.A. (2007). Montane and subalpine vegetation of the Sierra Nevada and Cascade ranges. In Barbour, M., Keeler-Wolf, T., & Schoenherr, & A. A. (Eds.), *Terrestrial Vegetation of California, 3rd Edition* (pp.456-501). Berkeley, CA: University of California Press.

Fites, J., Reiner, A., Campbell, M., Courson, M., Dailey, S., Noonan, E., Norman, T., Strawhun, M., Taylor, Z. (2006). *Ralston Incident Fire Behavior Assessment Report*. Summary Report. Unpublished document on file. Retrieved on January 24, 2018 from https://www.fs.fed.us/adaptivemanagement/projects_main_fbat.php.

Franklin, J. F., & Fites-Kaufman, J. A. (1996). Assessment of late-successional forests of the Sierra Nevada. In Sierra Nevada Ecosystem Project, *Sierra Nevada ecosystem project final report to Congress: Status of the Sierra Nevada* (Vol. 2, pp. 627–662). Davis, CA: Center for Water and Wildland Resources, University of California.

Hickman, W. L. (ed.) (1993). *The Jepson manual: higher plants of California*. University of California Press. 140 pages.

Klein, A., Crawford, J., Evens, J., Keeler-Wolf, T., Hickson, D. (2007). *Classification of the Vegetation Alliances and Associations of the Northern Sierra Nevada Foothills, California. Volume 1 or 2 – Introduction, Methods, and Results*. Unpublished document on file with the Resources Management and Policy Division, California Department of Fish and Game.

LANDFIRE (2017). Landscape Fire and Resource Management Planning Tools. Content at: https://www.landfire.gov/about.php

Long, J. W., Quinn-Davidson, L. N., & Skinner, C. N. (Eds.). (2014). *Science synthesis to support socioecological resilience in the Sierra Nevada and southern Cascade Range*. Gen. Tech. Rep. PSW-GTR-247. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

Lydersen, J. M., Collins, B. M., Ewell, C. M., Reiner, A. L., Fites, J. A., Dow, C. B., ... & Battles, J. J. (2014). Using field data to assess model predictions of surface and ground fuel consumption by wildfire in coniferous forests of California. *Journal of Geophysical Research: Biogeosciences*, *119*(3), 223-235.

Mallek, C. R. (2009). Fire history, stand origins, and the persistence of McNab cypress, northern California, USA. *Fire Ecology*, *5*(3), 100-119.

Mayer, K. E., & Laudenslayer, W. F. (1988). *A guide to wildlife habitats of California*. The Dept. of Fish and Game. 166 pages.

North, M. P., Stine, P., O'Hara, K., Zielinski, W., & Stephens S. (2009). *An ecosystem management strategy for Sierran mixed-conifer forests*, Gen. Tech. Rep. PSW-GTR-220. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

North, M. P. (Ed.). (2012). *Managing Sierra Nevada forests*, Gen. Tech. Rep. PSW-GTR-237. Albany (CA): U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

North, M.P., Boynton, R.M., Stine, P.A., Shipley, K.F., Underwood, E.C., Roth, N.E., Viers, J.H., Quinn, J.F. (2012). Geographic Information System Landscape Analysis Using GTR 220 Concepts. Chapter 10 in: North, M. P. (Ed.). *Managing Sierra Nevada forests*, Gen. Tech. Rep. PSW-GTR-237. Albany (CA): U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

Reiner, A. L., Vaillant, N. M., Fites-Kaufman, J., & Dailey, S. N. (2009). Mastication and prescribed fire impacts on fuels in a 25-year old ponderosa pine plantation, southern Sierra Nevada. *Forest Ecology and Management*, *258*(11), 2365-2372.

Reiner, A. L., Vaillant, N. M., & Dailey, S. N. (2012). Mastication and prescribed fire influences on tree mortality and predicted fire behavior in ponderosa pine. *Western Journal of Applied Forestry*, *27*(1), 36-41.

Reiner, A.L., Courson, M., Medrano, R., Ewell, C., Morgan, C., Dickinson, M., Blackburn, K., Sohl, Z., Key, H., Billings, S., Norman, T. (2014). *Beaver Fire Klamath National Forest, Fire Behavior Assessment Summary Report*. Unpublished document on file on: Retrieved on January 24, 2018 from https://www.fs.fed.us/adaptivemanagement/projects_main_fbat.php.

Reiner, A., Dickerson, M., Courson, M., Napier, K., Sexton, T., Miyagishima, A., Pasquale, R., Riggan, P. (2016). *Fire Behavior in Tree Mortality, Cedar Fire*. Unpublished document on file on: Retrieved on January 24, 2018 from https://www.fs.fed.us/adaptivemanagement/projects_main_fbat.php.

Reinhardt, E., Scott, J., Gray, K., & Keane, R. (2006). Estimating canopy fuel characteristics in five conifer stands in the western United States using tree and stand measurements. *Canadian Journal of Forest Research*, *36*(11), 2803-2814.

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

Safford, H. D., & Stevens, J. T. (2017). *Natural range of variation for yellow pine and mixed-conifer forests in the Sierra Nevada, southern Cascades, and Modoc and Inyo National Forests, California, USA*, Gen. Tech. Rep. PSW-GTR-256. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

Sawyer, J. O., Keeler-Wolf, T., & Evens, J. (2009). *Manual of California vegetation*. California Native Plant Society Press.

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

Scott, J. H., & Reinhardt, E. D. (2001). Assessing crown fire potential by linking models of surface and crown fire behavior. *USDA Forest Service Research Paper*, 1.

Scott, J. H., & Reinhardt, E. D. (2004). NEXUS 2.0. *Software program. (Systems for Environmental Management: Missoula, MT).*

Lutes, D.C., Keane, R.E. (2006). Fuel Load (FL) Sampling Method. In: Lutes, D.C., Keane, R.E., Caratti, J.F., Key, C.H., Benson, N.C., Sutherland, S., Gangi, L.J. (eds.), *FIREMON: Fire effects monitoring and inventory system*. USDA Forest Service, Rocky Mountain Research Station. Gen. Tech. Rep. RMRS-GTR-164-CD.

USDA Forest Service (2017). National Core Field Guide, Version 7.2. In: *National Forest Inventory and Analysis Handbook*. US Forest Service. Available on the web. Accessed on January 18, 2018 from: https://www.fia.fs.fed.us/library/field-guides-methods-proc/docs/2017/core_ver7-2_10_2017_final.pdf

Vaillant, N.M., Ewell, C.M., Fites-Kaufman, J.A. (2014). Capturing crown fire behavior on wildland fires – the Fire Behavior Assessment Team in Action. *Fire Management Today, 73*(4), 41-45.

Vaillant, N. M., Fites-Kaufman, J., Reiner, A. L., Noonan-Wright, E. K., & Dailey, S. N. (2009a). Effect of fuel treatments on fuels and potential fire behavior in California, USA, national forests. *Fire Ecology*, *5*(2), 14-29.

Vaillant, N.M., Fites-Kaufman, J.A. and Stephens, S.L., (2009b). Effectiveness of prescribed fire as a fuel treatment in Californian coniferous forests. *International Journal of Wildland Fire*, *18*(2), pp.165-175.

Vaillant, N.M., Noonan-Wright, E.K., Reiner, A.L., Ewell, C.M., Rau, B.M., Fites-Kaufman, J.A. and Dailey, S.N., (2015). Fuel accumulation and forest structure change following hazardous fuel reduction treatments throughout California. *International Journal of Wildland Fire*, *24*(3), pp.361-371.

van Wagtendonk, J. W., & Fites-Kaufman, J. A. (2006). Sierra Nevada bioregion. In Sugihara, N., van Wagtendonk, J. W., Shaffer, K., Fites-Kaufman, J. A., Thode, A., & Agee, J. (Eds.), *Fire in California's ecosystems* (pp. 264-294). Berkeley, CA: University of California Press.

Yuba Watershed Institute. (2000). *Final report: 'Inimim Forest timber harvest implementation plan* (Unpublished report). Nevada City, CA. Retrieved from http://yubawatershedinstitute.org/wp-content/uploads/2017/11/Final-Report_Inimim-Implementation-Plan_compressed.pdf.

Wagner, C. V. (1977). Conditions for the start and spread of crown fire. *Canadian Journal of Forest Research*, *7*(1), 23-34.