LITTLE BELTS LANDSCAPE ASSESSMENT

Vegetation Departure and Wildfire Threat Report

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for:

Lewis and Clark National Forest

Belt Creek, Judith, Musselshell, and White Sulphur Springs Ranger Districts

April 6, 2012

Table of Contents

List of Tables

List of Figures

Introduction

The purpose of this report is to provide a baseline for identifying and prioritizing potential management opportunities from a vegetative restoration and wildfire threat reduction perspective in the Little Belt Mountains of the Lewis and Clark National Forest. This baseline information will be built upon by other resource area specialists and compiled into a final document as part of the overall Little Belts Landscape Assessment. We conducted two analyses to guide our identification of treatment opportunities: 1) vegetation departure from reference conditions and 2) wildfire threat to highly valued resources and assets.

Forest vegetation is generally defined by a combination of climate, soil, and natural processes. Disturbance from wildfire, insects, and disease can substantially influence the distribution of species composition and structure at any given point in time. Wildfire in particular has had a major influence in shaping the vegetation of the Little Belt Mountains. In his 1904 report on historic forest conditions within the Little Belt Mountains Forest Reserve[1], Leiburg states "no large area of the reserve has remained untouched by fire during the last one hundred and fifty years." Leiberg further describes the age and structure of the forest as dominated by trees of the sapling to pole size with "red" (Douglas) fir and lodgepole pine occupying 79% of the area.

There have been relatively few acres burned in the Little Belts since Leiberg's review (figure 1). Today, forests are increasingly dominated by stands in the later development stages, with greater proportions of shade tolerant species, higher stand densities, and conifer regeneration in forest openings. Bark beetles have increased to epidemic levels, resulting in extensive areas with high tree mortality. Beetles have focused mainly on lodgepole pine, but have also impacted limber, whitebark, and ponderosa pine. Large areas of western spruce budworm have been defoliating Douglas-fir and other species, leading to tree mortality and lower growth rates.

These changes in vegetation composition and structure may or may not represent departed conditions depending on the natural range and variability which results from the predominant disturbance regimes the Little Belt Mountains, namely wildfire and insect outbreaks. In our first analysis we use a landscape-level approach to assess the departure of vegetative composition and structure from peer-reviewed reference conditions based on the historical range and variability (HRV). HRV concepts provide a useful framework for understanding ecological systems and providing guidance on management (Landres et al. 1999, Keane et al. 2009).

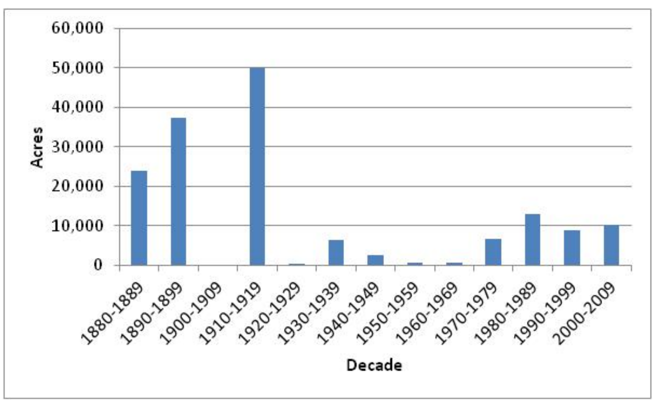

Figure 1: Acres burned by decade in the project area. Source: Lewis and Clark National Forest fire management geodatabase.

[1] In 1905 the Bureau of Forestry became the Forest Service and the previously named Forest Reserves became National Forests.

The forested land of the Little Belt Mountains is split almost equally by montane and subalpine forest types. At the lower elevations the montane types are comprised of Douglas-fir (*pseudotsuga menziesii*) and ponderosa pine (*pinus ponderosa*). As elevation increases lodgepole pine (*pinus contorta*) replaces the ponderosa as a co-dominant with Douglas-fir and provides an ecotone to the higher elevation subalpine type which is dominated by seral lodgepole pine. Whitebark pine (*pinus albicaulis*) resides at the highest elevations.

The historical fire regime in the montane types was characterized by relatively frequent, low to mixed severity fire with occasional stand-replacement fire (LANDFIRE 2011). In the subalpine types the fire regime was characterized by infrequent, mixed to high severity fire (LANDFIRE 2011). In his study on fire history of the Tenderfoot Creek Experimental Forest—an 8,600-acre Forest Service study area within the subalpine forests of the Little Belt Mountains—Barrett (1993) describes the fire regime being characterized predominantly by large, stand-replacing fire events occurring close in time, followed by long fire free intervals with occasional mixed-severity events, primarily on the more gently sloped mid- to upper-elevations of the study area. Much of the extensive even age classes of lodgepole pine seen today are the result of stand-replacing fires from the early- to mid-1700s and mid- to late-1800s (Leiburg 1904, Barrett 1993).

In the montane forest types the relative lack of fire over the last century may lead to stand conditions with higher potential for uncharacteristic fire effects, whereas in the subalpine forest types where long fire rotations and high severity are major components of the historical fire regime it is unlikely that the decrease of fire has had much influence from a fire effects or vegetation departure standpoint. However, the potential for high severity fire alone does not determine the wildfire hazard or threat to resources and assets.

In our second analysis we apply a wildfire threat assessment framework to assess the potential for adverse wildfire effects on highly valued resources and assets in the Little Belt Mountains. We define *wildfire hazard* as a fire environment—fuel, weather, topography, and ignition characteristics—with potential for causing damage to resources or assets. Fire hazard may be quantified as the annual burn probability and the distribution of wildfire intensity given that a fire does occur. That is, locations with high burn probability and predominance for high wildfire intensity have the highest hazard; locations with low burn probability and predominance for low wildfire intensity have the lowest hazard. *Wildfire threat* results from the combination of wildfire hazard and the vulnerability of resources and assets to fire. For example, the potential for wildfire damage to a residential building located in an area of flammable vegetation is the product of wildfire hazard (i.e., probability and intensity) and the vulnerability of the building to fire damage. Therefore, a theoretical fireproof building would not be threatened by wildfire.

The remainder of this report is presented in three sections. The *analysis overview* section discusses the concepts, data, and methodology used to assess vegetative departure and wildfire threat to highly valued resources and assets; the *landscape condition* section discusses the results of these two landscape-level analyses for the project area as a whole; and the *mid-scale opportunities* section identifies management opportunities for restoring departed vegetation and reducing wildfire threat to highly valued resources and assets in accordance with the Forest Plan (Forest Plan 1986).

A large amount of data has been compiled as a result of these two analyses which have application beyond what can be presented in this report. Appendix A outlines each of the data products which have been developed as part of this assessment. Further application of these data will depend on management objectives.

Analysis Overview

Vegetation Departure (FRCC)

Vegetation departure was assessed using the Fire Regime Condition Class Mapping Tool (FRCCmt) version 2.2.0 (FRCCmt 2008). Fire Regime Condition Class (FRCC) methodology provides a systematic process for comparing the current vegetation composition and structure to that of a reference condition (Barrett and others 2010). In this assessment, reference condition refers to an estimate of the vegetation composition and structure that may have existed under the landscape's historical fire regime prior to Euro-American settlement.

Biophysical setting and reference condition

Version 1.0.5 (Refresh 2001) of the biophysical setting (BpS) geospatial layer was downloaded from LANDFIRE. The BpS layer represents the natural plant communities that may have been dominant on the landscape during the reference period based on both the current biophysical environment and an approximation of the historical disturbance regime. For FRCC purposes, biophysical settings use dominant vegetation types and their associated fire regimes as a proxy for the integration of a landscape's biotic and abiotic components. Each BpS is associated with up to five succession classes, each representing a unique compositional and structural state within the BpS. Within a given BpS, an individual succession class (S-Class) may therefore be thought of as a stand—a homogenous area of vegetative composition, structure, and age class distribution. Figure 2 provides a stylized example of a forested BpS and the response of individual succession classes to successional and disturbance pathways. Note that multiple succession classes (i.e., multiple stands) may occur simultaneously across a given BpS. Note also that not all biophysical settings conform to the standard 5-box model. That is, some may have fewer than five succession classes (table 1).

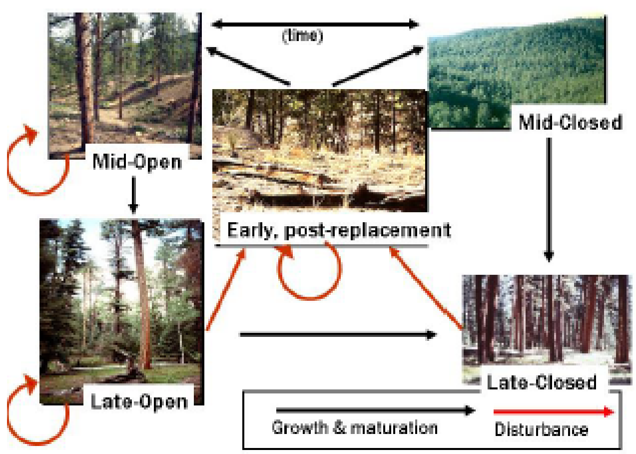

Figure 2: Stylized example of a standard "5-box" model for a forested biophysical setting.

Each BpS is associated with a vegetation dynamics model which is used to quantitatively assess information about vegetation succession and disturbances during the reference condition period[2]. Each model was built within the Vegetation Dynamics Development Tool (VDDT, www.essa.com) and run to develop a reference S-Class distribution. The reference S-Class

[2] Each vegetation dynamics model was created at regional modeling workshops held by the LANDFIRE program and underwent a review process that engaged regional experts from around the country and is based on expert knowledge and published literature.

distribution represents a mean percentage estimate for each S-Class that may have existed under the historical range and variability.

The Little Belts project area resides in LANDFIRE map zone 19 however is directly adjacent to map zone 20. Vegetation dynamics models may differ between map zones and therefore models for both zones were downloaded for evaluation. Each model includes comprehensive documentation that describes the vegetation, biophysical characteristics, disturbance regimes, and reference S-Class distribution of the BpS. A workshop was held in June 2011 with project team members to critique the vegetation dynamics models and participants decided which model best fit the project area based on local knowledge and expertise. The vegetation dynamics model and S-Class distribution used for each BpS in this assessment are shown in table 1.

Table 1: Vegetation dynamics model and succession class distribution of each biophysical setting assessed in the project area.

Biophysical Setting	Vegetation Dynamics Model	S-Class Distribution (percent)				
		A	B	C	D	E
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	2010550	15	35	20	30	NA
Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	1911661	20	15	30	20	15
Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest - Ponderosa Pine-Douglas-fir	2010451	10	15	20	40	15
Northern Rocky Mountain Subalpine Woodland and Parkland	1910460	20	40	15	5	20
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	2011390	15	85	NA	NA	NA
Rocky Mountain Subalpine/Upper Montane Riparian Systems	2011600	55	45	NA	NA	NA
Rocky Mountain Subalpine-Montane Mesic Meadow	2011450	5	20	75	NA	NA
Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	2010560	15	30	5	15	35
Rocky Mountain Foothill Limber Pine-Juniper Woodland	2010490	20	50	30	NA	NA
Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	2011060	10	45	45	NA	NA
Inter-Mountain Basins Big Sagebrush Steppe	2011250	35	35	30	NA	NA

Current vegetation

As mentioned above, FRCC methodology compares current vegetation composition and structure (i.e., S-Class) to that of a reference condition. The current S-Class layer was created using a custom S-Class mapping tool which assigns an S-Class value based on the combination of BpS, existing vegetation type (EVT), existing vegetation cover (EVC), and existing vegetation height (EVH). The S-Class layer characterizes the current vegetation composition and structure in the same successional classes that are defined in the vegetation dynamics model. Additional categories define uncharacteristic vegetation and areas such as water, urban, or agriculture which are omitted from the analysis of vegetation departure. Uncharacteristic conditions may include native vegetation with compositional or structural components outside the range and variability estimated for the reference period or introduced exotic vegetation.

Version 1.0.5 (Refresh 2001) of the EVT, EVC, and EVH geospatial layers were downloaded from LANDFIRE (2011) and used in mapping S-Class for the project area. Because the version 1.0.5 data represents the circa 2001 vegetation, the S-Class layer was updated to account for post-2000 wildfire and insect disturbance based on transition rules developed at the June workshop. Data of wildfire severity were acquired from the Monitoring Trends in Burn Severity program (MTBS 2010). Insect severity was derived from geospatial data of relative overstory canopy loss developed by the Region 1 Geospatial Services Group (Appendix B).

Calculating FRCC departure metrics

The reference S-Class distribution is based on historical disturbance regimes and therefore FRCC departure metrics are scale dependent. Because disturbance regimes operate at a landscape level it is important to understand and evaluate FRCC at the appropriate scale. In FRCC methodology, a *landscape* is defined as a contiguous area large enough to include the variation in vegetation composition and structure that would have existed under the historical disturbance regime. Therefore, the size of the landscape used to assess FRCC metrics is based on the dominant disturbance regime of each BpS. If the landscape is too small there may not be a good representation of the variability among S-Classes within a biophysical setting and the FRCCmt will often produce departure metrics that are too high. For example, one S-Class might dominate the landscape as the result of one large stand-replacement fire and result in an FRCC 3 (high departure) rating. Conversely, if the landscape is too large, small changes in FRCC departure metrics after future treatments or disturbances will be washed out.

Because wildfire is the dominant disturbance in the western United States, the FRCC guidebook (Barrett and others 2010) recommends delineating assessment landscapes based on the dominant fire regime group. That is, fire regimes with historically small patch-size variation can be assessed at smaller areas than those with large patch-size variation. Four fire regime groups are associated with the biophysical settings within the project area. A geospatial layer of landscape levels is required by the FRCCmt. This layer represents the geographic areas for deriving the composition of S-Class for any given BpS. In other words, the landscape and BpS layers together create the strata for which departure is assessed (Barrett and others 2010). In the western United States, Hydrologic Unit Code (HUC) boundaries often work well for FRCC landscape delineation. HUC data was acquired from the USDA Natural Resources Conservation Service and used to create a tri-level nested hierarchy for FRCC assessment. Table 2 lists the landscape levels used in this analysis for each BpS. Landscape level assignment was based on the historical fire regime and the amount and distribution of each BpS within landscape levels.

Table 2: Fire Regime Group and landscape level used to assess each biophysical setting.

Biophysical Setting	Acres within project area	Percent of project area	Fire Regime Group[1]	Landscape Level	Average acres within landscapes
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	264,544	29%	III	5th Level HUC	9,742
Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	264,164	29%	III	5th Level HUC	11,665
Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest - Ponderosa Pine-Douglas-fir	101,527	11%	I	6th Level HUC	1,211
Northern Rocky Mountain Subalpine Woodland and Parkland	46,276	5%	III	4th Level HUC	11,218
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	44,151	5%	II	6th Level HUC	4,123
Rocky Mountain Subalpine/Upper Montane Riparian Systems	40,823	5%	III	5th Level HUC	4,477
Rocky Mountain Subalpine-Montane Mesic Meadow	21,011	2%	II[2]	6th Level HUC	475
Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	15,600	2%	IV	Full Extent[3]	15,600
Rocky Mountain Foothill Limber Pine-Juniper Woodland	14,274	2%	III	4th Level HUC	3,946
Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	13,142	1%	IV	Full Extent	13,142
Inter-Mountain Basins Big Sagebrush Steppe	10,541	1%	IV	Full Extent	10,541
Other	62,614	7%	--	--	--

[1] Fire Regime Groups are: I: 0-35 year frequency, surface severity; II: 0-35 year frequency, replacement severity; III: 35-100+ year frequency, mixed severity; IV: 35-100+ year frequency, replacement severity; V: 200+ year frequency, replacement severity.

[2]Fire regime group assigned by workshop participants. Assignment differs from that in the vegetation dynamics model (table 1).

[3] Full extent refers to the extent of the geospatial data which includes the entire Little Belts project area.

Two levels of FRCC metrics are discussed in this report: Strata and stand. The Strata FRCC metric describes the departure across *all* succession classes within a particular BpS and landscape (i.e., strata). The strata FRCC metric classifies departure as FRCC 1(within the HRV), FRCC 2 (moderately departed from HRV), and FRCC 3 (highly departed from HRV). This metric is useful for identifying biophysical settings within a given landscape that may provide opportunity for restoration (Strata FRCC 2 and 3) or maintenance (Strata FRCC 1). At the stand level, the S-Class relative amount metric indicates *individual* succession classes that are departed within a given BpS and landscape. This metric is especially informative because it indicates whether the current amount of an individual S-Class is deficient or excessive relative to the reference condition and therefore may be used to identify treatable areas for meeting restoration or maintenance objectives. S-Class Relative Amount is divided into five categories: Trace, Under-represented, Similar, Over-represented, and Abundant. The S-Class relative amount metric is further classified into stand FRCC. Table 3 shows the relationship between percent difference (from reference condition), S-Class relative amount, and stand FRCC used by the FRCCmt version 2.2.0.

Table 3: Relationship between S-Class level percent difference, S-Class relative amount, and stand FRCC.

Range of Percent Difference	S-Class Relative Amount	Stand FRCC	Suggested Management[1]
< -66%	Trace	1	Maintain/Protect/Recruit
≥ -66% and < -33%	Under-represented	1	Maintain/Protect/Recruit
≥ -33% and ≤ 33%	Similar	1	Maintain/Protect
> 33% and ≤ 66%	Over-represented	2	Reduce
> 66%	Abundant	3	Reduce

[1] Given the objective is to manage towards reference conditions.

Wildfire Threat

We conducted a mid-scale multi-resource assessment of wildfire threat patterned after Calkin et al. (2010). Three main components are required to generate wildfire threat outputs: 1) spatial data of burn probability and wildfire intensity generated from simulations (wildfire hazard), 2) spatially identified highly valued resources and assets (HVRAs), and 3) response functions that describe the effects of fire to each HVRA. Figure 3 illustrates the conceptual approach to assessing wildfire threat in a spatially explicit, quantitative framework. Pairing components 1 and 2 provides important information regarding where on the landscape HVRAs will likely interact with fire, and under what fire behavior conditions (also known as exposure analysis). Component 3 further attempts to characterize the impacts to various HVRAs from this interaction with fire, which is very useful to inform planning efforts aimed at minimizing wildfire-related losses.

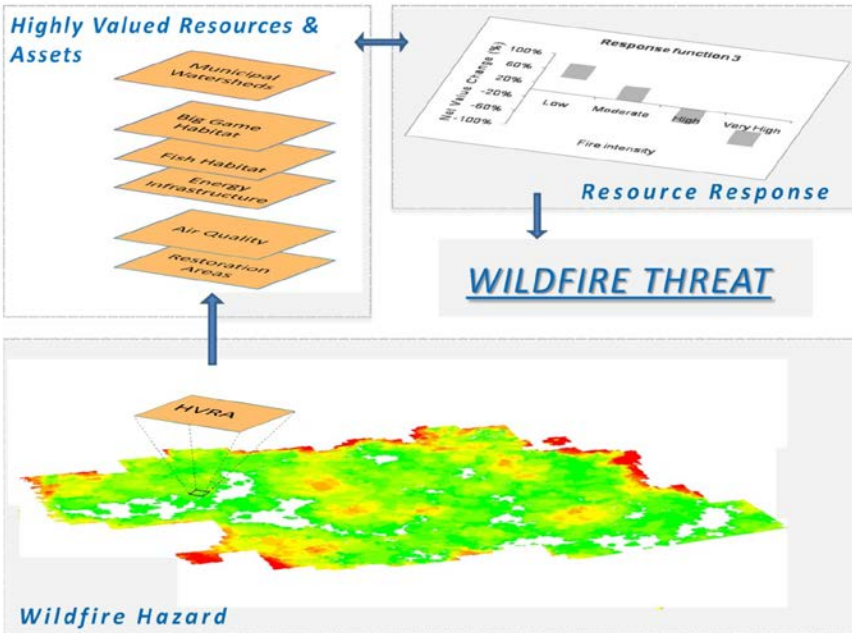

Figure 3: Spatially-explicit, quantitative approach to assessing wildfire threat. From Calkin et al. 2010.

Wildfire Hazard

Wildfire hazard can be described qualitatively by the fire environment (i.e., fuel, weather, topography, and ignition characteristics) or quantitatively as the probability distribution of wildfire intensity. That is, a location where wildfire is more likely to occur or is expected to be more intense has greater potential for causing damage and therefore is more hazardous. We used the large fire simulator (FSim) to model wildfire hazard. FSim is a comprehensive fire occurrence, growth, behavior, and suppression simulation system that uses locally relevant fuel, weather, topography, and historical fire occurrence information to estimate the spatially resolved burn probability and expected distribution of fireline intensity at each point across a landscape (Finney et al. 2011).

The same LANDFIRE geospatial layers of BpS, EVT, EVC, and EVH described in the previous section were used to develop fuels data for estimating wildfire hazard. Together with local Forest specialists we used the Total Fuel Change Tool (ToFu Delta; LANDFIRE 2010) to critique and update fuels data for use in the assessment. As in the vegetation departure analysis, spatial data of post-2000 wildfire severity (MTBS 2010) and overstory canopy loss from insects (Appendix B) were used to update the ca. 2001 LANDFIRE layers. Forest vegetation height was assumed to remain unchanged after low and moderate severity fire, but forest cover was reduced to a specified fraction of the pre-fire level (table 4). Post-wildfire canopy base height and canopy bulk density were adjusted using the methods in ToFu Delta. All canopy characteristics were set to zero in the case of high (stand-replacement) severity fire.

For insect disturbance, canopy height and canopy base height were assumed to remain unchanged following the disturbance, the rationale being that it is rare for all overstory trees to be killed and therefore canopy height, an average of the dominant vegetation, would not be affected and that the beetle species currently affecting the project area typically do not have a large effect on the smaller trees that contribute most to canopy base height. Canopy bulk density and canopy cover were reduced in proportion to the Region 1 canopy loss values (table 5; Scott and Reinhardt 2007, Reeves et al. 2009).

The effects of insect infestations on fuel and fire behavior vary with time since disturbance (Page and Jenkins 2007, Klutsch et al. 2009, Simard et al. 2010). Early in the infestation the surface fuel model and most canopy characteristics remain unchanged, but the reduced moisture content of the foliage temporarily increases the likelihood of crown fire (Jolly et al. 2012). This is called the “red phase” of the infestation. We did not simulate this phase because it is of relatively short duration at any given place on the landscape, usually 3-5 years. Instead, we simulated the longer-duration standing-gray phase during which the foliage and fine branches of dead trees have fallen to the ground—so canopy bulk density is reduced and surface fuel is slightly increased—but the dead trees remain standing with most of their branchwood still attached. Decades after the outbreak these dead trees will be falling to the ground, exacerbating fuel consumption, smoke production, and resistance-to-control in the event of a wildfire. We did not simulate this later phase of the current outbreak.

Geospatial topography data (elevation, slope, and aspect) were downloaded from LANDFIRE (2011) and combined with the updated fuels data for use in FSim.

Table 4: Forest canopy cover and height adjustments for wildfire disturbance.

Canopy Attribute	Low Severity	Moderate Severity	High Severity
Forest canopy cover reduction	10%	40%	100%
Forest canopy height reduction	None	None	100%

Table 5: Forest canopy cover and bulk density adjustments for insect disturbance.

Canopy Attribute	Low (10-25% loss)	Moderate (25-50% loss)	High (50-75% loss)	V. High (75-100% loss)
Forest canopy cover and bulk density reduction	17.5%	37.5%	62.5%	87.5%

Highly Valued Resources and Assets

The Forest had identified five general highly valued resources and assets (HVRAs) to be analyzed in this assessment:

- Wildland Urban Interface
- Infrastructure
- Critical Wildlife Habitat
- Green Trees
- High Value Watersheds

Each project resource specialist was asked to fill out a survey to characterize the HVRA in the context of their resource area and describe factors that affect how the resource or asset responds to fire. Survey responses were used in a workshop setting to further characterize the HVRAs (appendix C). To obtain more precision in the application of response functions, many of the general HVRAs were divided into sub-HVRAs and variants of sub-HVRAs (table 6). Finally, GIS specialists mapped each HVRA/sub-HVRA/Variant combination for use in the threat assessment.

The wildland urban interface (WUI) HVRA was characterized as areas where there are more than 0.1 structures per square kilometer within a 3-kilometer search radius. Structure data was acquired from the Montana structures framework dataset (available online: http://giscoordination.mt.gov/) and a density raster was created in ArcGIS. The infrastructure HVRA was divided into four sub-HVRAs: general-investment infrastructure, high-investment infrastructure, power lines, and electronics sites. GIS specialists worked with Forest staff to categorize spatial data from the Forest cooperate geodatabase into the sub-HVRA categories. Critical wildlife habitat was divided into seven sub-HVRA/variant combinations using vegetation as a surrogate for habitat. LANDFIRE EVT spatial data were used to characterize and map the aspen, sagebrush steppe, and whitebark pine sub-HVRAs; LANDFIRE BpS spatial data were used to characterize and map the riparian sub-HVRA; ungulate winter range and old growth were available from the Forest corporate geodatabase but LANDFIRE EVT was used to differentiate between the wet and dry old growth variants. Green trees were divided into five sub-HVRA/variant combinations. The Tenderfoot Creek Experimental Forest boundary, including the Research Natural Area within its perimeter characterizes the sub-HVRA. The timber base sub-HVRA is characterized as the Forest's management area B; LANDFIRE EVT was used to differentiate between the cover types. The visual quality sub-HVRA was characterized as a ¼ mile buffer around point and linear features deemed to have visual quality significance by Forest staff. Areas which have experienced 75 percent or greater canopy loss from wildfire or insects were excluded from the visual quality sub-HVRA. LANDFIRE EVT was used to differentiate between the cover types. High value watersheds were divided into four sub-HVRA/variant combinations. The westslope cutthroat trout sub-HVRA was characterized as 7^{th} level HUC watersheds that include greater than 90 percent genetically pure populations. A 35 percent slope threshold was further applied as a variant. Municipal watershed boundaries were available in the Forest corporate geodatabase. This sub-HVRA also used a 35 percent slope threshold as a variant.

Response Functions

Forest staff members quantified the relative response to wildfire (net value change) for each HVRA/sub-HVRA/Variant combination (table 6). With the exception of WUI, all the general HVRAs were divided so that different response functions or different weights could be applied to each sub-HVRA and/or variant of the sub-HVRA. The response function values reflect the relative net change in value of a unit area of the HVRA if it burns in each of six fire intensity levels (FILs). Positive response function values indicate a benefit, or increase in value; negative response function values indicate a loss, or decrease in value. Response function values ranged from -100 (greatest possible loss of resource value) to +100 (greatest increase in value).

Table 6. Baseline tabular response functions and relative importance for each HVRA. Response function values represent the net percentage change in value of the HVRA for a given fire intensity level. Negative numbers indicate a loss of value; positive numbers indicate an increase in value.

HVRA	Sub-HVRA	Variant	HVRA RI	Sub RI	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
WUI	WUI	--	100	--	-10	-30	-60	-80	-100	-100
Infrastructure	general-investment infrastructure	--	90	60	0	-10	-40	-70	-90	-90
	high-investment infrastructure	--		100	-10	-30	-60	-80	-100	-100
	power lines	--		50	0	-10	-20	-40	-80	-80
	electronics sites	--		30	0	-10	-20	-40	-60	-80
Critical Wildlife Habitat	aspen	--	50	100	80	100	100	50	-10	-20
	old growth	dry site		50	75	50	30	0	-50	-100
	old growth	wet site			0	-10	-30	-50	-80	-100
	riparian	--		100	20	0	-20	-50	-80	-100
	sagebrush steppe	--		80	-10	-30	-50	-90	-100	-100
	ungulate winter range	--		40	20	10	-30	-50	-80	-100
	whitebark pine	--		100	80	100	80	-30	-80	-100
Green Trees	Tenderfoot Creek Experimental Forest	--	30	100	-100	-100	-100	-100	-100	-100
	timber base	PP/DF		50	40	10	-20	-80	-100	-100
	timber base	Other types			-10	-30	-70	-90	-90	-100
	visual quality	PP/DF/Juniper		40	50	30	10	-50	-70	-100
	visual quality	Other types			10	-20	-40	-80	-80	-90
High Value Watersheds	westslope cutthroat trout streams	slope < 35%	70	90	20	20	10	0	-30	-50
	westslope cutthroat trout streams	slope >= 35%			20	20	-10	-30	-50	-80
	municipal watersheds	slope < 35%		100	0	0	0	-10	-20	-40
	municipal watersheds	slope >= 35%			0	0	-10	-30	-50	-80

Fire intensity levels are represented as flame length in feet: FIL1: 0 to 2 ft, FIL2: greater than 2 to 4 ft, FIL3: greater than 4 to 6 ft, FIL4: greater than 6 to 8 ft, FIL5: greater than 8 to 12 ft, and FIL6: greater than 12 ft.

The above response functions can be applied as-is to each HVRA individually, but doing so without modification does not allow the individual responses to be added into an overall response to all HVRAs. Summing the response to wildfire across all HVRAs requires an estimate of the relative importance of each to the others. This was accomplished by Forest staff in a workshop setting. First, the most important resource on the Forest was identified and given a Relative Importance (RI) value of 100. Structure density, or WUI, was judged to be the most important HVRA on the Forest by Forest leadership (table 6).

Next, RI values were assigned to each of the remaining HVRAs. Infrastructure (general- and high-investment, power lines, and electronics sites) was given a value of 90, meaning that, overall on the whole Forest, infrastructure is 90 percent as important as WUI. Staff also assigned a relative importance value to each of the sub-resources. These values represent the share of the parent HVRA's overall importance.

The relative importance values apply to the overall HVRA on the Forest as a whole. The calculations need to take into account the relative extent of each HVRA to avoid overemphasizing those that cover many acres. This was accomplished by normalizing the calculations by the relative extent of each HVRA on the forest. Here, relative extent refers to the number of pixels mapped to each HVRA. In using this method, the relative importance of each HVRA is spread out over the HVRAs extent. An HVRA with few pixels can have a high importance per pixel; an HVRA with a great many pixels has a low importance per pixel.

Landscape Condition

In this section we present the results of the individual vegetation departure and wildfire threat analyses. The focus is on landscape-scale condition without consideration of management opportunities which are discussed in the next section.

Vegetation Departure

The eleven biophysical settings assessed for vegetation departure cover 93 percent of the project area. Figures 4 and 5 show their distribution graphically and spatially.

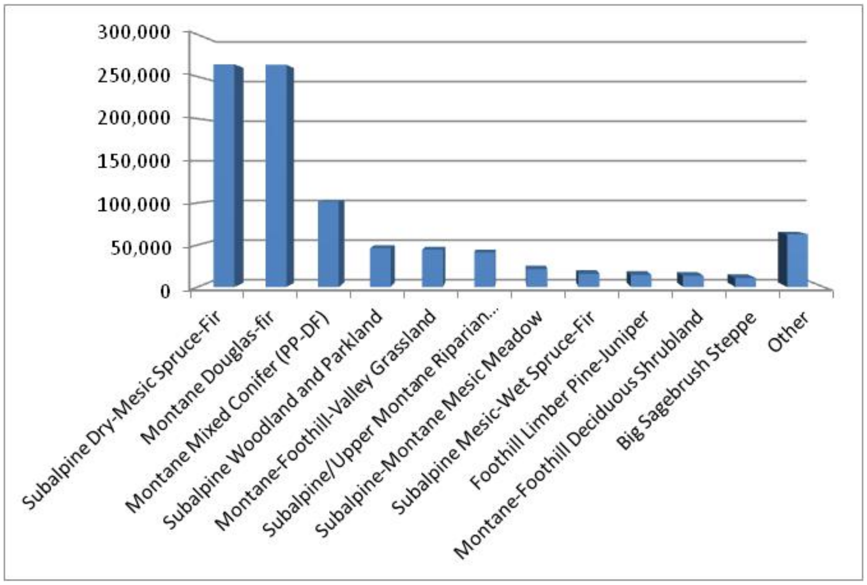

Figure 4: Acres of biophysical settings within project area.

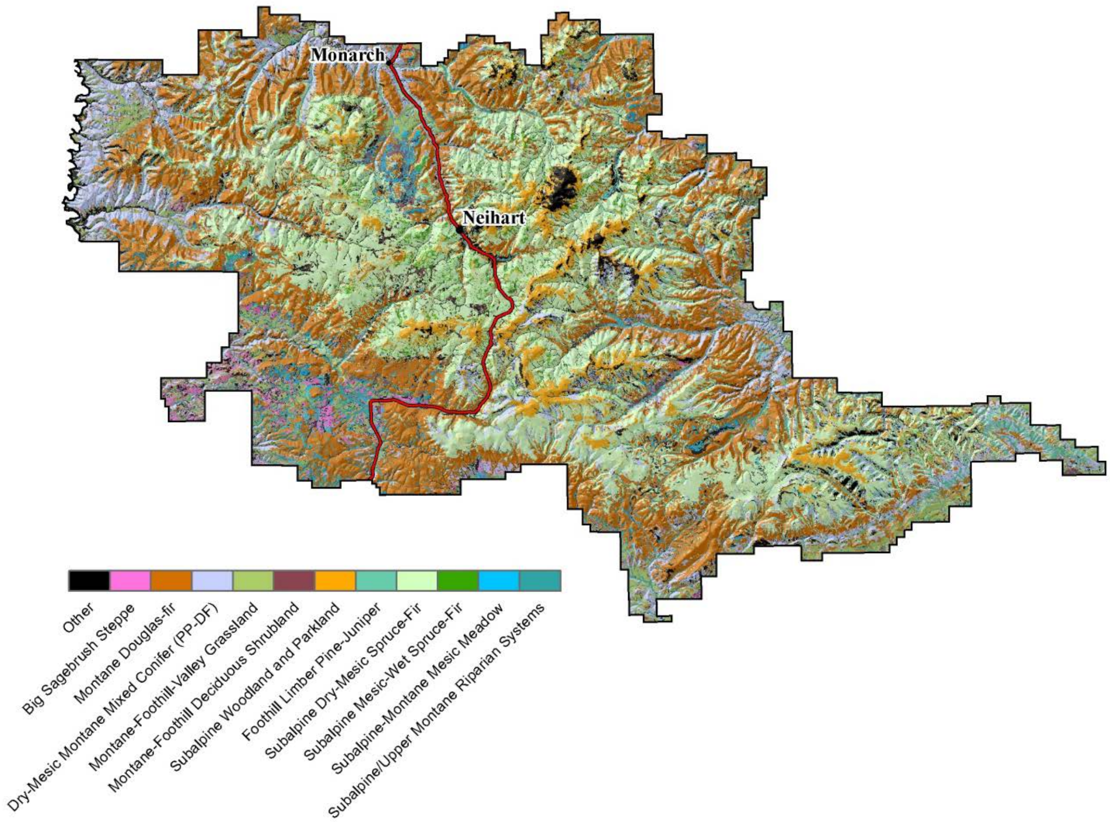

Figure 5: Spatial distribution of biophysical settings in the project area. Highway 89, towns, and hillshade shown for reference.

Overall, vegetation in the Little Belt Mountains is primarily in a state of moderate departure from the historical range and variability at the strata level (figure 6). At the S-Class, or stand, level variability exists across ranger districts (figures 7 and 8) but overall departure is primarily the result of one or two S-Classes dominating within a BpS.

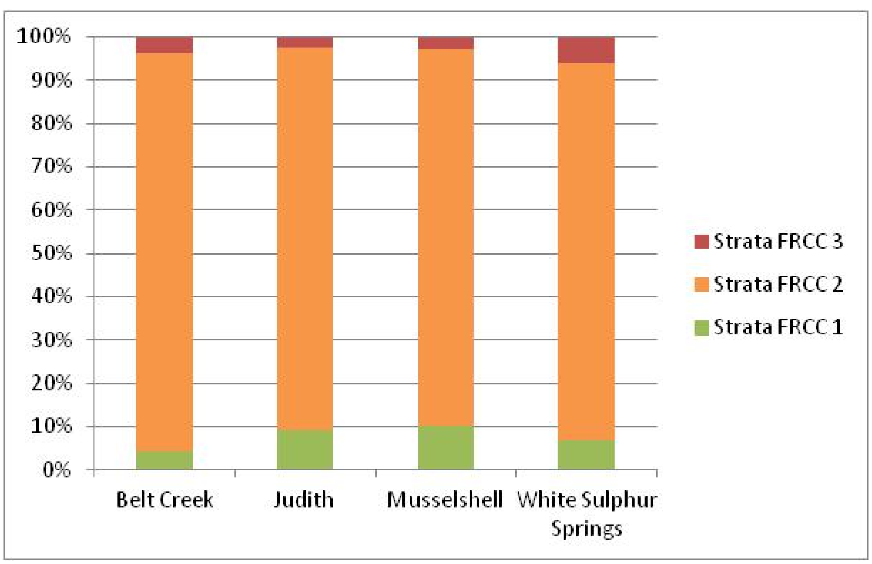

Figure 6: Strata FRCC by Ranger District in the Little Belt Mountains.

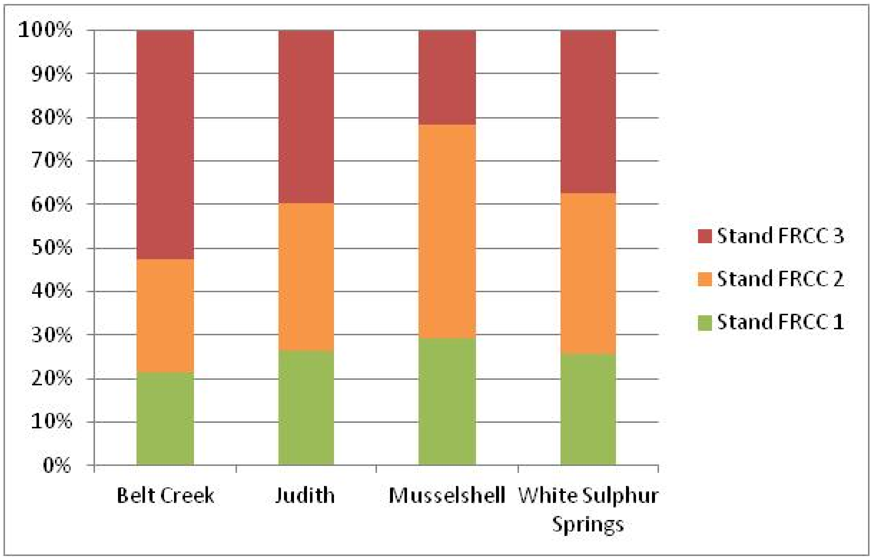

Figure 7: Stand FRCC by Ranger District in the Little Belt Mountains.

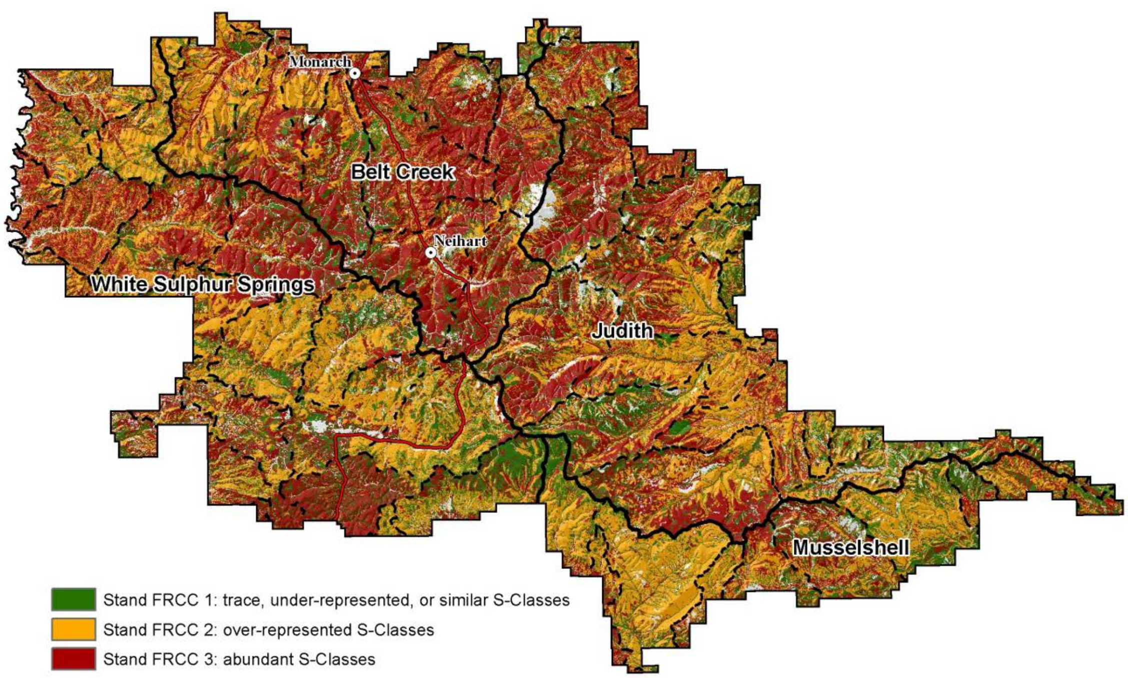

Figure 8: Stand FRCC in the Little Belt Mountains. Highway 89, towns, and 6th level HUC subwatersheds (dashed lines) shown for reference.

The four most prominent forested BpSs include:

- Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
- Middle Rocky Mountain Montane Douglas-fir Forest and Woodland
- Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest - Ponderosa Pine-Douglas-fir

- Northern Rocky Mountain Subalpine Woodland and Parkland.

Cumulatively these four BpSs represent 74% of the project area. These four BpSs were used in the identification of management opportunities and therefore are discussed individually below. Information on the vegetation departure analysis for the remaining BpSs is available in the project record (appendix A).

Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland

The Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland BpS is mapped to 29% of the project area (figure 5). This BpS is dominated by lodgepole pine, subalpine fir (*abies lasiocarpa*), and Engelmann spruce (*picea engelmannii*). The vegetation dynamics model uses four S-Classes to describe this BpS (table 7). The upper canopies of classes A through C are dominated by lodgepole pine. Class D is distinguished from class C by species composition rather than structure, with D being dominated by mature spruce and fir. Canopy cover of less than 20 percent in mid- and late-seral stands is considered to be uncharacteristic for this BpS.

The distribution of vegetation composition and structure in this BpS is largely driven by the wildfire history. As mentioned previously, much of the extensive even age classes of lodgepole pine seen today in the Little Belts are the result of stand-replacing fires from the early- to mid-1700s and mid- to late-1800s (Leiburg 1904, Barrett 1993). Fire frequency and severity vary with factors such as terrain, climatic variability, and neighboring fire regimes but the historical fire regime in this BpS was predominantly characterized by infrequent, stand-replacement events. After approximately 80-100 years without fire, forests will typically experience some level of mortality from insects and disease (LANDFIRE 2011), as is evident in the Little Belts today. Spruce beetle and mountain pine beetle can influence species composition and structure leading to changes in the S-class distribution. Mountain pine beetle for example, may act to accelerate succession by removing the lodgepole pine and promoting the more shade-tolerant species.

The forests of this BpS are forests of recovery and the absence of large wildfires since their establishment has allowed succession to progress without major interruption leading to a dominance of vegetation in later development stages. This trend has been partially offset through regeneration harvests or high canopy loss from mountain pine beetle transitioning stands back to class A. The near future trend in distribution changes is largely a factor of mortality to the lodgepole pine from mountain pine beetle or wildfire.

Table 7 shows the S-Classes used in this BpS and compares the reference and current distributions. 79 percent of the acres are in the late-seral classes C and D. The mid-seral class B represents only five percent of the BpS currently, compared to 35 percent under the reference condition.

Table 7: Succession class distribution of Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland BpS within the project area compared to reference condition.

S-Class	Age/Structure	General Description	Reference %	Current %	Current Acres[1]
A	Early seral, all structures	0 to 100% canopy cover of grasses, forbs, low shrubs and lodgepole pine seedlings/saplings. Tree height ≤ 5 meters.	15%	12%	32,113
B	Mid-seral, all structures	21 to 100% canopy of pole-sized trees. Lodgepole pine dominates upper canopy, subalpine fir present in middle canopy. Stand height 5 to < 10 meters.	35%	5%	12,524
C	Late-seral, closed structure	21 to 100% canopy of medium-sized trees. Lodgepole pine dominates upper canopy, subalpine fir present in mid-upper canopy. Stand height 10 to < 25 meters.	20%	64%	170,413
D	Late-seral, closed structure	21 to 100% canopy of mature subalpine fir and Engelmann spruce. Stand height 5 to < 25 meters.	30%	15%	39,244
U	--	Mid to late seral, ≤ 20% canopy cover.	0%	4%	9,645

[1] Sum does not include permanently converted areas of the BpS (e.g., agriculture, urban).

This BpS was assessed at the watershed scale (5th level HUC). At the strata level 95 percent of the BpS is moderately departed (Strata FRCC 2) and five percent is within the HRV (Strata FRCC 1). The strata FRCC 2 rating is driven by the surplus of class C and large deficit of class B.

In general the White Sulphur Springs and Musselshell Ranger Districts are slightly less departed at the stand, or S-Class, level than the Belt Creek and Judith Ranger Districts where the watersheds show an abundance of class C and associated stand FRCC 3 rating (figures 9 and 10).

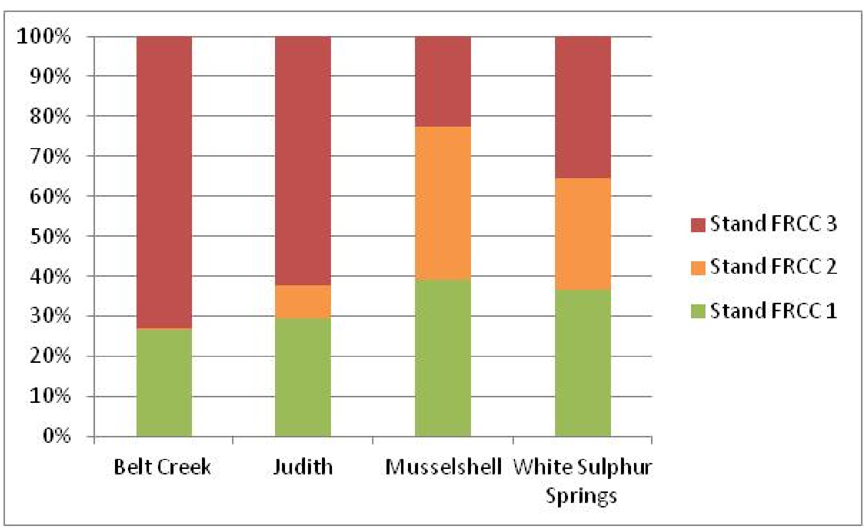

Figure 9: Stand FRCC in the Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland BpS summarized by Ranger District.

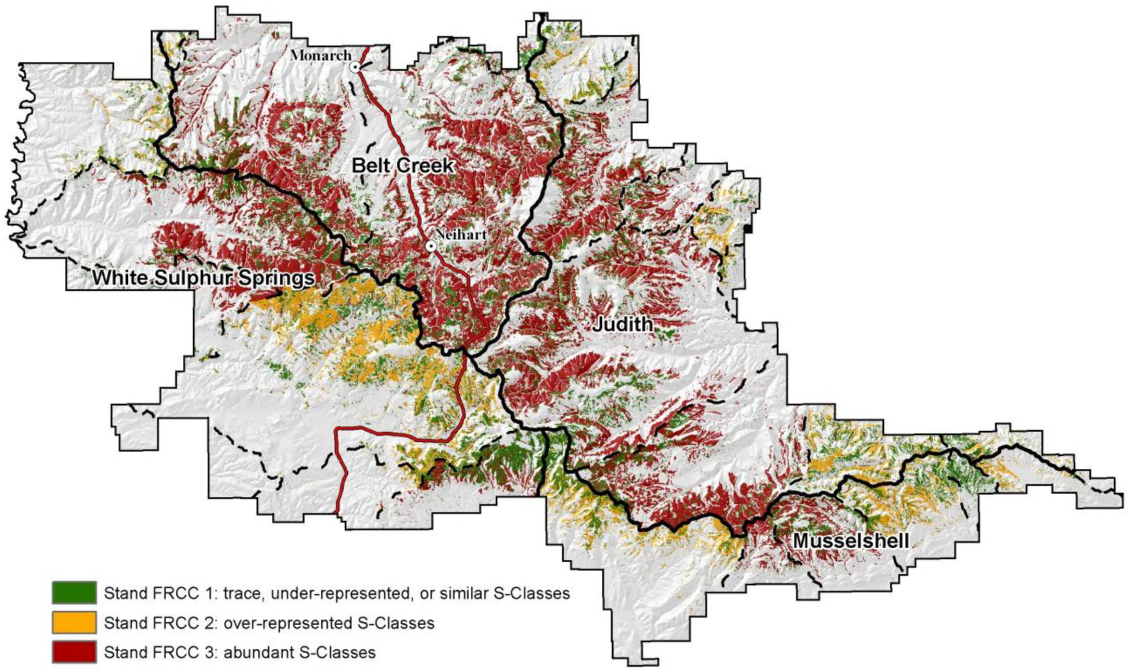

Figure 10: Spatial distribution of stand FRCC in the Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland BpS. Solid black lines represent ranger district boundaries; dashed black lines represent 5th level HUC watershed boundaries. Highway 89 and towns shown for reference.

Middle Rocky Mountain Montane Douglas-fir Forest and Woodland

The Middle Rocky Mountain Montane Douglas-fir Forest and Woodland BpS is mapped to 29% of the project area (figure 5). This BpS is dominated by Douglas-fir with an understory of grasses and sparse shrubs. Limber pine (*pinus flexilis*) may be present and lodgepole pine can co-dominate on cooler sites. The vegetation dynamics model uses five S-Classes to describe this BpS (table 8). S-Classes are distinguished by both tree size and density. Canopy cover exceeding 90 percent or less than 20 percent in mid- and late-seral classes is considered as uncharacteristic. It is worth noting that the vegetation dynamics model for this BpS classifies stands greater than 10 meters in height as late-seral—a breakpoint value considered to be low by some project specialists for differentiating between mid- and late-seral.

The historical fire regime in this BpS was predominantly characterized by relatively frequent, mixed severity fire but included occasional surface and stand-replacement fire as well (LANDFIRE 2011). The relative absence of fire in recent history has allowed Douglas-fir to increase in stand density resulting in a predominance of closed canopy structure. Comparison of reference to current S-Class distribution shows a deficiency in the early- and mid-seral classes A through C (table 8). Forest canopy loss from insects over approximately the last decade is responsible for 55 percent of the current open canopy structure. Canopy loss within this BpS was observed as pockets of lodgepole pine mortality from mountain pine beetle.

Table 8: Succession class distribution of Middle Rocky Mountain Montane Douglas-fir Forest and Woodland BpS within the project area compared to reference condition.

S-Class	Age/Structure	General Description	Reference %	Current %	Current Acres[1]
A	Early seral, all structures	0 to 90% canopy cover of grasses and Douglas-fir, lodgepole pine and/or limber pine seedlings/saplings. Tree height ≤ 5 meters.	20%	5%	13,053
B	Mid-seral, closed structure	41 to 90% canopy of pole to medium sized Douglas-fir, lodgepole, or limber pine. Stand height 5 to < 10 meters.	15%	0%	325
C	Mid-seral, open structure	21 to 40% canopy of medium-sized Douglas-fir, lodgepole, or limber pine. Stand height 5 to < 10 meters.	30%	7%	17,941
D	Late-seral, open structure	21 to 40% canopy of medium to large lodgepole pine and/or limber pine and large to very large Douglas-fir. Stand height 10 to < 25 meters.	20%	48%	125,918
E	Late-seral, closed structure	41 to 90% canopy cover, multi-storied Douglas-fir with lodgepole and limber pine sometimes present. Stand height 10 to < 25 meters.	15%	37%	97,426
U	--	> 90% canopy cover or ≤ 20% cover in mid- and late-seral classes.	0%	4%	9,256

[1] Sum does not include permanently converted areas of the BpS (e.g., agriculture, urban).

This BpS was assessed at the watershed scale (5th level HUC). At the strata level all watersheds within the project area are moderately departed from the HRV (strata FRCC 2). The strata FRCC 2 rating is driven by the deficiency in early- and mid-seral vegetation.

At the stand, or S-Class, level the Musselshell Ranger District has the least amount of S-Classes in an abundant (stand FRCC 3) status (figures 11 and 12). The other ranger districts show slightly more variability in S-Class distribution across watersheds.

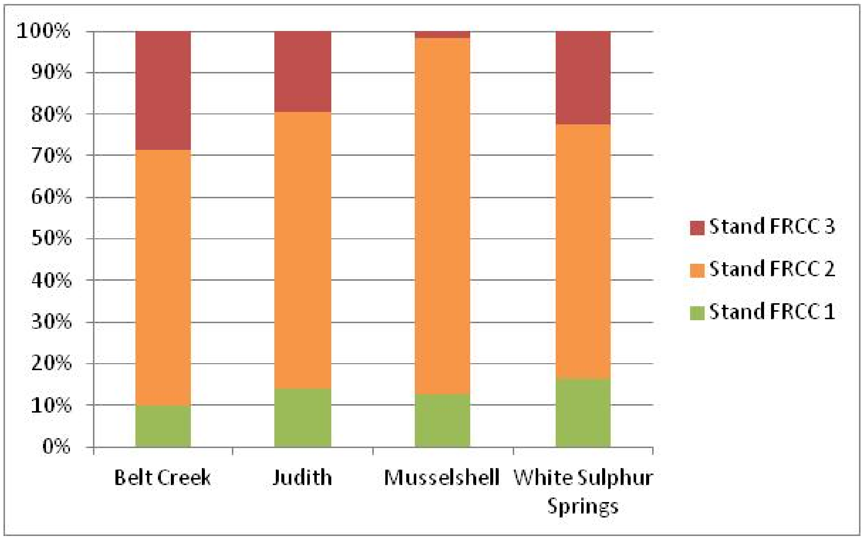

Figure 11: Stand FRCC in the Middle Rocky Mountain Montane Douglas-fir Forest and Woodland BpS summarized by Ranger District.

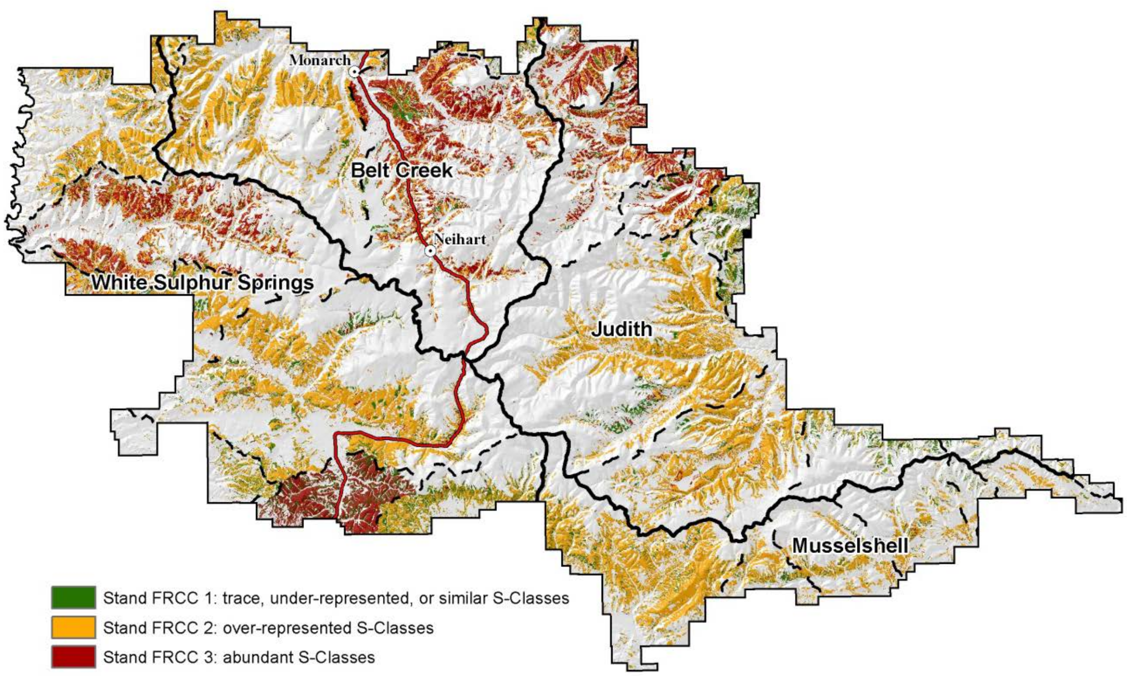

Figure 12: Spatial distribution of stand FRCC in the Middle Rocky Mountain Montane Douglas-fir Forest and Woodland BpS. Solid black lines represent ranger district boundaries; dashed black lines represent 5th level HUC watershed boundaries. Highway 89 and towns shown for reference.

Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest - Ponderosa Pine-Douglas-fir

Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest - Ponderosa Pine-Douglas-fir BpS is mapped to 11% of the project area (figure 5). Open stands of ponderosa pine are generally dominant on southerly aspects and drier sites. Northerly aspects and more mesic sites generally support more closed, Douglas-fir dominated stands. In the absence of fire, Douglas-fir dominates stand understories on both dry and mesic sites. Lodgepole pine may also be present but is poorly represented in this BpS. The vegetation dynamics model uses five S-Classes to describe this BpS (table 9). S-Classes are distinguished by both tree size and density. Canopy cover exceeding 70 percent in mid-seral stands and less than 20 percent or greater than 80 percent in late-seral stands is considered as uncharacteristic in this BpS (LANDFIRE 2011).

The historical fire regime of this BpS was characterized primarily by low and mixed severity fires at varying frequency intervals. Occasional stand-replacement fires also occurred. Mixed and stand-replacement severity would have been more common on the mesic sites. Insects and disease play an important role, especially in the absence of fire. Bark beetles such as mountain pine beetle, western pine beetle, and Douglas-fir beetle are active in the mid- and late-seral stages, especially in closed canopies. Weather related disturbances, including drought, tend to affect the late closed structure more than other structural stages (LANDFIRE 2011).

As in the middle rocky mountain montane Douglas-fir BpS the relative absence of fire in recent history has allowed Douglas-fir to increase in stand density in this BpS as well. Insect activity has been reducing some of the overstory canopy. Canopy loss associated with insect outbreaks is responsible for 64% of the mid-seral, open class C. Observed mortality has been limited in extent from individual trees to small pockets of ponderosa pine. Near future trends are likely to be similar until mountain pine beetle activity subsides.

Table 9: Succession class distribution of Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest - Ponderosa Pine-Douglas-fir BpS within the project area compared to reference condition.

S-Class	Age/Structure	General Description	Reference %	Current %	Current Acres[1]
A	Early seral, all structures	0 to 100% canopy cover of grasses, forbs, and Douglas-fir and ponderosa pine seedlings/saplings. Tree height ≤ 5 meters.	10%	7%	7,324
B	Mid-seral, closed structure	31 to 70% canopy of pole to medium-sized ponderosa pine and sapling to pole-sized Douglas-fir. Stand height 5 to < 25 meters.	15%	48%	48,894
C	Mid-seral, open structure	0 to 30% canopy of medium to large-sized ponderosa pine and pole to medium-sized Douglas-fir. Stand height 5 to < 25 meters.	20%	41%	41,815
D	Late-seral, open structure	21 to 60% canopy of very large ponderosa pine and Douglas-fir. Stand height 25 to < 50 meters.	40%	0%	222
E	Late-seral, closed structure	61 to 80% canopy of very large ponderosa pine and Douglas-fir. Stand height 25 to < 50 meters.	15%	0%	164
U	--	> 70% canopy cover in mid-seral classes and ≤ 20% or > 80% in late-seral classes.	0%	3%	2,902

[1] Sum does not include permanently converted areas of the BpS (e.g., agriculture, urban).

Comparison of reference to current S-Class distribution indicates a surplus of mid-seral vegetation and near absence of late-seral vegetation (table 9). This BpS was assessed at the subwatershed (6^{th} level HUC) scale. At the strata level all subwatersheds within the project area are moderately departed from the HRV (strata FRCC 2). The strata FRCC 2 rating is driven by the deficiency in late-seral vegetation.

At the stand, or S-Class, level variability exists between subwatersheds based on the proportion of mid-seral, closed class B to mid-seral, open class C. S-Class B is more abundant in the subwatersheds of the Belt Creek, Judith, and White Sulphur Springs Ranger Districts than it is in the subwatersheds of the Musselshell Ranger District resulting in the difference in proportions of stand FRCC 2 and 3 seen in figure 13. The abundance of class B is spatially most concentrated in the northwestern portion of the project area, in the Belt Creek and White Sulphur Springs Ranger Districts (figure 14).

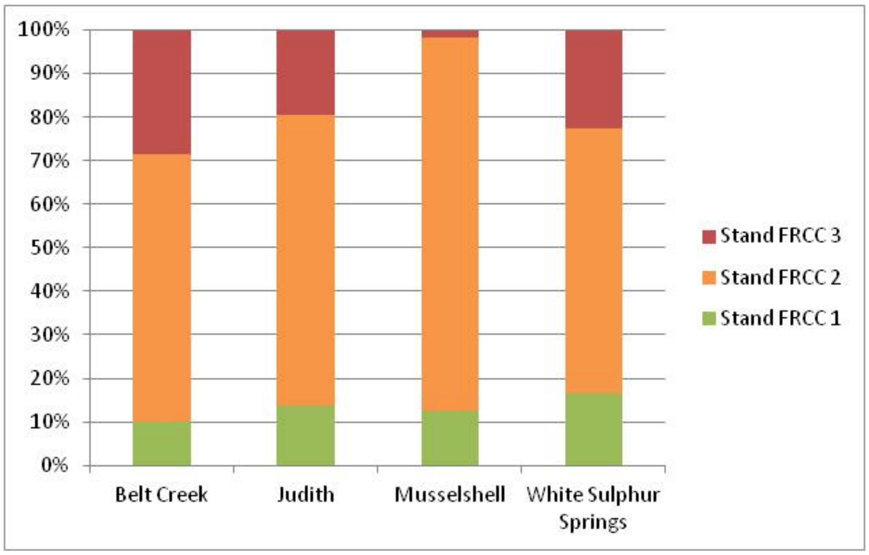

Figure 13: Stand FRCC in the Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest - Ponderosa Pine-Douglas-fir BpS summarized by Ranger District.

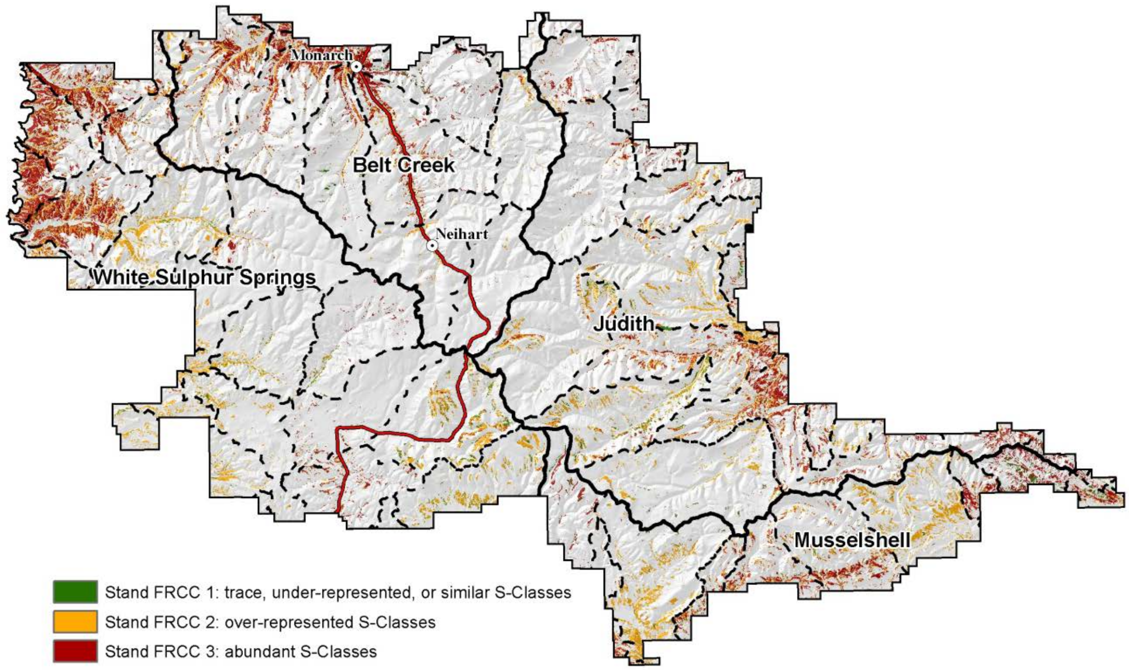

Figure 14: Spatial distribution of stand FRCC in the Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest - Ponderosa Pine-Douglas-fir BpS. Solid black lines represent ranger district boundaries; dashed black lines represent 6th level HUC subwatershed boundaries. Highway 89 and towns shown for reference.

Northern Rocky Mountain Subalpine Woodland and Parkland

The Northern Rocky Mountain Subalpine Woodland and Parkland BpS is mapped to only five percent of the project area (figure5) but is an important ecosystem type both locally and regionally. Forest vegetation ranges from nearly homogeneous stands of whitebark and limber pines on the harshest, highest elevation or southern aspect sites to mixed species stands comprised of shade tolerant subalpine fir and Engelmann spruce on more northern aspect sites. Lodgepole pine may be present as an early successional species. The vegetation dynamics model uses five S-Classes to describe this BpS (table 10). Although tree size and density delineate the S-Classes in the model, the closed classes B and E are primarily due to the presence of subalpine fir. Forest stands greater than 25 meters in height are considered uncharacteristic in this BpS.

The historical fire regime was characterized by infrequent mixed and stand-replacement severity fires (LANDFIRE 2011). Although lightning ignitions are frequent, fires seldom carry due to the general lack of continuous fuel in this BpS. Torching of individual or groups of trees under dry and windy conditions is the common mechanism of fire-induced tree mortality. Mountain pine beetle is an important disturbance agent in this BpS. Observed mortality indicated substantial loss of individual and groups of whitebark and limber pine resulting in loss of canopy cover and acceleration to subalpine fir. Given that much of the pine in this type has been lost, future mountain pine beetle activity would have little influence on further changes to the current S-class distribution.

Table 10: Succession class distribution of Northern Rocky Mountain Subalpine Woodland and Parkland BpS within the project area compared to reference condition.

S-Class	Age/Structure	General Description	Reference %	Current %	Current Acres[1]
A	Early seral, all structures	Early succession after infrequent disturbance. Whitebark pine, limber pine, and subalpine larch are typical early pioneers. Lodgepole pine may be present. Tree height ≤ 5 meters.	20%	12%	5,390
B	Mid-seral, closed structure	31 to 100% canopy of pole-sized mix of shade tolerant and intolerant species. Stand height 5 to < 10 meters.	40%	2%	697
C	Mid-seral, open structure	0 to 30% canopy of pole-sized mix of shade tolerant and intolerant species. Stand height 5 to < 10 meters.	15%	13%	5,895
D	Late-seral, open structure	0 to 40% canopy of medium-sized mixed conifer species in small to moderate size patches. Stand height 10 to < 25 meters.	5%	25%	11,649
E	Late-seral, closed structure	41 to 100% canopy of medium-sized mixed conifer species in small to moderate size patches. Subalpine fir encroachment likely. Stand height 10 to < 25 meters.	20%	49%	22,589
U	--	≥ 25 meter stand height.	0%	0%	24

[1] Sum does not include permanently converted areas of the BpS (e.g., agriculture, urban).

Comparison of reference to current S-Class distribution reveals a significant deficit in mid-seral, closed class B and a surplus of late-seral classes D and E (table 10). It is unlikely that a lack of wildfire has had much effect on this BpS due to its long-interval fire regime but mountain pine beetle is responsible for transitioning 743 acres of mid-seral, closed class B to mid-seral, open class C (13 percent of class C) and 814 acres of late-seral, closed class E to late-seral, closed class D (7 percent of class D) based on the relative canopy loss data (appendix B).

This BpS was assessed at the subbasin (4th level HUC) scale. At the strata level all subbains within the project area are moderately departed from the HRV (strata FRCC 2). The strata FRCC 2 rating is driven by the surplus of late-seral vegetation and high deficiency of mid-seral, closed class B.

At the stand, or S-Class, level the White Sulphur Springs Ranger District is the most departed due to it having over 70% of its S-Classes in an abundant (stand FRCC 3) status. There is little variability across the remaining ranger districts (figures 15 and 16).

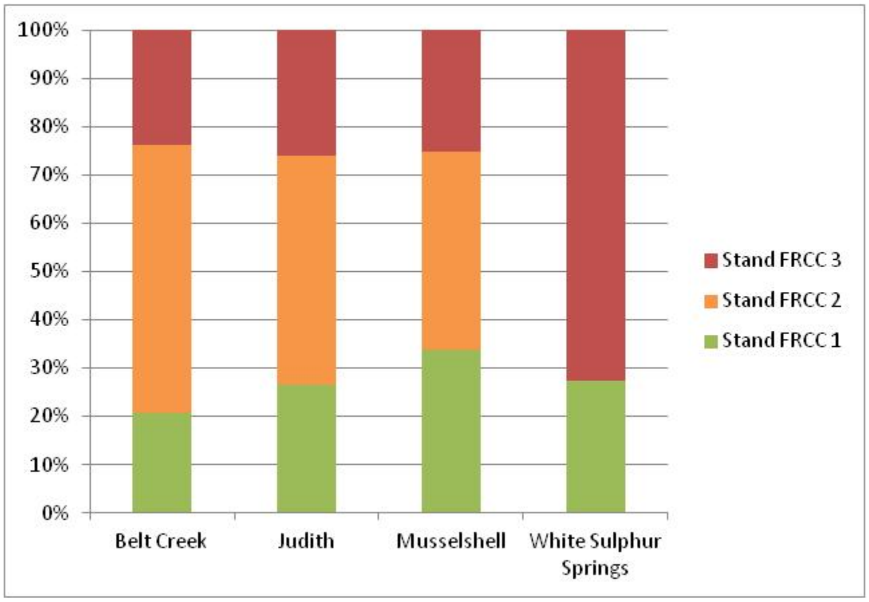

Figure 15: Stand FRCC in the Northern Rocky Mountain Subalpine Woodland and Parkland BpS summarized by Ranger District.

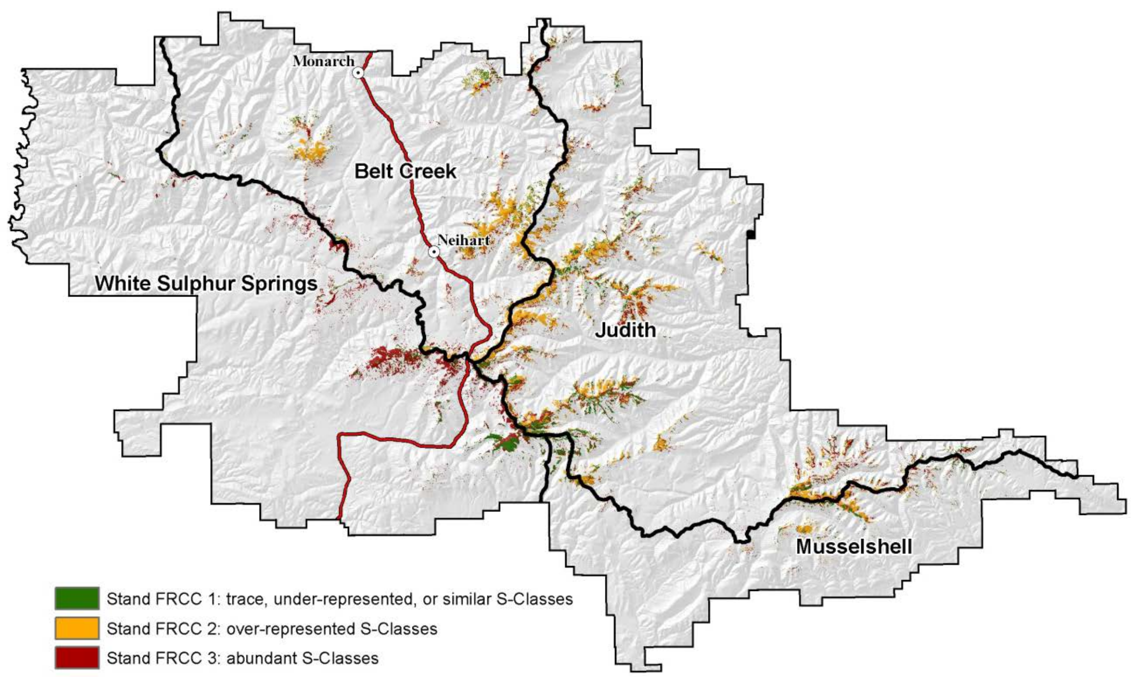

Figure 16: Spatial distribution of stand FRCC in the Northern Rocky Mountain Subalpine Woodland and Parkland BpS. Solid black lines represent ranger district boundaries; 4th level HUC subbasin boundaries roughly follow the ranger district boundaries and are omitted. Highway 89 and towns shown for reference.

Wildfire Threat

Wildfire threat and benefit is non-uniformly distributed across the Little Belts project area. Threat and benefit are instead concentrated in certain HVRAs and in certain geographic locations. The WUI structures HVRA is the most threatened of all the HVRAs assessed (figure 17). This is a result of several co-incident factors: relatively high burn probability and flame length where WUI structures are mapped, a response function that includes some strongly negative wildfire response, and the highest relative importance value of all the HVRAs (table 6). The next most threatened HVRA, high investment infrastructure, has only about one-quarter the importance-weighted threat represented by the WUI. On the other end of the spectrum, the aspen vegetation type, representing wildlife habitat, is the HVRA most benefited from wildfire within the project area. Municipal watersheds could experience a benefit or threat, depending on the fire intensity and slope steepness. On balance, the beneficial and adverse effects on municipal watersheds balance out, and the overall net response is zero.

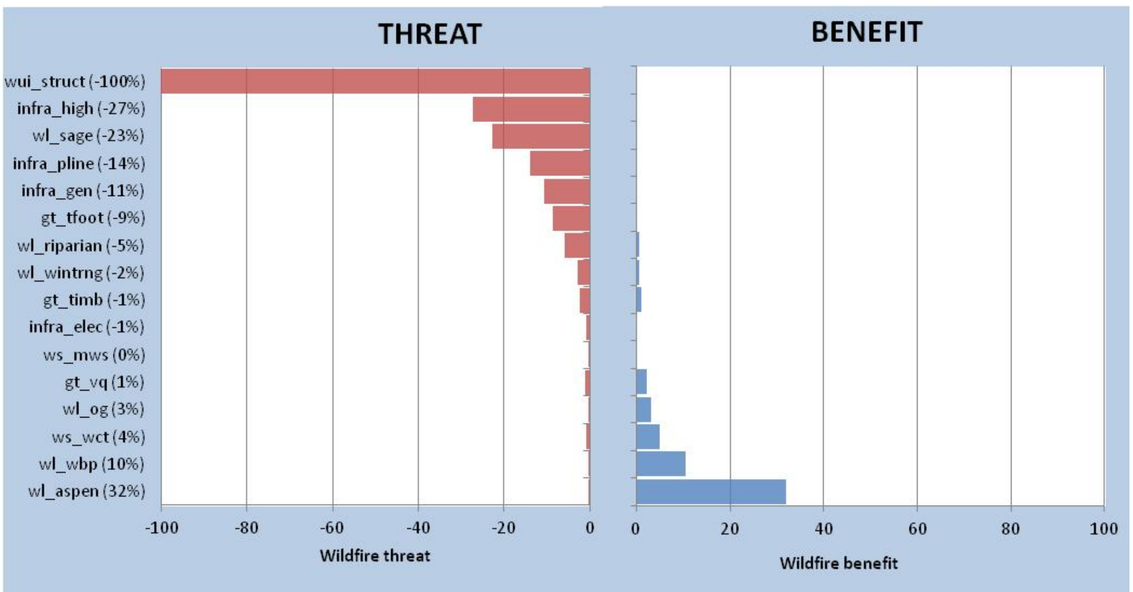

Figure 17: Wildfire threat and benefit to highly valued resources and assets (HVRA) in the Little Belts project area. Values are scaled to the highest threatened HVRA. Percentages in parenthesis indicate net result.

Net response is the sum of threat (represented as a negative response) and benefit (positive response) across all HVRAs that may be present at a given pixel. Geographically, most of the net threat in the Little Belts project area occurs in the White Sulphur Springs Ranger District (figure 18). The Belt Creek Ranger District has just one-third as much net threat; the Judith and Musselshell Ranger Districts have about one-third that of Belt Creek. Net response also incorporates the differing land area in each of the ranger districts. That is, the larger the land area, the greater the potential net response.

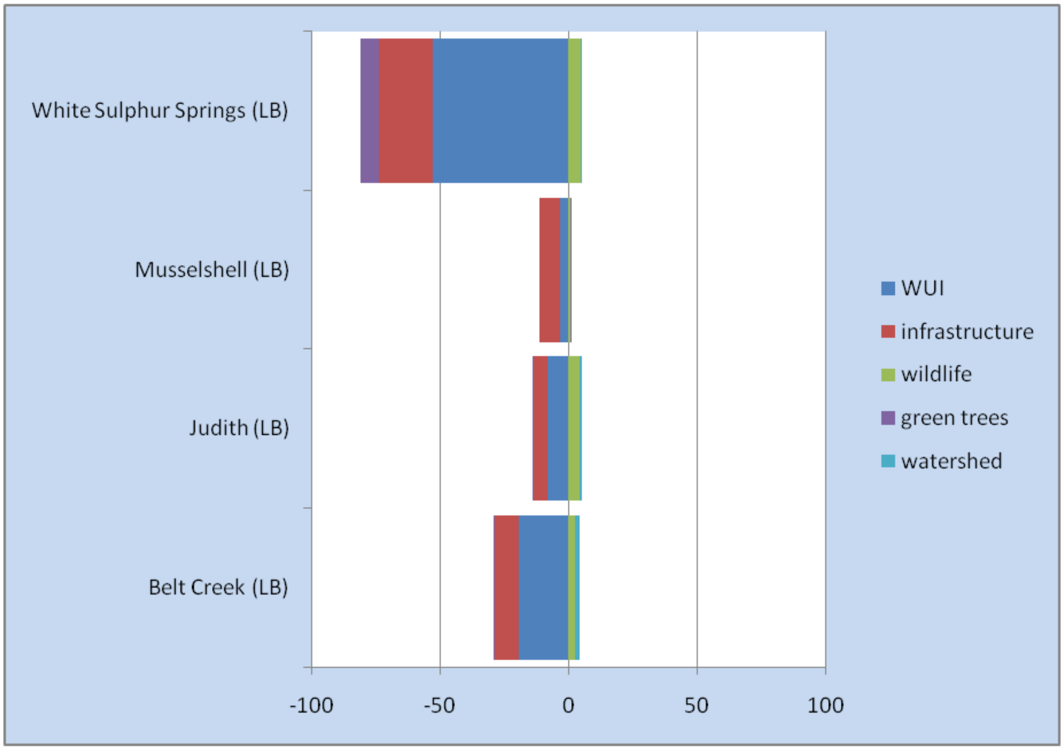

Figure 18. Distribution of net wildfire response across the four ranger districts in the Little Belts project area.

Across the Little Belts project area as a whole, net wildfire response is not uniformly distributed from acre to acre. To illustrate this result, we accumulated benefit and threat starting from pixels with either zero net response or where no HVRAs were present (figure 19). On this figure, landscape percentile refers to an ordinal ranking of pixels within the Little Belts project area starting from the pixel with the greatest benefit up to the pixel with the greatest threat. The blue line represents the 30 percent of the project area on which the net response is positive—a net benefit. The dark gray line represents the 29 percent of the project area on which no HVRAs were mapped, so there can be no wildfire response. Finally, the red line represents the 42 percent of the project area on which the net response is negative—a net threat. Within these acres of net threat, a small number of the most-threatened acres contain most of the cumulative threat. In fact, 40% of the cumulative net threat occurs on just 1% of the project area; 90% of the threat occurs on just 10% of the project area. This result suggests that threat reduction activities could perhaps be focused on the relatively small fraction of the project area where the bulk of it occurs. That is, instead of focusing fuel treatments on landscape-level activities designed to reduce BP across a large portion of the landscape, it may instead be more efficient to focus fuel treatments on the relatively small portion of the landscape where the bulk of the adverse effects take place.

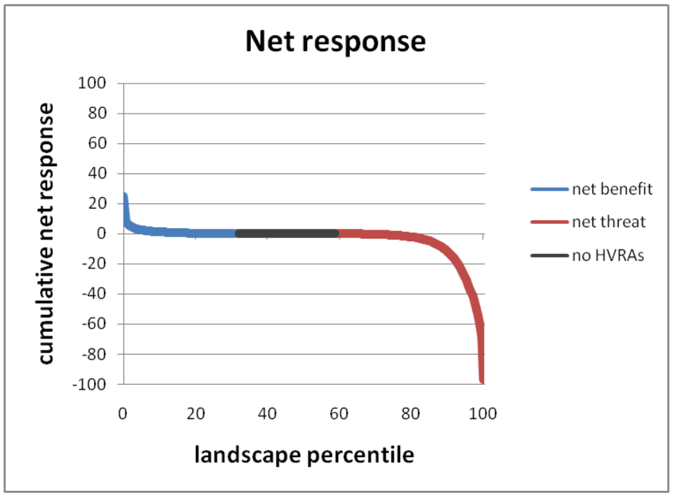

Figure 19. Cumulative net response (benefit or threat) across the Little Belts project area. 'Landscape percentile' refers to each pixel, sorted from most beneficial to most threatened, with pixels with no HVRAs in between. The bulk of the benefit and threat occurs on a small fraction of the project area.

Figures 20-22 spatially display the cumulative threat-only, benefit-only and net response across the Little Belts project area. Looking first at just wildfire threat (not considering any offsetting benefit), the SW portion of the project area and areas along the highway corridor north of White Sulphur Springs and between Neihart and Monarch have a greater concentration of high-threat pixels than other portions of the landscape (figure 20). This is due to several factors, including a higher annual burn probability in the SW resulting from its proximity to fast-spreading grass-shrub fuel.

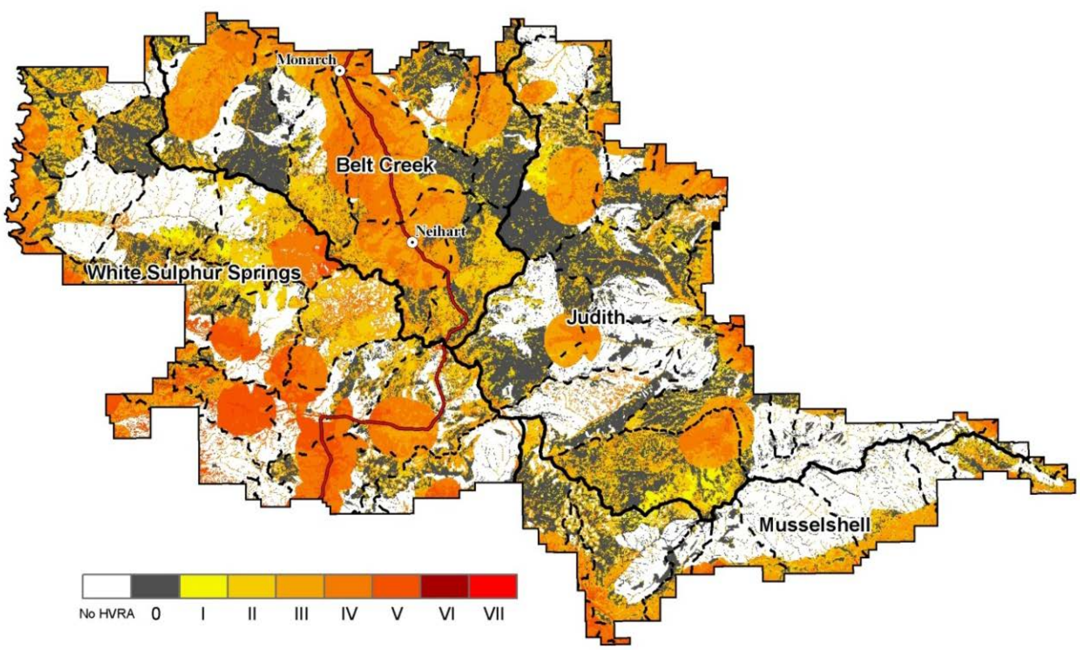

Figure 20: Wildfire threat to highly valued resources and assets (excluding offsetting benefits). Threat displayed on a logarithmic scale ($\log_{10}$). Each category is an order of magnitude (10 times) greater than the previous. Solid black lines represent ranger district boundaries; dashed black lines represent 6th level HUC subwatershed boundaries. Highway 89 and towns are shown for reference.

Areas with the greatest benefit from wildfire (without considering offsetting threat) are scattered throughout the landscape but concentrated in the central portion of the project area (figure 21). At first it may seem counter-intuitive that the same areas of the landscape can have both threat and benefit. However, recall from the analysis overview section that the threat or benefit to an HVRA is determined both by the likelihood of burning and the susceptibility of the HVRA to different FILs. Some of the HVRAs in these areas benefit from wildfire at one or more of the FILs while others do not. Figure 20 displays only the benefits to an HVRA, so the overall net result could still be negative even where benefits are high. For this reason it is also valuable to look at the *net response* of HVRAs to wildfire which accounts for the offsetting effect of threat and benefit when the response varies by FIL, or when two or more HVRAs overlap in the same area.

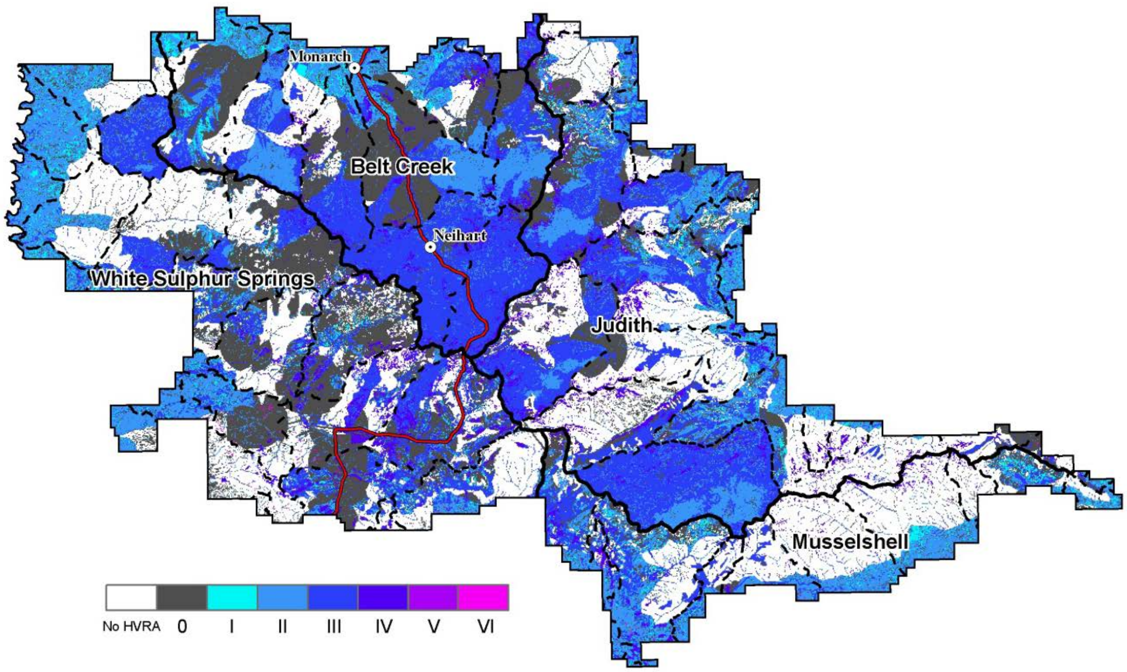

Figure 21: Wildfire benefit to highly valued resources and assets (excluding offsetting threat). Benefit displayed on a logarithmic scale (log_{10}). Each category is an order of magnitude (10 times) greater than the previous. Solid black lines represent ranger district boundaries; dashed black lines represent 6th level HUC subwatershed boundaries. Highway 89 and towns are shown for reference.

Threat and benefit offset each other at each pixel, producing a complex pattern across the project area (figure 22). Despite the offsetting benefits however, the most threatened pixels are still concentrated in the SW portion of the project area and along the highway corridor north of White Sulphur Springs and between Neihart and Monarch. The areas with the most net benefit are scattered throughout the project area with higher concentrations in the Belt Creek and Judith Ranger Districts.

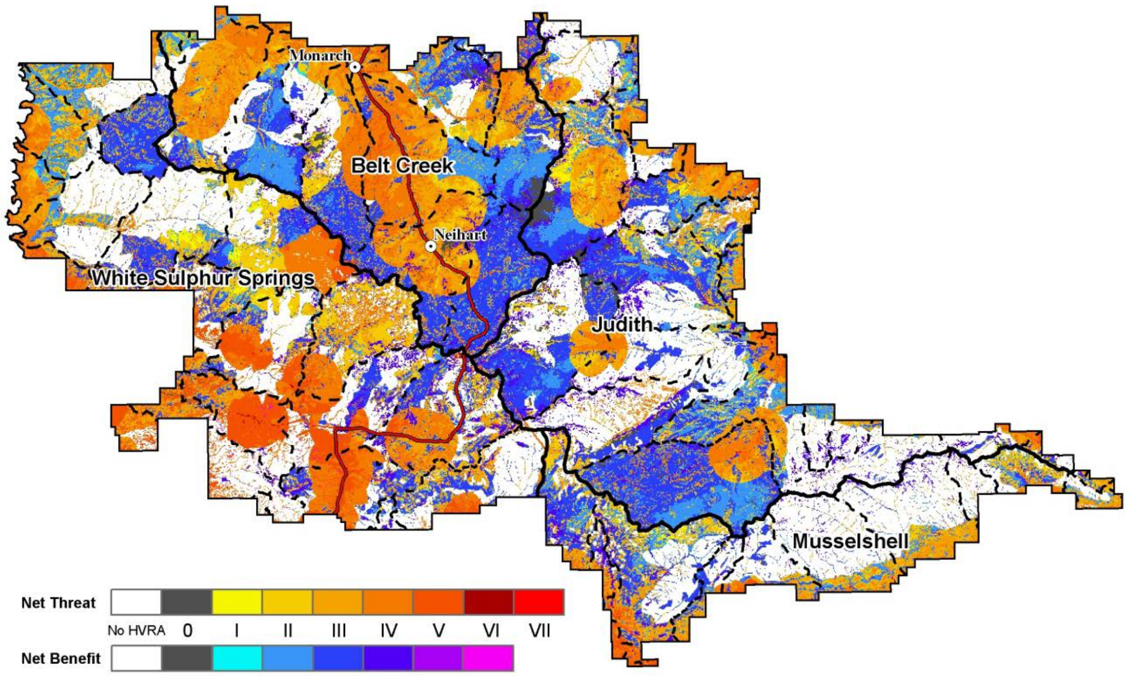

Figure 22: Net response of highly valued resources and assets to wildfire. Net threat and net benefit displayed on a logarithmic scale (log_{10}). Each category is an order of magnitude (10 times) greater than the previous. Solid black lines represent ranger district boundaries; dashed black lines represent 6th level HUC subwatershed boundaries. Highway 89 and towns are shown for reference.

Landscape-Scale Summary

Our analysis of the Little Belt Mountains shows vegetation composition and structure to be moderately departed from the HRV. Across each of the major biophysical settings in the project area the departure is driven by a skewed distribution of S-Classes, where one or two classes dominate, compared to that under the HRV. There is some variability across analysis units (5th or 6th level HUCs) but in general vegetation composition and structure is relatively homogenous in the Little Belts. These results suggest that natural processes (e.g., wildfire, insect and disease, hydrologic cycle) that are interrelated with the variability of vegetative composition and structure may also be moderately departed from the HRV. Efforts to restore the reference condition distribution of S-Classes may increase the integrity of terrestrial and aquatic ecosystems within the project area and their resiliency to future stressors.

Wildfire threat to HVRAs is a function of HVRA susceptibility and importance, coupled with wildfire hazard (burn probability and intensity) where the HVRAs occur. Within the Little Belts project area, the most-threatened HVRA is the WUI, in-part because it was given the highest relative importance of all HVRAs. The WUI HVRA also occurs in portions of the landscape with higher burn probability and, in some cases, higher fire intensity as well. High-investment infrastructure was the next most-threatened HVRA, but accounted for just one-quarter of the cumulative threat as the WUI. Not surprisingly, some fire-adapted wildlife habitats are expected to have a net benefit response to wildfire. The HVRAs expected to benefit most from future wildfire are represented by aspen and whitebark pine vegetation types. Nonetheless, given the relative importance assigned to the HVRAs, the cumulative benefits on the landscape amount to just 20 percent of the cumulative threat. This indicates that, across the landscape as a whole, future wildfire can be expected to have a negative net effect. However, threat and benefit vary greatly across the landscape, so it is possible to determine which portions of the landscape benefit from fire and which do not.

Mid-Scale Opportunities

In this section we identify management opportunities from a vegetative restoration and wildfire threat reduction perspective. A management opportunities workshop was held in October 2011 where criteria were developed for identifying mid-scale opportunity areas. First, the four most prominent biophysical settings were assessed as to whether each of four general treatment types is feasible for restoring vegetative conditions by treating specific surplus S-Classes[3] within the BpS (table 11). Similarly, each HVRA was assessed as to whether the treatment types are feasible in reducing wildfire threat to the resource or asset (table 12). Next, the restoration and threat opportunities under each treatment type were mapped both independently and where they overlap. That is, where both objectives can be met on the same piece of ground (i.e., pixel). Finally, the acres of restoration opportunity, threat reduction opportunity, and overlapping restoration and threat opportunity were summarized independently for each treatment type (tables 13-16). These tables also include the acres of opportunity within five areas subject to regulatory sideboards: Inventoried Roadless Area (IRA) less than 1,500 feet from a road, IRA greater than 1,500 feet from a road, Research Natural Area (RNA), Tenderfoot Creek Experimental Forest (TCEF), and Wilderness Study Area (WSA).

Table 11: Treatment types applied to biophysical setting/succession class combinations to indicate a vegetative restoration opportunity. 'X' indicates valid treatment type.

Biophysical Setting	Succession Classes	NC	CT	RH	RX
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	C & D	--	--	X	X
Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	D & E	--	--	X	X
Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest - Ponderosa Pine-Douglas-fir	B & C	X	X	--	X
Northern Rocky Mountain Subalpine Woodland and Parkland	D & E	X	X	X	X

Treatment types are: NC: non-commercial, CT: commercial thinning, RH: restoration harvest, and RX: prescribed fire.

[3] Excluded from the analysis are opportunities for maintenance, or retention, of desirable S-Classes within each BpS, however the data in appendix A could be used to indentify these opportunities.

Table 12: Treatment types applied to sub-HVRA/variant combinations to indicate wildfire threat reduction opportunity. 'X' indicates valid treatment type.

HVRA	Sub-HVRA	Variant	NC	CT	RH	RX
WUI	WUI	--	X	X	X	X
Infrastructure	General-investment infrastructure	--	X	X	X	X
	High-investment infrastructure	--	X	X	X	X
	Power lines	--	--	--	--	--
	Electronics sites	--	X	X	X	X
Critical Wildlife Habitat	Aspen	--	X	X	X	X
	Old growth	dry site	X	--	--	X
	Old growth	wet site	X	--	--	--
	Riparian	--	X	--	--	--
	Sagebrush steppe	--	--	--	--	--
	Ungulate winter range	--	X	--	--	X
	Whitebark pine	--	X	X	X	X
Green Trees	Tenderfoot Creek Experimental Forest	--	--	--	--	--
	Timber base	PP/DF	X	X	X	X
	Timber base	Other types	X	X	X	X
	Visual quality	PP/DF/Juniper	X	X	--	X
	Visual quality	Other types	X	X	--	X
High-value Watersheds	Westslope cutthroat trout streams	--	X	X	--	X
	Municipal watersheds	--	X	X	X	X

Treatment types are: NC: non-commercial thinning, CT: commercial thinning, RH: restoration harvest, and RX: prescribed fire.

Non-commercial Thinning Opportunities

Non-commercial treatments refer to intermediate treatments in which trees to be removed are too small for commercial utilization. Non-commercial thinning objectives are to alter stand density and structure, ladder fuels, and species composition to meet vegetative restoration or wildfire threat reduction goals. Examples of likely treatments in this category include reduction in understory conifer trees to reduce ladder fuels, removal of conifer trees to release aspen, removal of conifer encroachment for sagebrush restoration, or reduction of disease activity. Tables 11 and 12 above show which BpS/S-Class combinations and HVRAs were considered suitable for non-commercial thinning. Figure 23 shows where in the project area restoration opportunity, threat reduction opportunity, and overlapping restoration and threat reduction opportunity occur. Table 13 summarizes, by sideboard, the acres of opportunity suitable for non-commercial thinning. Non-commercial thinning primarily provides opportunity for wildfire threat reduction in the project area but some areas of restoration and dual restoration and threat reduction opportunity exist.

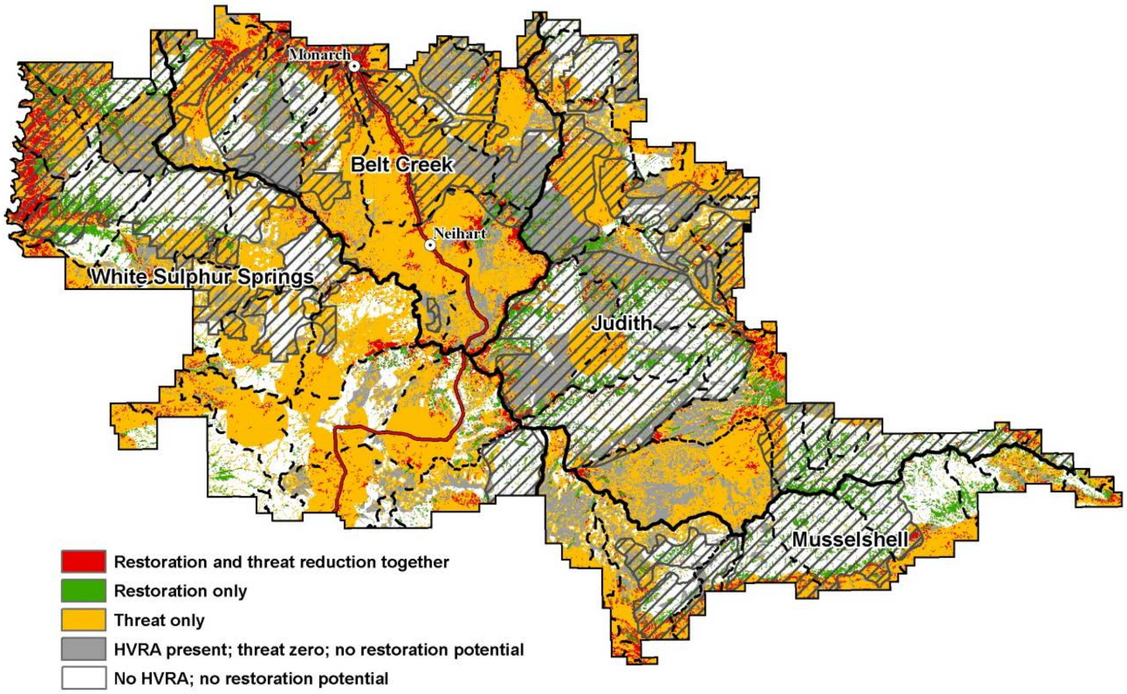

Figure 23: Total mid-scale opportunity using non-commercial thinning techniques. Gray hashing indicates one or more regulatory sideboards. Solid black lines represent ranger district boundaries; dashed black lines represent 6th level HUC subwatershed boundaries.

Table 13: Acres of mid-scale opportunity using non-commercial thinning techniques. Summarized by opportunity type and regulatory sideboard.

Regulatory sideboard	Acres of threat reduction potential	Acres of restoration potential	Acres of both threat reduction and restoration potential
IRA Inside Buffer	42,184	11,949	7,708
IRA Outside Buffer	116,318	36,836	19,969
RNA	3,206	280	266
TCEF	1,735	340	184
WSA	14,967	7,634	2,442
None	278,918	40,238	29,845
Project Area Total[1]	439,492	89,359	57,706

[1]Does not equal sum of area inside and outside of constraints due to overlap.

Commercial Thinning Opportunities

Commercial thinning treatments refer to intermediate treatments in which trees to be removed are large enough for commercial utilization. Treatments may include cleaning, thinning, salvage, sanitation, and shelterwood preparation cutting. Treatment objectives are to alter stand density and structure, ladder fuels, and species composition to meet vegetative restoration or wildfire threat reduction goals. Examples of likely treatments include reduction of mature ponderosa pine trees to reduce risk of crown fire, removal of conifer trees for aspen release, conversion of closed to open Douglas-fir stands, promotion of mid-seral ponderosa pine towards late-seral, or reduction of mountain pine beetle activity to retain mature trees. Tables 11 and 12 above show which BpS/S-Class combinations and HVRAs are considered suitable for commercial thinning. Figure 24 shows where in the project area restoration opportunity, threat reduction opportunity, and overlapping restoration and threat reduction opportunity occur. Table 14 summarizes, by sideboard, the acres of opportunity suitable for commercial thinning. Commercial thinning primarily provides opportunity for wildfire threat reduction in the project area but some areas of restoration and dual restoration and threat reduction opportunity exist, some of which is in areas with regulatory sideboards that may restrict the use of commercial thinning techniques.

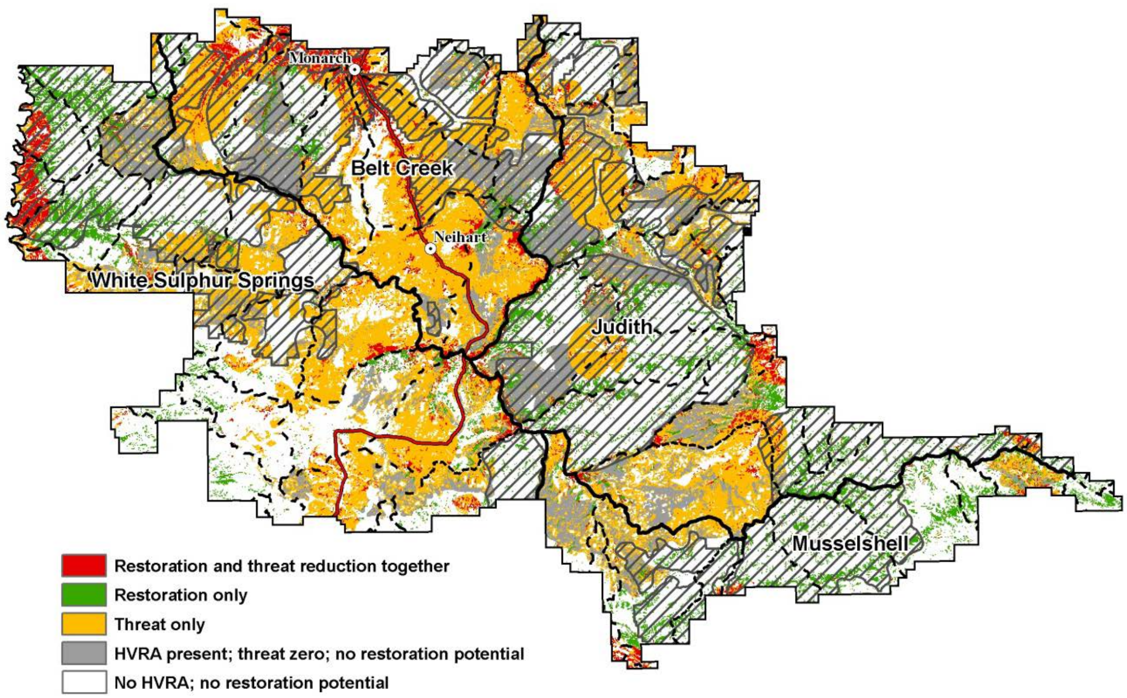

Figure 24: Total mid-scale opportunity using commercial thinning techniques. Gray hashing indicates one or more regulatory sideboards. Solid black lines represent ranger district boundaries; dashed black lines represent 6th level HUC subwatershed boundaries.

Table 14: Acres of mid-scale opportunity using commercial thinning techniques. Summarized by opportunity type and regulatory sideboard.

Regulatory sideboard	Acres of threat reduction potential	Acres of restoration potential	Acres of both threat reduction and restoration potential
IRA Inside Buffer	25,399	8,184	5,126
IRA Outside Buffer	82,370	26,360	14,603
RNA	2,730	276	248
TCEF	801	262	96
WSA	8,733	5,818	1,653
None	192,353	33,537	25,117
Project Area Total[1]	301,149	68,340	44,942

[1]Does not equal sum of area inside and outside of constraints due to overlap.

Regeneration Harvest Opportunities

Regeneration harvest treatments refer to a commercial treatment designed to regenerate a timber stand or release a regenerated stand. Treatments may include clearcut, removal cut of a shelterwood or seed tree system, salvage, and selection cuts. Treatment objectives are to regenerate a stand back to the seedling stage to meet vegetative restoration or wildfire threat reduction goals. Treatment examples include regenerating a mature dying lodgepole pine stand back to the early-seral stage (i.e., S-Class A), converting a conifer/aspen stand to young aspen, or developing a multi-storied Douglas-fir structure. Tables 11 and 12 above show which BpS/S-Class combinations and HVRAs are considered suitable for regeneration harvest techniques. Figure 25 shows where in the project area restoration opportunity, threat reduction opportunity, and overlapping restoration and threat reduction opportunity occur. Table 15 summarizes, by sideboard, the acres of opportunity suitable for regeneration harvest. Large areas of threat reduction and restoration opportunity by regeneration harvest are found throughout the project area and in many areas these opportunities overlap.

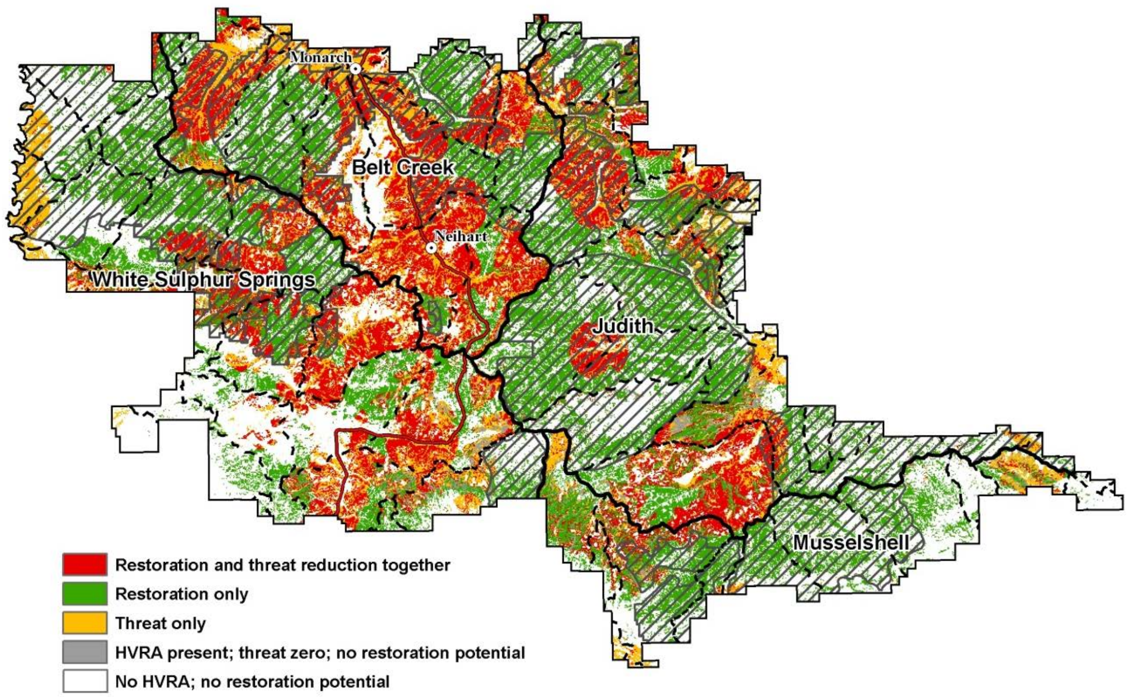

Figure 25: Total mid-scale opportunity using regeneration harvest techniques. Gray hashing indicates one or more regulatory sideboards. Solid black lines represent ranger district boundaries; dashed black lines represent 6th level HUC subwatershed boundaries.

Table 15: Acres of mid-scale opportunity using regeneration harvest techniques. Summarized by opportunity type and regulatory sideboard.

Regulatory sideboard	Acres of threat reduction potential	Acres of restoration potential	Acres of both threat reduction and restoration potential
IRA Inside Buffer	23,232	18,272	12,668
IRA Outside Buffer	73,229	60,229	44,313
RNA	2,316	1,561	1,055
TCEF	72	246	54
WSA	6,329	7,926	4,696
None	181,229	132,736	104,403
Project Area Total[1]	277,840	211,980	161,460

[1]Does not equal sum of area inside and outside of constraints due to overlap.

Prescribed Burning Opportunities

Prescribed burning refers to an intentionally ignited fire to meet specific objectives. Prescribed fire behavior can vary from low to high intensity using a variety of methods to meet vegetative restoration or wildfire threat reduction goals. Treatment examples include the use of low intensity ground fire to reduce ground fuels within ponderosa pine, moderate intensity (mixed severity) fire within Douglas-fir to reduce stand density, or high intensity fire to restore aspen. Tables 11 and 12 above show which BpS/S-Class combinations and HVRAs are considered suitable for prescribed burning. Figure 26 shows where in the project area restoration opportunity, threat reduction opportunity, and overlapping restoration and threat reduction opportunity occur. Table 16 summarizes, by sideboard, the acres of opportunity suitable for prescribed burning. Large areas of threat reduction and restoration opportunity by prescribed burning are found throughout the project area and in many areas these opportunities overlap.

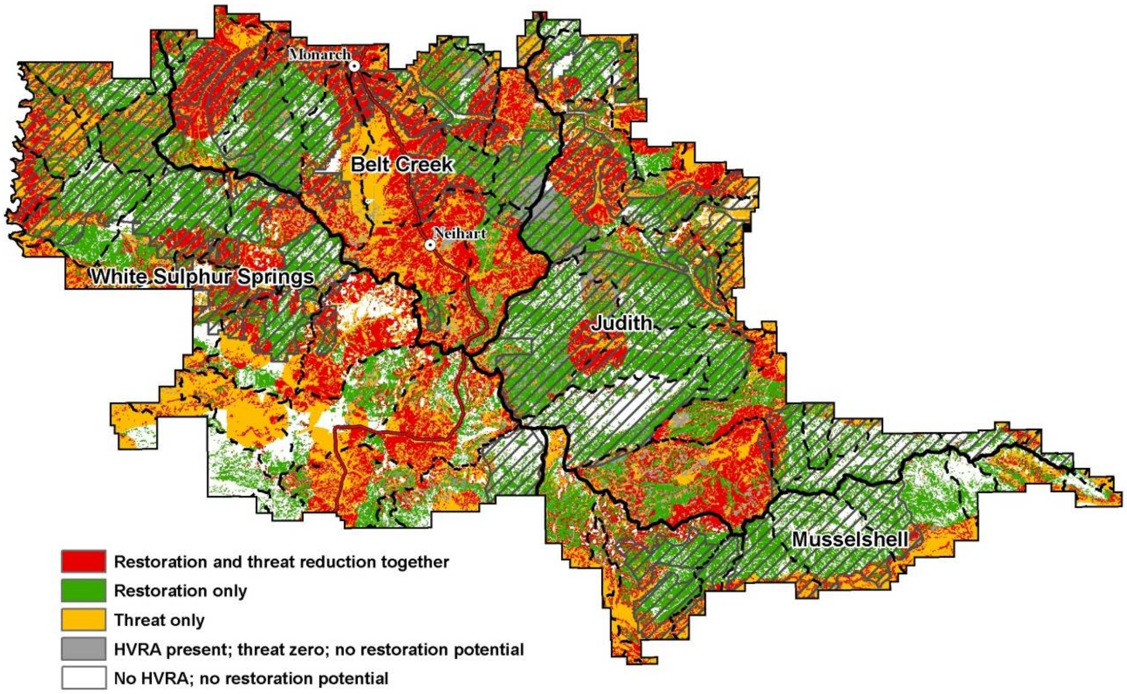

Figure 26: Total mid-scale opportunity using prescribed fire techniques. Gray hashing indicates one or more regulatory sideboards. Solid black lines represent ranger district boundaries; dashed black lines represent 6th level HUC subwatershed boundaries.

Table 16: Acres of mid-scale opportunity using prescribed fire treatment. Summarized by opportunity type and regulatory sideboard.

Regulatory sideboard	Acres of threat reduction potential	Acres of restoration potential	Acres of both threat reduction and restoration potential
IRA Inside Buffer	39,364	36,305	21,844
IRA Outside Buffer	107,437	135,438	67,007
RNA	2,864	1,915	1,513
TCEF	837	1,157	442
WSA	10,860	22,471	7,085
None	270,960	185,758	135,332
Project Area Total[1]	418,858	359,091	224,772

[1]Does not equal sum of area inside and outside of constraints due to overlap.

Mid-Scale Opportunity Summary

The management opportunities identified above are from a vegetation restoration and wildfire threat reduction perspective. Opportunity varies by treatment type throughout the project area and is a function of the spatial distribution of BpS, S-Class, and HVRAs, coupled with the suitability criteria developed by Forest managers and resource specialists. These opportunities are meant to provide "mid-scale" information for use by managers and specialists in identifying and prioritizing projects that move the landscape toward the desired condition as presented in the Forest Plan.

Thinning activities (non-commercial and commercial) primarily provide opportunity for reduction of wildfire threat with little opportunity for restoration. The lack of restoration opportunity using these techniques is due to the assumption that they would not be suitable for reducing the surplus of late-seral vegetation while increasing the deficit of mid-seral vegetation in the two largest BpSs (subalpine spruce-fir and montane Douglas-fir) in the project area (table 11).

Regeneration harvest and prescribed burning show the most restoration opportunity due to their suitability in restoring early- and mid-seral conditions in the subalpine spruce-fir and montane Douglas-fir BpSs (table 11). Regeneration harvest is not a suitable treatment option for threat reduction to some HVRAs (table 12) or restoration of the ponderosa pine/Douglas-fir mixed-conifer BpS and therefore provides less acres of overall opportunity than prescribed fire. Of the four treatment methods, prescribed fire shows the most acres of both restoration and threat reduction opportunity.

Assumptions and Limitations

Given the uncertainty of any modeling exercise, the results of this report are best used to compare the relative, rather than absolute differences across the landscape. Interpretation, professional judgment, and local knowledge of ecology and fire behavior were used to evaluate the inputs to, and outputs from, the models used in this assessment and adjustments were made as necessary to refine the predictions. The following sections discuss the primary assumptions and limitations of the two models used in this assessment.

Vegetation Departure (FRCCmt)

The vegetation departure estimates presented in this report were derived using the standard landscape mapping method with the FRCC mapping tool version 2.2.0. Key assumptions and limitations of this methodology include:

- The reference condition refers to an estimate of the vegetation composition and structure that may have existed under the landscape's historical disturbance regime prior to Euro-American settlement. It is assumed that the reference conditions used in this analysis represent conditions that are resilient and capable of supporting future biodiversity at the landscape scale.
- Reference conditions may portray climatic conditions that are not representative of current and future conditions. It is assumed that reference conditions still provide an appropriate benchmark for assessing and managing for the ecological integrity of vegetative systems.
- Reference S-Class distributions are determined using non-spatial state and transition modeling methods. Reference conditions do not account for the unique topography and spatial distribution of vegetation.
- Reference conditions used in this assessment provide central tendency estimates of S-Class distribution rather than a range and variation.
- The vegetation departure methodology used in this assessment describes only the current S-Class distribution in relation to reference distribution. Vegetation departure metrics presented in this report do not address the question of natural spatial patterns. For example, a low departure rating such as FRCC 1 can result even where patch sizes and arrangements currently are beyond the natural range and variation.
- The BpS layer represents an estimate of the ecological systems that may have existed historically given an approximation of the historical disturbance regime. It is assumed that the

ecological systems and the associated reference conditions are an appropriate estimate of the range and variation that existed on the landscape historically.

- Vegetation departure metrics are sensitive to the S-Class layer. It is assumed that the distribution of S-Classes as mapped by LANDFIRE and updated by project members accurately represent the current distribution of vegetation composition and structure on the landscape.

Wildfire Threat (FSim)

The FSim large fire simulator (Finney et al. 2011) is a comprehensive fire occurrence, growth, behavior and suppression simulation system that uses locally relevant fuel, weather, topography and historic fire occurrence information to simulate the spatially resolved burn probability and expected distribution of fireline intensity at each point across a landscape. The fire growth and behavior modeling portion of FSim is based on the minimum travel time (MTT) fire growth simulation method used in FlamMap (Finney 2006) and FSPro. As such, the limitations and assumptions of MTT carry over to FSim.

Winds

FSim uses monthly joint frequency distributions of wind speed and direction to select daily wind characteristics during a simulation. It is implicitly assumed that sufficient data exist to populate these distributions, and that the distributions adequately reflect the likelihood of each wind speed and direction. There is no temporal autocorrelation of wind speed and direction, so wind events lasting longer than one day may not be well represented. Wind speed and direction is assumed to be constant for each burning period, which last up to five hours.

Fire occurrence

The Energy Release Component (ERC) of the National Fire Danger Rating System (NFDRS) forms the basis of fire occurrence simulation. ERC is calculated using NFDRS fuel model “G” (ERC-G), regardless of actual fuel type within the landscape. ERC-G is well correlated with fire occurrence across a wide spectrum of fuel types. Large fire occurrence in FSim is related only to ERC-G whereas in many landscapes time of year also plays a significant role, so FSim could establish fires outside of the normal fire season. Simulation of ERC-G is temporal but non-spatial, so coordinating ERC-G across very large landscapes is problematic.

Fuel moisture

ERC-G is heavily influenced by the moisture content of coarse woody fuel particles (greater than 3 inches diameter), whereas fire behavior characteristics are influenced primarily by the moisture content of very fine fuel particles (less than ¼-inch diameter). There is no dead fuel moisture conditioning in FSim, so the same moisture content value is used (for each fuel model separately) regardless of slope steepness, aspect, canopy cover, or elevation, all of which are known to influence dead fuel moisture. The ability to set moisture content for each fuel model separately allows modest ability to condition fuels to the extent that fuel models tend, very generally, to be found in similar conditions of slope, aspect, canopy cover and elevation. Fuel moisture is held constant for the burn period of each day, which last from 1 to 5 hours. During that time the fine dead fuel moisture content could vary enough to affect fire behavior.

Simulation parameters

FSim assumes that certain simulation parameters (e.g., daily burn period, spotting settings) are related to percentile classes of ERC-G. FSim assumes no spread on days for which the simulated

ERC-G is below the year-long 80th percentile. The duration of a fire event in FSim is not constrained by historic burn duration, but instead is sensitive to ERC-G (staying below 80th percentile) and fire containment by suppression action, which is simulated probabilistically (Finney et al. 2009).

Fire start locations

FSim assumes that large fires are randomly located across a landscape, but the random location can be informed by geospatial data regarding the historic density of large fire occurrence as was done in this assessment.

Fire containment

The fire containment algorithm (Finney et al. 2009) is probabilistic rather than mechanistic – on each day of a simulated fire, FSim estimates the probability of containment for the day, then compares that probability against a random number. For random numbers smaller than the probability of containment, the fire is considered contained and no longer spreads. Therefore, the containment algorithm influences final fire size only to the extent that it limits the number of days of spread. The containment module does not limit fire size during the period before containment. That is, the effect of perimeter control on reducing the area burned is not currently simulated in FSim.

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Appendix A: Data Overview

The data compiled during this assessment have application beyond what can be presented in this report. This appendix provides a general description of each of the data products that have been developed. Further application of these data will depend on management objectives.

Vegetation Departure (FRCC)

frcc2009final folder:

This folder contains the output from the FRCC Mapping Tool v2.2.0 used in the vegetation departure analysis. It contains the individual raster datasets (ESRI Grid format), a sub-folder of ArcGIS layer files, and two Microsoft Excel spreadsheets of results. 2009 represents the year to which the spatial data were updated to account for wildfire and insect disturbance. Each of the raster datasets have associated metadata that can be viewed in ArcCatalog for more specific information.

RasterLayers folder:

This folder contains ArcGIS layer files (.lyr) for displaying standard FRCC Mapping Tool symbology in ArcMap.

frcc2009_Summary Report.xlsx:

Standard summary report from the FRCC Mapping Tool.

SClassDistribution.xlsx:

Standard summary report reformatted with pivot tables and charts.

Wildfire Threat

FSIM_50kResults.gdb:

File geodatabase containing wildfire behavior output from the Large Fire Simulator (FSIM). Individual datasets include annual burn probability in six fire intensity level classes, overall annual burn probability, and mean fireline intensity. Individual datasets have associated metadata that can be viewed in ArcCatalog for more specific information.

LB_Castle_HVRA.gdb

File geodatabase containing highly valued resources and assets (HVRAs) used in wildfire threat calculations. HVRAs mapped to the Castle Mountains are also included. Each of the raster datasets have associated metadata that can be viewed in ArcCatalog for more specific information.

LB_Castle_WildfireResponse.gdb

File geodatabase containing the cumulative and individual threat, benefit, and net response of HVRAs from wildfire. Cumulative threat, benefit, and net response from wildfire are represented by the *threat_all, benefit_all, and net_all* raster datasets. Values are relative, with negative values indicating threat (the more negative the greater the threat) and positive values indicating benefit (the greater the value the greater the benefit). Cumulative (i.e., across all HVRAs) are presented in this report. The individual threat, benefit, and net response to individual HVRAs can be mapped and analyzed using the data in this database. The dataset naming convention for individual HVRAs follows the format: *response type_HVRA_sub-HVRA.*

Response types:

t: threat only – threat only raster datasets show the threat from wildfire to an individual HVRA without consideration of offsetting benefit from wildfire.

b: benefit only – benefit only raster datasets show the benefit from wildfire to an individual HVRA without consideration of offsetting threat from wildfire.

n: net response – net response raster datasets show the net response from wildfire to an individual HVRA considering both threat and benefit.

HVRA types:

gt: green tree

infra: critical infrastructure

wl: critical wildlife habitat

ws: high valued watersheds

wui: wildland urban interface

sub-HVRA types:

tfoot: Tenderfoot Creek Experimental Forest

timb: timber base (management area ‘B’)

vq: visual quality

elec: electronic sites

gen: general investment infrastructure

high: high investment infrastructure

pline: power lines

aspen: aspen

og: old growth

riparian: riparian

sage: sagebrush

wbp: white bark pine

wintrng: ungulate winter range

mws: municipal watersheds

wct: westslope cutthroat trout

Mid-Scale Opportunities

LB_MgtOpportunities.gdb:

File geodatabase containing management opportunity datasets. Individual datasets have associated metadata that can be viewed in ArcCatalog for more specific information. The dataset naming convention follows the format: *opportunity type_method*

opportunity types:

r_opp: restoration opportunity

t_opp: threat reduction opportunity

cmb_opp: combined threat reduction and restoration opportunity

ManagementOpportunities(11-17-2011).xlxs:

Spreadsheet summarizing opportunities considered for each HVRA as determined in IDT workshop.

MgtOppSummary*XX*.xlsx:

These spreadsheets summarize management opportunity by 6th-level HUC, ranger district, and regulatory sideboards. There is one spreadsheet for each treatment type: CT = commercial thinning, NC = non-commercial thinning, Regen = regeneration harvest, and Rx = prescribed fire. Each spreadsheet contains two pivot tables: overview and detail. The "overview" table allows the user to see the results by 6th-level HUC, with filters for ranger district and constraint. The "details" table allows a closer look at any 6th-level HUC or ranger district to see how the sideboards play a role in limiting opportunity. "None" indicates where no sideboard was mapped; "N/A" indicates all opportunity without regard to sideboards. The non-commercial thin spreadsheet only shows the N/A category due to file size constraints.

Appendix B: Relative Overstory Canopy Loss

Forests are dynamic and changes in composition and structure are associated with natural and management induced disturbances such as fire, silviculture, and insect and disease activity. Although each type of disturbance has its own set of consequences and recovery trajectories, the change detection product provided here is focused on forest canopy loss due to Mountain Pine Beetle, Doug Fir Beetle, and Spruce Budworm.

Random Forest is the classification software used to complete the change detection as it provides an efficient method to detect “change” in relation to tree canopy loss. Random Forest creates ten to thousands of decision trees. Each decision tree is built from a random subset of the training data and then replacing that data to be used in another decision tree. The decision tree model is based on a different random subset of the training dataset and a random subset of the available variables. These datasets are then is used to choose how best to partition the dataset at each node. Each decision tree created will then vote for the results and the majority wins.

Landsat imagery from 2000 and 2009 were used to assess the change over the nine year time span. Landsat derived images such as, NDVI, dNBR, TC, and PCA were all used to assist in the classification (see Table A1. for all images used in classification).

Five change classes were established.

No Change
10% - 24.9%
25% - 49.9%
50% - 74.9%
75%+

Training data was collected through image interpretation. A set of 500 random points were created equally across the landscape. The random points were given a buffer of 100 meters in order to provide an area in which to assess canopy loss. Outlying classes such as the two higher classes, 25%-49.9% and 50%-74.5%, were not sufficiently accounted for in the random selection of training data sites, so additional data was purposively collected in order to effectively represent all classes. The integrity of the other classes was kept by adding additional samples to keep the original sample proportions.

The training data was then used in the classifier Random Forest. A model cross validation was performed internally using Random Forest to give an indication of model performance, and then an independent accuracy assessment was conducted using a set of random locations within the model area, thereby providing an independent validation of the resulting classification. The independent accuracy assessment results are shown in Table 2.

Table A1: Input 30 m Image Data for Classification with the Random Forest Algorithm

Image Layer	Description
B1	Spectral Band 1 of Landsat TM5
B2	Spectral Band 2 of Landsat TM5
B3	Spectral Band 3 of Landsat TM5
B4	Spectral Band 4 of Landsat TM5
B5	Spectral Band 5 of Landsat TM5
B6	Spectral Band 6 of Landsat TM5
dNBR	Difference Normalized Burn Ration
DiffB1	Difference of Band 1 2000 and Band 1 2009
DiffB2	Difference of Band 2 2000 and Band 2 2009
DiffB3	Difference of Band 3 2000 and Band 3 2009
DiffB4	Difference of Band 4 2000 and Band 4 2009
DiffB5	Difference of Band 5 2000 and Band 5 2009
DiffB6	Difference of Band 6 2000 and Band 6 2009
NDVI	Normalized Difference Vegetation Index
PCA1	Principal Component 1 of Landsat TM5 Spectral Bands 1-6
PCA2	Principal Component 2 of Landsat TM5 Spectral Bands 1-6
PCA3	Principal Component 3 of Landsat TM5 Spectral Bands 1-6
TC1	Tasseled Cap Transformation 1 of Landsat TM5 Spectral Bands 1-6
TC2	Tasseled Cap Transformation 2 of Landsat TM5 Spectral Bands 1-6
TC3	Tasseled Cap Transformation 3 of Landsat TM5 Spectral Bands 1-6
TC PCA1	Tasseled Cap Transformation 1 of Principal Component 1
TC PCA2	Tasseled Cap Transformation 2 of Principal Component 2
TC PCA3	Tasseled Cap Transformation 3 of Principal Component 3
Unsupervised Classification	Classification of Both, Pre and Post Image Using 50 Classes

Canopy Loss Map Accuracy

Reference data was collected from image interpretation of 2009 color infrared NAIP imagery. If the reference point is within 5% of the map class, it is given an acceptable value and counted correct. The accuracy assessment completed for the canopy loss change detection is shown in figure A1. The overall accuracy of the classification is 69%.

		Reference						
		No Change	10% - 24.5%	25% - 49.9%	50% - 74.5%	75% +	Total	User Accuracy %
Map Class	No Change	73	25	18	2	2	120	60.83%
	10% - 24.5%	0	50	9	2	3	64	78.13%
	25% - 49.9%	4	27	80	3	6	120	66.67%
	50% - 74.5%	0	3	1	20	0	24	83.33%
	75% +	0	0	3	0	18	21	85.71%
Ref Total		77	105	111	27	29	349	
Producer Accuracy %		94.81%	47.62%	72.07%	74.07%	62.07%		
Overall Accuracy %	69.05%							

Figure A1: Accuracy Assessment for Little Belts Relative Canopy Loss.

Appendix C: HVRA Response Function Descriptions by Resource Specialists

Wildland Urban Interface

Specialists: Jess Secrest, Rob Marshall, Clint Kolarich, Darwin Reynolds, Katie Hetts, Kelly Keim

Sub-HVRA: none

0-2’	2-4’	4-6’	6-8’	8-12’	12+’
-10	-30	-60	-80	-100	-100

Description/justification:

Any fire impingement on a structure will have a negative effect, greater the fire intensity the greater the loss of the value at risk. At FIL 5 and 6 the fire intensity will result in a complete loss.

Infrastructure

Specialists: Jess Secrest, Rob Marshall, Clint Kolarich, Darwin Reynolds, Katie Hetts, Kelly Keim

Sub-HVRA: High Investment Infrastructure (Admin sites, cabin rentals, Campground, Lookout (RAWS, repeater, etc.), Rec. residences, winter recreation)

Response function:

0-2’	2-4’	4-6’	6-8’	8-12’	12+’
-10	-30	-60	-80	-100	-100

Description/justification:

Any fire impingement on a structure or related high investment infrastructure value will have a negative effect, the greater the fire intensity the greater the loss of the value at risk. At FIL 5 and 6 the fire intensity will likely result in a complete loss.

Sub-HVRA: Normal/General Investment Infrastructure (Campsite, Picnic Area, Point of Interest, Fishing Access, Trailhead)

Response function:

0-2’	2-4’	4-6’	6-8’	8-12’	12+’
0	-10	-40	-70	-90	-90

Description/justification:

Any FIL greater than FIL 1 on a normal/general investment infrastructure value will have a negative effect, the greater the fire intensity the greater the loss of the value at risk. At FIL 5 and 6 the fire intensity will likely result in a significant loss.

Sub-HVRA: Power lines

Response function:

0-2'	2-4'	4-6'	6-8'	8-12'	12+'
0	-10	-20	-40	-80	-80

Description/justification:

Susceptibility of loss increases with flame length.

Sub-HVRA: Electronic sites

Response function:

0-2'	2-4'	4-6'	6-8'	8-12'	12+'
0	-10	-20	-40	-60	-80

Description/justification:

Susceptibility of loss increases with flame length.

Critical Wildlife Habitat

Specialists: Steve Babler, Laura Conway

Sub-HVRA: Aspen

Response function:

0-2'	2-4'	4-6'	6-8'	8-12'	12+'
80	100	100	50	-10	-20

Description/justification:

Aspen has evolved as fire enhanced species. Light FIL may not kill surrounding competing species, but should stimulate sprouting of clones. Moderate FIL should kill more competing species and stimulate sprouting. Higher FILs may harm clones and cause negative response.

Sub-HVRA: Old Growth, dry and wet variants

Response function: Dry site variant

0-2'	2-4'	4-6'	6-8'	8-12'	12+'
75	50	30	0	-50	-100

Response function: Wet site variant

0-2'	2-4'	4-6'	6-8'	8-12'	12+'
0	-10	-30	-50	-80	-100

Description/justification:

Dry-site habitats evolved with frequent fire eliminating fuel-build-up. Light to moderate fire benefits old growth habitat by removing fuels on a frequent basis and preventing catastrophic events. FILs on wet sites mainly negative due to desire to maintain multiple vegetation layers.

Sub-HVRA: Riparian Habitat

Response function:

0-2’	2-4’	4-6’	6-8’	8-12’	12+’
20	0	-20	-50	-80	-100

Description/justification:

FILs in riparian habitat mainly negative due to desire to maintain multiple vegetation layers, shade, and cover.

Sub-HVRA: Sagebrush Steppe

Response function:

0-2’	2-4’	4-6’	6-8’	8-12’	12+’
-10	-30	-50	-90	-100	-100

Description/justification:

FILs in sage habitat is negative with increasing negativity with increasing FIL, unless desire is to eradicate sage for other resource benefits.

Sub-HVRA: Winter Range

Response function:

0-2’	2-4’	4-6’	6-8’	8-12’	12+’
20	10	-30	-50	-80	-100

Description/justification:

Low FILs are beneficial in stimulating grass/forb production. Higher FILs may damage the range and set productivity back. Winter range is a broad range of veg types. Will consider splitting out by veg types (wooded vs. grassland) after critiquing results.

Sub-HVRA: Whitebark Pine

Response function:

0-2’	2-4’	4-6’	6-8’	8-12’	12+’
80	100	80	-30	-80	-100

Description/justification:

Low FILs are beneficial in killing competing subalpine fir and spruce species. Older WB Pine has evolved to withstand light to moderate fire. Cannot withstand Higher FILs which may destroy and set-back the stand to early seral stage.

Green Trees

Specialists: David Keefe, Timothy Lahey, Frank Yurczyk

Sub-HVRA: Tenderfoot Creek Experiment Forest

Response function:

0-2'	2-4'	4-6'	6-8'	8-12'	12+'
-100	-100	-100	-100	-100	-100

Description/justification:

Any type of fire intensity could endanger ongoing studies within the experimental forest. All fire intensity levels were assigned the most negative value possible.

Sub-HVRA: Visuals – Juniper, PP and DF variant

Response function:

0-2'	2-4'	4-6'	6-8'	8-12'	12+'
50	30	10	-50	-70	-100

Description/justification:

Dry forest type composed of primarily Douglas-fir with lesser ponderosa pine and juniper, high stand density levels, and multiple canopy layers. A positive value was assigned for low intensity fire by reducing stocking/lower canopy layers which leads to increasing sustainability yet maintains a forested appearance. A negative value was assigned once predicted mortality will dominate the forest setting.

Sub-HVRA: Visuals – Other types variant

Response function:

0-2'	2-4'	4-6'	6-8'	8-12'	12+'
10	-20	-40	-80	-80	-90

Description/justification:

Composed of the more moist forest types with the lodgepole pine type as forming the basis for the response. Lowest intensity is somewhat beneficial based on predicted low mortality. As intensity levels increase, negative values were assigned based on increasing mortality reducing the forested appearance in the short term but offset slightly due to long term establishment of lodgepole pine regeneration.

Sub-HVRA: Timber – Douglas-fir and ponderosa pine variant

Response function:

0-2’	2-4’	4-6’	6-8’	8-12’	12+’
40	10	-20	-80	-100	-100

Description/justification:

Dry forest type composed of primarily Douglas-fir with lesser ponderosa pine and juniper, high stand density levels, and multiple canopy layers. Values were based on the benefit of re-introduction of fire within systems that have been absent of fire and this type represents in the near future the source of forest products for the forest. Benefit is reduction in stocking levels leading to healthier growing conditions. Risk is mortality from fire and insects.

Sub-HVRA: Timber – Other types variant

Response function:

0-2’	2-4’	4-6’	6-8’	8-12’	12+’
-10	-30	-70	-90	-90	-100

Description/justification:

Composed of the more moist forest types with the lodgepole pine type as forming the basis for the response. Assumption is the MPB will eliminate most of the pine trees. Not all areas will be harvested in time to recover dead trees. Fire has a negative effect by accelerating deterioration as a forest product. Fire has a positive effect by accelerating regeneration in the long term.

High Value Watersheds

Specialists: Wayne Green, Tricia Burgoyne, Kendall Cikanek, John Hamann, Brooke DeVault, Camilo Arias

Sub-HVRA: Westslope cutthroat trout, <35% slope variant

Response function:

0-2’	2-4’	4-6’	6-8’	8-12’	12+’
20	20	10	0	-30	-50

Description/justification:

We are ignoring any other impacts including grazing, road densities, stream functioning, climate etc. We are assuming our timeframe is between 8-10 years. Nutrient cycling at lower intensity fires would be positive because nutrient inputs have been suppressed in the past. May get some woody debris recruitment. Effects of fire are not long term. Negative effect is suppression of age classes for 3-4 years, but Bitterroot research showed benefits after 4 years. There is a risk that we could lose isolate populations.

Sub-HVRA: Westslope cutthroat trout, >35% slope variant

Response function:

0-2’	2-4’	4-6’	6-8’	8-12’	12+’
20	20	-10	-30	-50	-80

Description/justification:

Erosion and sedimentation will increase at 6-8 ft due to loss of ground cover to a point that it is impacting populations. Increased water flows could affect bank stability, some viability risk to small populations. At greater flame lengths we will have a moderate risk of viability, suppression of age classes would last 5-6 years. Greater debris flow potential. 12 foot lengths, could wipe out populations above barriers. Increased viability risks especially in populations competing with brook trout.

Sub-HVRA: Municipal Watersheds, <35% slope variant

Response function:

0-2’	2-4’	4-6’	6-8’	8-12’	12+’
0	0	0	-10	-20	-40

Description/justification:

At lower flame lengths, sediment delivery would be minimal and there would be no benefit. With increased flame lengths we start adding sediment to treatment facilities, increasing cost and maintenance. At 6-8 ft flame lengths we start losing ground cover.

Sub-HVRA: Municipal Watersheds, >35% slope variant

Response function:

0-2’	2-4’	4-6’	6-8’	8-12’	12+’
0	0	-10	-30	-50	-80

Description/justification:

At lower flame lengths, sediment delivery would be minimal and there would be no benefit. With increased flame lengths we start adding sediment to treatment facilities, increasing cost and maintenance. At 4-6 ft flame lengths, small ground cover losses translate to more erosion because of steeper slopes. 8-12 ft flame lengths will lead to significant loss of ground cover and increased erosion and sediment delivery, impacting the operation.