Fire Regime Condition Class and Associated Data for Fire and Fuels Planning: Methods and Applications

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Abstract—*A pilot project was conducted in the Trout West watersheds of the Pike National Forest in Central Colorado. Maps and interpretations were developed to support prioritization, planning, and effects analysis for fuel and ecosystem restoration to achieve National Fire Plan Cohesive Strategy options. The area is about 65,000 hectares (135,000 acres) in size and representative of Southern Rocky Mt. Province ponderosa pine ecosystems. Fire regime potential vegetation-fuel types, departure from central tendency of the historical range of variability (HRV), fire regime condition class, wildfire ignition risk, wildland urban interface, fuel models, and associated information were mapped. An analysis was conducted indicating that treatment of about 10,000 hectares (25,000 acres) of high and moderate HRV departure areas, and maintenance of about 2000 hectares (5000 acres) of low departure areas, could achieve condition class 1 over a 5-year period. Treatment and maintenance focused on a landscape design substantially reduced wildfire risk to both wildland urban interface and ecosystems. A treatment option focused only on wildland urban interface and buffer areas did not substantially reduce risk to communities or ecosystems when compared to the no-treatment option.*

Introduction

The Pike National Forest is located in central Colorado and contains much of the Rocky Mountain Front between Pueblo and Denver. Wildfire is a substantial risk to National Forests as well as adjacent homeowners in the wildland urban interface. A Forest Service pilot project was conducted to evaluate methods for mapping and interpretation of hazardous fuel and associated data for prioritization and planning of restoration projects to reduce risks to ecosystems and people. The area selected for the project was the Trout West watersheds located west of Colorado Springs. The ecosystems of these watersheds are considered representative of the ponderosa pine ecosystems of the Southern Rocky Mt. Province (Bailey 1995). These watersheds also contain considerable wildland surban interface near the community of Woodside, Colorado.

Hann and Bunnell (2001) provide an overview of multi-scale methods for planning and implementation of the National Fire Plan using the Forest Service cohesive strategy (USDA Forest Service 2000) guidance across multiple scales of planning. In the overview they emphasize the importance of stepping down the coarse-scale fire regime condition class data developed by Hardy and others (2001) along with other key data for prioritization and planning at finer scales. Hann and Bunnell (2001) provide definitions of the natural fire

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regime groups and fire regime condition classes that we refined for this study (tables 1 and 2).

The primary objective of the Trout West pilot project was to develop the finer scale methods and applications for fire regime condition class. In addition, a number of other variables, including wildland urban interface, wildfire occurrence risk, and fuel models, were also developed. A suite of additional resource and geographic variables was also used in the integrated prioritization and planning process.

Table 1—Natural (historical) fire regime classes from Hardy et al. (2001) and Schmidt et al. (2002) as interpreted by the authors for modeling landscape dynamics in the Trout West watersheds.

Fire regime class	Frequency (mean fire return interval)	Severity	Modeling assumptions
I	0 – 35+ years, Frequent	Surface and mixed	Open forest, woodland, and savannah structures maintained by frequent fire; also includes frequent mixed severity fires that create a mosaic of different age post-fire open forest, woodland, shrub, or herb patches that make a mosaic of structural stages. Mean fire interval can be greater than 35 in systems with high temporal variation.
II	0 – 35+ years, Frequent	Replacement	Shrub or grasslands maintained or cycled by frequent fire; fires kill non-sprouting shrubs which typically regenerate and become dominant within 10-15 years; fires remove tops of sprouting shrubs which typically resprout and dominate within 5 years; fires typically remove most tree regeneration.
III	35 – 100+ years, Infrequent	Mixed and surface	Mosaic of different age post-fire open forest, early to mid-seral forest structural stages, and shrub or herb dominated patches generally <40 hectares, maintained or cycled by infrequent fire. Interval can range up to 200 years.
IV	35 – 100+ years, Infrequent	Replacement	Large patches generally >40 hectares, of similar age post-fire shrub or herb dominated structures, or early to mid-seral forest cycled by infrequent fire. Interval can range up to 200 years.
V	200+ years	Replacement, mixed, and surface	Variable size patches of shrub or herb dominated structures, or early to mid to late seral forest depending on the type of biophysical environment. Cycled by rare fire or other disturbance events. Often have complex structures influenced by small gap disturbances and understory regeneration.

Methods

Findings on assessment of methods for project and watershed scale fire regime condition class rating were reported by Hann (2003). Use of these methods for mapping fire regime condition class and associated variables were initially tested in a smaller, approximately 9,000 hectare (20,000 acre) watershed restoration-planning project on the San Isabel National Forest to the west, which resulted in a number of recommendations for improvement (McNicoll and Hann 2003). We decided to further test and develop these methods in the Trout West watersheds, a larger area of about 53,000 hectares (130,000 acres) that had both different ecosystems and different types of base vegetation, fuels, and fire data.

Table 2—Condition classes from Hardy et al. (2001) and Schmidt et al. (2002) as interpreted by the authors for modeling landscape dynamics and departure from historical or natural range of variability in the Trout West watersheds. Historical range of variability (HRV) is the variability of regional or landscape composition, structure, and disturbances, during a period of time of several cycles of the common disturbance intervals, and similar environmental gradients, referring, for the United States, to a period prior to extensive agricultural or industrial development (synthesized from Morgan et al.1994; Landres et al. 1999; Hann et al. 1997). Natural range of variability (NRV) - the ecological conditions and processes within a specified area, period of time, and climate, and the variation in these conditions that would occur without substantial influence from mechanized equipment.

Class	NRV or HRV departure	Description
Condition class 1	Low	Vegetation composition, structure, and fuels are similar to those of the natural regime and do not predispose the system to risk of loss of key ecosystem components. Wildland fires are characteristic of the natural fire regime behavior, severity, and patterns. Disturbance agents, native species habitats, and hydrologic functions are within the natural range of variability.
Condition class 2	Moderate	Vegetation composition, structure, and fuels have moderate departure from the natural regime and predispose the system to risk of loss of key ecosystem components. Wildland fires are moderately uncharacteristic compared to the natural fire regime behaviors, severity, and patterns. Disturbance agents, native species habitats, and hydrologic functions are outside the natural range of variability.
Condition class 3	High	Vegetation composition, structure, and fuels have high departure from the natural regime and predispose the system to high risk of loss of key ecosystem components. Wildland fires are highly uncharacteristic compared to the natural fire regime behaviors, severity, and patterns. Disturbance agents, native species habitats, and hydrologic functions are substantially outside the natural range of variability.

The project was organized through the identification and management of 10 steps. These involved:

1) Identify and map fire regime potential vegetation-fuel types (FRPVT)
2) Model historical range of variation (HRV)
3) Assess current conditions
4) Compare current vegetation-fuel conditions with central tendency of HRV
5) Compare current fire interval and severity with central tendency of HRV
6) Summarize fire regime condition class for each FRPVT
7) Summarize area to treat and maintain to achieve condition class change
8) Map wildfire occurrence risk
9) Map fuel models
10) Map the wildland urban interface (WUI)

Identify and Map Fire Regime Potential Vegetation-fuel Types (FRPVT)

Methods for classification of natural fire regime potential vegetation-fuel type (FRPVT) stratification were based on several criteria (Hann 2003). The overall objective was to stratify based on identification of biophysical conditions that create substantial differences in management implications for restoration of fire-adapted ecosystems and reduction of risk to people and property. These key management implications involved identifying those factors that have caused substantial change in the natural fire regime conditions, such as:

1) exclusion of fire through suppression and lack of wildland fire use that mimics the natural regime;

2) past management (for example, harvest and grazing practices) that have not mimicked the natural effects of fire and other disturbance regimes; and
3) exotic invasions (for example cheatgrass, knapweed, and blister rust).

Criteria recommended to aid in stratification of FRPVT include biophysical type differences in:

1) pre-suppression fire interval group (0-35+, 35-100+, >200 years);
2) pre-suppression fire severity (surface versus replacement versus mixed);
3) upper layer lifeform potential (herbland, shrubland, woodland, forestland, barrenlands, ag-urban);
4) dominant upper layer species complexity potential (if one, two, or greater than two dominant species);
5) lower layer (understory) lifeform indicator species;
6) standing and down fuels - duff/litter layer potential;
7) climate (temperature/ moisture zones not associated with slope-aspect); and
8) slope-aspect (such as flat, cool aspect slopes, and warm aspect slopes).

The Land Type Association (LTA) map was used to examine broad vegetation type differences, and then further divided topographically to reflect changes in fire regimes. FRPVT classes were not broken down as finely as may be available in detailed plant association or habitat type maps, as this would cause a large number of stratifications that would not be meaningful for development of management implications. As such, the FRPVT was identified first relative to the fire regime group and secondarily to vegetation-fuel type species indicators that are important for management implications. The key was to define the fire regime group first, then stratify the vegetation biophysical type associated with a fire regime group that provides the linkage for development of management treatments.

Reconnaissance transects were driven or walked to identify the elevation, aspect, and slope breaks associated with changes in fire regime group and associated vegetation-fuel types. Initial field classification of fire regime group and potential vegetation type followed the methods outlined by Hann (2003). Fire scarred trees were located and tree boring and scar counting methods were used to nondestructively classify the pre-suppression fire interval group. Fire scarred stumps were located and cross-sections were cut to allow more accurate counts of the intervals between scars in order to validate the classification of the fire interval group. Initial classification of fire severity group was assigned based on substantial presence (surface fire regime), presence (mixed fire regime), or absence (replacement fire regime) of fire scarred trees or stumps. In a later step, simulation modeling of historical range of variability (HRV) of fire interval and fire severity was used to crosscheck these classifications.

Intensive fire scar cross-dating, tree ring chronology, and ground mapping were not conducted. Methods for characterization of FRPVT and the HRV were designed for rapid ground reconnaissance combined with use of available data, review of the literature, and comparison of historic and current photographs for integration using simulation modeling. For this study we decided to limit ourselves to a level of inventory and analysis effort that could typically be expended on most fire and fuel management projects. Therefore we decided not to impose intensive and costly methods typically used for fire history research.

Most FRPVT(s) were mapped using GIS map query assignments to terrain model classes of elevation, aspect, and slope. Digital elevation models (DEM) were utilized to derive these aspect, slope, and elevation terrain models. However, the riparian valley FRPVT could not be mapped using this process so the land type association map was used to make this assignment. The high elevation grassland FRPVT also could not be mapped using the terrain model and was delineated using aerial photos and digital orthophotos. Urban polygons were also identified from photo interpretation. Lakes were available from existing map coverages.

Model Historical Range of Variation (HRV)

The HRV for vegetation-fuel conditions, fire frequency, and fire severity was simulated using the vegetation development dynamics tool software (VDDT) (Beukema and Kurz 2001). We opted to use the standardized succession and disturbance model called the "box" model in order to have an organizational framework with predefined successional stages and disturbances (Hann 2003).

Using the "box" model we conducted numerous simulations of HRV for vegetation-fuel class composition, fire interval group, and fire severity group by adjusting fire, other disturbance, and succession probabilities. Landscape conditions that would have existed before active fire suppression were simulated over a 500-year period with a climate similar to the current. Native American influences on fire frequency and intensity were considered part of the natural or native system (Barrett and Arno 1982). Utilizing fire scar interval counts and other historical clues from the reconnaissance transects, probabilities of fire occurrence and succession were calculated and used as a range of inputs to sensitivity test the models. This information was then combined with evaluation of historical and current photos, literature (Brown and others 1999, Kaufmann 2000, Kaufmann and others 2000 and 2001), local knowledge, and results of the sensitivity testing to determine the final combination of disturbances and succession probabilities. The final HRV was simulated 10 times to account for variability. The key was to develop an estimate of the variation in natural landscape dynamics that would occur without active fire suppression and other modern anthropogenic influences over a long time period under the current climate.

We did not have an objective to attempt to simulate HRV with high accuracy or conduct extensive validation. The objective was to simply identify the major trends of conditions and processes that occurred in HRV to use as a broad reference for determining departure of current conditions and processes. From this we calculated an average for the HRV class composition, fire interval, and fire severity. This average provided an estimate of the central tendency of the HRV to be used as a reference condition for comparison with current conditions. The methods for comparison of current conditions with the reference estimate of central tendency follow those of Clements (1934) and Mueller-Dombois and Ellenberg (1974). Because of the lack of intensive FRPVT specific HRV ground truth, we followed Hann (2003) in using plus or minus 33% from the HRV average as including the typical HRV. This is a compromise between the plus or minus 25% recommended by Keane et al. (1996, 1997, 2002) for simulation modeling and the 80% median range recommended by Hessburg (1999) for historical photo analysis.

For each FRPVT, the "box" model classes were cross-referenced with the current vegetation-fuel classification for cover type, size class, and canopy closure classes. The HRV composition was then calculated. This provided a characterization for the vegetation-fuel class composition specific to the FRPVT that could be cross-walked to the current vegetation-fuel map data. An example is provided in table 3 for the frequent surface fire regime lower elevation undulating ponderosa pine FRPVT. In addition, the average fire interval, amount of surface fire, replacement fire, and total fire were also determined from this final simulation data.

Table 3—Simulated average for each class of the "box" model during the historical range of variation (HRV) for the frequent surface fire regime lower elevation undulating ponderosa pine FRPVT. The average was used as the measure of central tendency for the HRV. A plus or minus 33% variation or range of 66% was used as a measure of the range of variation.

"Box" model class	Box model description	FRPVT current vegetation class description	HRV % average
A	Early development	Tree regeneration open/grassland	14
B	Mid development closed	Closed canopy pole	4
C	Mid development open	Open canopy pole	11
D	Late development open	Open canopy mid mature–mature	59
E	Late development closed	Closed mid mature - mature	12
F – L	Did not occur in HRV	Other vegetation classes	
Total			100

The valley riparian and high elevation meadows were not modeled for the HRV because there would be little to no active management in these areas (the grasslands are almost entirely on private land).

Assess Current Conditions

The Resource Inventory System (RIS) map coverage was used as the vegetation data source for cover type and structure. Many polygons lacked canopy closure data; some lacked cover type. Vegetation data of this scale was not available for private lands. Consequently, we digitized stand polygons across private lands and populated these with photo interpreted cover type and structure to fill the missing data. Missing data in National Forest polygons were also attributed utilizing aerial photo interpretation.

Canopy closures from the RIS maps were combined into three classes:

Shrub/herb/tree seedling (S): <5-10% sapling and larger tree cover, corresponds with HRV class A;

Open forest (O): generally 11-50% canopy closure of sapling and larger trees, corresponds with HRV classes C or D; and

Closed forest (C): generally > 50% canopy closure of sapling and larger trees, corresponds with HRV classes B or E.

Structural classes (as defined by size) from RIS were also combined:

Early seral (1): tree seedling, shrub, herb (attributed in RIS as Structural Habitat Stage 1; corresponds with HRV class A;

Mid seral (2 and 3): sapling (2) and pole (3) (attributed in RIS as structural habitat stage 2 or 3; corresponds with HRV class B or C; and

Late seral (4 and 5): mature saw timber (4) and old growth (5) attributed in RIS as Structural Habitat Stage 4 or 5; corresponds with HRV class D or E.

During the reconnaissance transects we recognized substantial Douglas-fir tree mortality in many stands. We decided to identify stands with substantial (>50%) recent mortality due to Tussock moth and Douglas-fir beetle. Local insect and disease inventories indicate that these landscape scale outbreaks were due to the much greater amount of Douglas-fir in the landscape than would naturally occur without fire suppression. This greater amount results in high current landscape level vulnerability to mortality, rather than the historical individual tree or group mortality in scattered stands. Although a few stands within the landscape may have been characteristic of mortality during the HRV, we concluded that many stands within the landscape would be uncharacteristic of conditions in the HRV. Unfortunately, the local forest insect and disease aerial survey maps were mapped at too coarse a scale for stand level attribution of mortality. Consequently, we utilized our most recent aerial photos (1997) and local knowledge to identify those stands with substantial mortality.

In summary, the following vegetation attributes were required for the analysis:

1. Cover type
2. Canopy closure
3. Structural (size) class
4. Substantial mortality

The current average fire interval was estimated to be 1% based on the fire occurrence data for the whole Trout West watershed area. This was determined as an average for the whole area rather than for each FRPVT because the fire occurrence data only exists for the past 30 years and locations and net size of fires have low accuracy. Current amount of replacement fire as a percent of total fire was estimated at 90% based on reconnaissance of recent wildfire areas and local knowledge of fire behavior in typical stand conditions.

Compare Current Vegetation-Fuel Conditions With HRV

Utilizing a variety of GIS and other computer tools (Spatial Tools, Arcview, Arcinfo, Excel), a frequency table was derived to depict each unique combination of FRPVT, cover type, size class, canopy cover, and mortality for the current map coverage. Each combination was concatenated and added to a new item labeled "Key."

A "Class" item was then added, and each unique combination (Key) was cross-referenced to the associated HRV Structural Class (A, B, C, D, E). In addition to the standard HRV classes A-E, "box" model Classes I-L applies to uncharacteristic conditions. These were not included in the HRV characteristic classes on the premise that historical conditions would have contained none or very minimal (<1%) amounts of such types at a landscape scale:

Class G: Uncharacteristic Timber Harvest (harvesting has produced a type that did not occur at a landscape scale in HRV);

Class I: Uncharacteristic Succession (succession has proceeded beyond the HRV range producing a type that did not occur at a landscape scale in HRV); and

Class L: Uncharacteristic Insect or Disease mortality (insect and disease mortality creating a type that did not occur at a landscape scale in HRV).

A corresponding item "Name" was created as a class descriptor, and attributed with a label, such as Open Mid-Development. An acre field was added to depict the corresponding acreages for each Class. Utilizing Excel, a sum is calculated within each FRPVT for each class. A similarity comparison was then made between HRV and current vegetation-fuel conditions for each FRPVT (table 4). This measure of similarity was developed by Clements (1934) and is considered to be one of oldest and most straightforward measures of similarity or its inverse, which is dissimilarity (100-similarity). In this study we use the term "departure" in the same manner as dissimilarity. The difference for any one class was calculated as (current – HRV average)/(current + HRV average) expressed as a percent. A departure contribution of low was considered to be within a range greater than -25% and less than +25% difference from the average for HRV. The contribution of moderate was considered to be less than or equal to -25%, but greater than -75%, and greater than or equal

Table 4—Example calculation of similarity of current conditions to HRV for the frequent surface fire regime lower elevation undulating ponderosa pine FRPVT. The similarity for any Class is the smaller of HRV or current amounts.

"Box" model class	HRV %	Current %	Similarity %	Difference %	Departure contribution	Abundance	Management implication
A	14	9	9	- 22	Low	Similar	Maintain
B	4	5	4	+ 11	Low	Similar	Maintain
C	11	2	2	- 69	Moderate	Rare	Recruit
D	59	20	20	- 49	Moderate	Rare	Recruit
E	12	31	12	+ 44	Moderate	High	Reduce
F – L	0	33	0	+ 100	High	High	Reduce
Total	100	100	47				

to +25%, but less than +75%, while the high class accounted for -75% to -100% and +75% to +100%. Abundance was considered to be rare if less than -25%, similar if between plus or minus 25%, and high if equal or greater than 25%. The general management implication for landscape scale restoration to reduce departure would be to maintain similar classes, maintain and recruit rare classes, and reduce the high classes.

The sum of similarity for classes was calculated. An example for the frequent surface fire regime low elevation undulating ponderosa pine (FRPVT 1) is depicted in table 4.

We would emphasize that as discussed by Hann (2003), HRV similarity or departure, as well as fire regime condition class, are landscape and not stand variables. Any specific fine scale pixel or stand can occur in any one of the characteristic HRV classes (A through E). The similarity to HRV or departure depends on how much of each of these classes occurred during HRV vs. how much now occur.

However, in order to identify the risk that a given stand or pixel contributes to the condition class or departure from central tendency and the management implications, we calculate additional variables that represent the Departure Contribution and HRV Conditions for each Class (example in table 4):

Departure Contribution:
Low Contribution: Classes A-E; < ± 25% difference from HRV
Moderate Contribution: Classes A-E; ≥ ± 25% difference from HRV; <75%
High Contribution: Classes A-E ≥ 75% difference from the HRV; plus uncharacteristic types
HRV Conditions (management implications) or abundance classes:
Maintain: Classes A-E; < ± 25% difference from HRV
Similar Abundance
Recruit: Classes A-E; > -25% difference from HRV
Rare Abundance
Reduce: Classes A-E; > +25% difference from HRV
High Abundance
Restore: Classes F-I (Uncharacteristic types)
High Abundance

This difference was calculated as (current – historic)/(current + historic) * 100.

Utilizing GIS and other computer tools (Spatial Tools, Excel, Arcinfo, and Arcview) these departure contribution classes were displayed spatially and summarized.

Compare Current Fire Interval and Severity With HRV

To compare the current fire interval and severity with HRV, we followed the method outlined by Hann (2003). Since these values are measured in years (fire interval) and percent canopy replacement (fire severity) the similarity of historical to current can be determined by calculating a ratio of the smaller divided by the larger (Mueller-Dombois and Ellenberg 1974). The departure can then be calculated by subtracting the ratio from 1 and multiplying times 100. If the current interval is less than the HRV average (currently more frequent) the current is divided by the HRV average, while if the current interval is greater than the HRV average (less frequent fire) the order is reversed. If the current interval is determined to be still within the HRV range for the fire regime group then the HRV average is equal to the current interval resulting in 100 % similarity. Classification of departure from the HRV average assumes that the variation from 0 to 33 % is within HRV, while higher values of departure are outside the HRV.

The basis for using the larger of the current interval or the HRV average as the denominator was to provide an estimate of the proportional ratio of change irrespective of the direction (more or less frequent). As long as variation was allowed within the departure and condition classes to account for the HRV variation and a rule was imposed for those FRPVT and landscapes where fire interval was not outside of the HRV interval range, this methodology normalizes the differences.

The current fire interval probability was calculated as the current percent occurrence divided by 100. As discussed earlier, the current fire occurrence was estimated at 1 per cent, or a .01 probability for the Trout West landscape or for any FRPVT in the Trout West landscape. The HRV fire interval probability was calculated by dividing 1 by the HRV mean fire interval. An example calculation for the frequent surface fire regime low elevation gentle ponderosa pine follows:

Current fire probability = 1/100 = .01
HRV mean fire interval = 21 years
HRV fire interval probability = 1/21 = .047
Current to historical interval similarity = (.01/.047) * 100 = 21%.

The current severity probability is the percent occurrence of current replacement fire divided by 100. This was estimated to be 90 per cent, or a .9 probability for the Trout West landscape or for any FRPVT in the Trout West landscape. The HRV severity probability was calculated by dividing the average percent of HRV replacement fire by 100. An example calculation for the frequent surface fire regime low elevation gentle ponderosa pine follows:

Current replacement fire probability = 90/100 = .9
HRV mean replacement fire = 24 %
HRV replacement fire probability = 24/100 = .24
Current to historical severity similarity = (.24/.90) * 100 = 27%

The combined fire interval-severity similarity was calculated as the sum divided by 2, giving each component equal weight:
Current to historical fire interval-severity similarity = (21+27)/2 = 24%.

Summarize Fire Regime Condition Class for Each FRPVT

HRV departure from central tendency for any given attribute is calculated by subtracting the percent similarity from 100 (Hann 2003). In the frequent surface fire regime low elevation gentle slope ponderosa pine FRPVT example:

Vegetation-Fuels departure = 100 – 47 = 53%
Fire interval-severity departure = 100 –24 = 76%

The vegetation-fuel condition class was determined by calculating departure (100-sum of similarity) and classifying condition class 1 between 0-33% (considered to be within HRV), 2 from 34-66%, and 3 from 67-100% (table 5). The estimate of treatment in FRPVT 3 was designed to move this component two condition classes, from Condition Class 3 to the upper boundary (33% departure) of condition class 1, while the estimate in FRPVT 1, 2, and 4 were to move one condition class. This method of estimating treatment would respond to a management scenario focused on landscape scale restoration for reduction of risk from both wildland fires during severe fire weather conditions and risks to ecosystem sustainability of HRV departure. The choice of use of the upper boundary of a class, the midpoint of that class, or some other measure for the class depends on the management scenario.

Using the standard class breaks from Hann (2003) the two components (vegetation-fuels departure and fire interval-severity departure) of the fire regime condition class were categorized as follows for the frequent surface fire regime low elevation gentle slope ponderosa pine type:

Vegetation-fuel departure condition class = 2
HRV vegetation-fuel departure class = Moderate
Fire interval-severity condition class = 3
HRV fire interval-severity departure class = High

The intersection of the two departure points, rather than a sum and division, was used to assign the final natural fire regime condition class (Hann 2003).

Fire regime condition class = 3
HRV departure class = High

The break between frequent and infrequent fire regimes is typically an average fire interval of 35 years (figure 1 and table 1). However, this break should

Table 5—Summary of Trout West fire regime potential vegetation types (FRPVT) with associated area, vegetation-fuel condition class (Veg-Fuel CC), vegetation-fuel departure (Veg-Fuel Dep.), and estimates of area to treat and maintain.

FRPVT code	FRPVT description	Area hectares (acres)	Veg-fuel CC	Veg fuel dep.	Area to treat (acres)	Area to maintain (acres)	Total area (Acres)
1	Gentle ponderosa pine	16,662 (41,173)	2	53	3333 (8235)	583 (1,440)	3916 (9675)
2	Low elevation south aspect ponderosa pine	4788 (11,832)	2	39	287 (710)	287 (576)	520 (1286)
3	Low elevation north aspect ponderosa pine -Douglas-fir	2934 (7251)	3	73	1174 (2900*)	1174 (219)	1263 (3119)
4	High elevation ponderosa pine –aspen -Douglas-fir –spruce -lodgepole pine	25,617 (63,301)	2	55	5636 (13,926)	5636 (2947)	6829 (16,873)
Sum		50,002 (123,558)	2	54	10,429 (25,771)	2098 (5182)	12,528 (30,953)

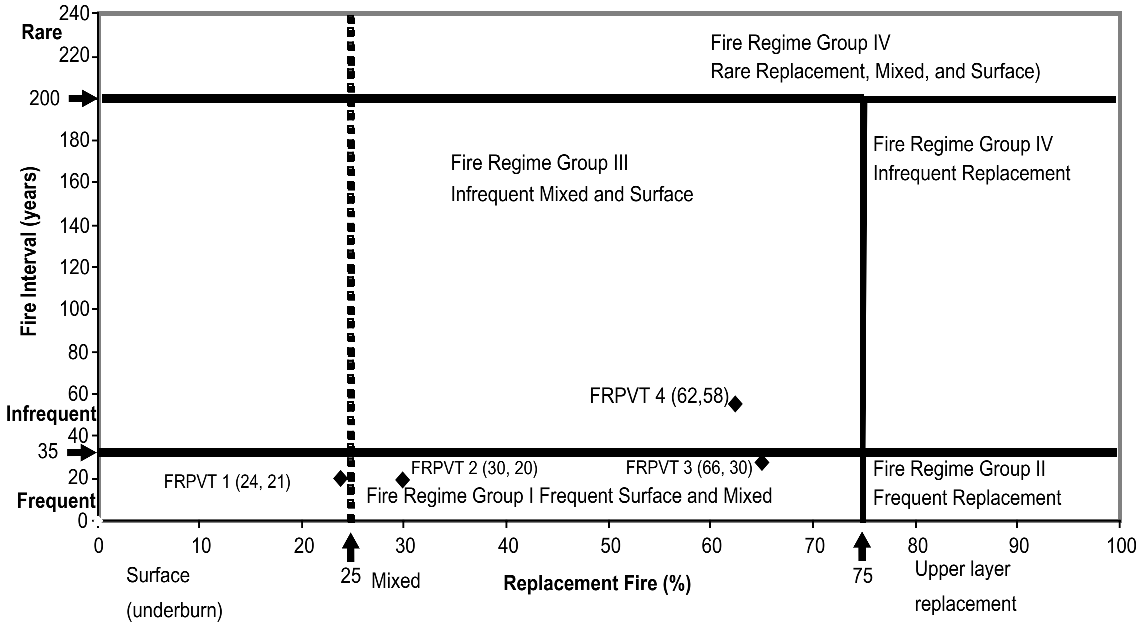


Figure 1. Graphical representation of natural fire regime group boundaries for inputs of fire interval (frequency) and fire severity (% replacement upper layer) showing the x and y axis intersects of FRPVT 1 (21, 24), 2 (20, 30), 3 (30, 66), 4 (58, 62) and the Trout West landscape (T-W-LS as a whole (40, 47).

be increased to 50 years for regimes with high temporal variation or the median should be used rather than the mean. The break between infrequent and rare is typically 100 years, but can range up to 200 years. Classification breaks for fire severity are 25% between surface and mixed and 75% between mixed and replacement. Fire regime group 1 is dominated by surface fire but contains substantial amounts of mixed fire regimes, while group 2 is limited to replacement regimes. Fire regime group 3 is dominated by mixed fire regimes but includes some surface fire regimes, while group 4 is limited to replacement regimes. In fire regime group 5 fires rarely occur but can range from replacement to mixed to surface in effects. In the Trout West analysis FRPVT 1 was the only regime to classify as a frequent, surface fire regime, and this is borderline. Given a plus or minus 33% variation, FRPVT 1, 2, and 3 could have a fire interval between 35 and 50 years, but given they are dominated by fires that are mixed in time they would still be classified in the frequent regime.

We would like to emphasize that the vegetation-fuel departure was based on cover type and structure, and the departure in these attributes only act as a proxy for departure in species composition, fuels, and mosaic patterns, which are important components of the natural vegetation-fuel system. In a similar vein the mean fire interval and simple classification of severity only acts as a proxy for departure in season of fire occurrence, variation in fire occurrence, fire behavior, and severity of fire effects, which are important components of the natural fire interval-severity system. However, in order to keep the analysis simple enough to complete in a short time with readily available data, the use of vegetation cover type-structure and fire interval-severity departure appears to be the best proxy to overall landscape departure from HRV and in fire regime condition class. An even greater reduction in complexity and time can be accomplished by using vegetation departure alone as a proxy for all vegetation-fuel and fire interval-severity components. However, this can be misleading, particularly for ecosystems that contain fire dependent or associated species that require fire effects for germination or to maintain a competitive advantage (Hann 2003).

Summarize Area to Treat and Maintain

It is very useful to have some estimate of the area to treat (recruit, reduce and restore) in order to achieve a fire regime condition class or HRV departure option. This was calculated for each FRPVT. An example is provided in table 5. In the example the option was to improve the FRPVT to the upper range of condition class 1 and lower HRV departure to conditions similar to the HRV regime based on the vegetation-fuel departure. The minimum area treated to achieve this option was calculated as follows:

Minimum area to treat = (Vegetation-fuel Departure- 0.33) * FRPVT area, where .33 is the upper boundary of Condition Class 1.

For the frequent surface fire regime low elevation gentle ponderosa pine FRPVT example, the calculation was: area to treat = (0.53 - 0.33) * 16,662 ha (41,173 acres) = 3333 ha (8235 acres). Given that condition class 1 includes the normal range of natural or historical variability, this level of treatment mimicking natural disturbance effects would move this FRPVT to a composition with borderline similarity to the HRV.

However, this calculation of treatment does not account for the need to maintain acres that are currently contributing to natural vegetation-fuel HRV conditions that could be lost due to natural succession over the project implementation period. For large landscape restoration projects the project implementation period can often range from 5 to 15 years. The amount similar to the HRV averages for classes A, B, C, and D were summed and multiplied times the area of the FRPVT to determine area similar to HRV. The amount from class E was not included in the calculation, because this class will not lose area to another class due to succession over the project implementation period. The amount of area similar to the HRV averages was divided by an average successional period for the implementation period. This successional period was estimated from the successional rates in the "box" model to be about 50 years. The project implementation period was estimated to be about 5 years. As an example (table 5), the amount that needs to be maintained in the frequent surface fire regime low elevation gentle ponderosa pine:

HRV similar area = (A + B + C + D similarity) * FRPVT Area
HRV similar area = (.09 + .04 + .02 + .20) * FRPVT Area
HRV similar area = (0.35 * 16,662 ha (41,173 ac.)) = 5832 ha (14410 acres)
Implementation successional period = 50/5 = 10
Area to maintain = HRV similar area / implementation successional period
Area to maintain = 5832 ha (14410 acres) / 10 = 583 ha. (1440 acres).

A simpler way to approximate amount to maintain would be to map the area that was classified with a "maintain" management implication (same as "similar" abundance class) in combination with moderate and high risk of departure, which can be used as a proxy for ecological sustainability risk. However, this does not account for differences in succession rates.

The calculation of area to treat and maintain uses the vegetation-fuel departure and not the fire interval-severity departure or both. This was because the management option was to improve sustainability of the current vegetation-fuel landscape, such that habitats would be more characteristic of natural conditions, and when wildfire occurs, the risk of uncharacteristic behavior and effects would be much less. The overall goal was not to mimic the frequency and behavior of the natural fire interval-severity system. However, the knowledge that this part of the system is in condition class 3 and high departure can be used to focus wildland fire use and prescribed fire programs on this FRPVT.

Map Wildfire Occurrence Risk

This analysis was designed to quantitatively predict future fire probabilities of wildfire occurrence based on past fire occurrences. The process was divided into three steps. The first step was to classify ignition frequency. Historic ignition point data was incorporated into a grid composed of .25 square kilometer cells. The ignition sources were grouped into two classes: L = Lightning and O = Non-Lightning. The number of ignition points present in each cell were counted and grouped into the following categories: lightning, non-lightning, and all sources. Ignition point classes were developed based upon: 1) the total number of ignition points in the map extent and 2) the range of total ignition points within the cells. The ignition point classes were defined as follows: low (L) = 1 ignition source; Moderate (M) = 2 to 3 ignition sources; and High (H) = 4 or more ignition sources.

The second step was to attribute ignition class to the vegetation polygon coverage. The vegetation polygon layer accounted for all ownership types (National Forest and private). Each polygon was assigned an ignition point class for each ignition point category (refer to the Ignition Class by Frequency process). This process set each ignition point class to a unique numeric value for the polygon by assigning class: H = 1000; M = 100; and L = 1. Then these numeric point values were summed for each polygon. The sum value was then used to classify the polygon ignition point class of: High = >999); Moderate = >100 – 999; and Low = 0 - 100.

The third step was to classify the wildfire occurrence risk by combining the polygon's ignition class with its FRCC departure contribution class. An ignition class and departure contribution matrix (table 6) was used as a guide to query for those combinations and assign the wildfire occurrence risk class to each vegetation polygon.

Table 6—Wildfire occurrence risk class matrix formed from the combination of FRCC departure contribution class and polygon ignition class. Polygon ignition class relative risk levels were calculated using recent wildland fire occurrence data for the Pike and San Isabel National Forests. Numbers of wildland fires were summarized across this larger area, the Trout West area, by watershed, and by departure contribution class to calculate and classify relative risk of wildland fire occurrence during the fire weather season. Final relative classes included very high (VH), high (H), moderate (M), low (L), and non-applicable (NA).

Departure contribution class	Polygon ignition class			
N	L	M	H	
High	L	M	H	VH
Moderate	L	M	M	H
Low	L	L	M	M
None, non-applicable, Water	NA	NA	NA	NA

Fuel Model Mapping

Anderson and National Fire Hazard Danger Rating System (NFDRS) fuel models were assigned using the descriptions from Anderson (1982) and local knowledge of fire behavior. Both fuel model classification systems focus on the fire behavior of the fuel model. Consequently, the assignment process focuses on the expected fire behavior of a vegetation-fuel type rather than the specific fuel loading and distribution characteristics of the vegetation-fuel type. Each unique combination of FRPVT, cover type, canopy closure, size class,

Table 7—The process for assigning Anderson and NFDRS fuels models from Anderson (1982) to vegetation cover type, canopy closure, size class, and mortality class combinations resulted in a large set of tabular values The data from FRPVT 1, the frequent surface fire regime lower elevation gentle ponderosa pine, is shown in the table as an example.

FRPVT	Cover type	Canopy closure	Size class	Mortality class	Anderson fuel model	NFDRS fuel model
1	Grass	Shrub-grass	0	N	1	L
1	Shrub	Shrub-grass	0	N	6	T
1	Ponderosa Pine	Closed	Pole	N	8	H
1	Douglas-fir	Closed	Large	Y	10	G

and mortality class was attributed with the corresponding fuel model class that best fit the expected fire behavior. There were about 25 to 50 unique combinations for each FRPVT, which were too many to display for this paper. An example set of combinations is provided in table 7 to display the assignment process. The data was displayed in both Anderson and NFDRS Fuel Model maps. Both fuel model classifications are very coarse but are useful for evaluating fire-planning scenarios or for use where fuels field data and custom fuel models are not available.

Map the Wildland Urban Interface

The wildland urban interface (WUI) and associated attributes were mapped and linked to the vegetation-fuel polygons. While mapping of WUI was not needed for FRCC analysis, this variable was important for defining and addressing fire management issues. A land use map was used to identify if a polygon was urban or not urban. Photo interpretation was used to identify all non-urban polygons as to being WUI or non-WUI. The wildland urban interface was defined as a polygon having at least one house in 16 hectares (40 acres). This value was selected because of the zoning regulations in Colorado that typically create subdivisions with one or more houses per 16 hectares (40 acres). Each WUI polygon was then attributed to a housing density class with the following definitions: low is 1 house per 16 hectares (40 acres) to 1 house per 2 hectares (5 acres); moderate is more than 1 house per 2 hectares (5 acres) to 1 house per .4 hectare (1 acre); and high is >1 house per .4 hectare (1 acre).

Once the Urban and WUI polygons were identified, a GIS buffer was created to depict areas in relatively close proximity to WUI polygons, and to quantify how many acres of National Forest land exist in the WUI buffer zone. The amount of buffer needed between a crowning wildland fire front and the urban interface varies depending both on fuels and fire weather conditions and the values of local residents. If structure protection alone is the key value then a much narrower buffer is viable if homeowners manage for defensible space. If local residents include values such as risk of smoke and loss of local scenic values then this buffer should be much broader. One of the biggest problems in effective fire management to suppress unwanted wildland fire and protect structures and utilities occurs when suppression forces are pinched into a narrow zone between a flaming wildland fire front and urban areas with one-way roads, non-defensible structures, and utilities. This substantially increases safety hazards to people, property, and firefighters and limits use of air support, equipment, and backfiring. By overlaying this buffer with the FRCC layers, areas close to homes can be displayed that are in high departure from natural conditions, within hazardous fuel models, and at high risk for future wildfire occurrence.

Although there is no standard buffer width for WUI, a two-mile width has commonly been used, as large wildfires can throw spot fires or make runs of this distance. However, the use of a two-mile buffer resulted in nearly the entire planning area being within the buffer, obviously defeating the intent of identifying a priority zone. We then reduced the buffer to a one-mile width, which was more effective in displaying a corridor around WUI areas sufficiently narrow to differentiate this high priority zone from other wildland vegetation polygons.

Results and Discussion

Identify and Map Fire Regime Potential Vegetation Types (FRPVT)

The Trout West planning area was stratified into six Fire Regime Potential Vegetation Types (FRPVT). Each type represents a broad aggregate of land with similar homogeneous fire regimes (both in historical fire interval and fire severity) and vegetation potentials. The six different types plus designation of urban areas and lakes included:

- <u>FRPVT 1</u> – Low Elevation Gentle Slope Ponderosa Pine
  Natural fire regime group I: frequent surface fires
  Ponderosa pine/herb with aspen in draws
  Flat to undulating topography: less than 15% slope
  Montane / lower elevation: less than 8500 feet
  16,669 hectares (41,173 acres)
- <u>FRPVT 2</u> South Slope Low Elevation Ponderosa Pine
  Natural fire regime group I: frequent mixed fires
  Ponderosa pine/shrub/herb – small amount of Douglas-fir
  South-facing slopes: >15% slope
  Montane/lower elevation: less than 8700 feet
  4790 hectares (11,832 acres)
- <u>FRPVT 3</u> North Slope Low Elevation Ponderosa Pine – Douglas-fir
  Natural fire regime group I – frequent mixed fires
  Ponderosa pine – Douglas fir/shrub-herb
  North-facing slopes: >15% slope
  Montane/lower elevation: less than 8300 feet
  2936 hectares (7251 acres)
- <u>FRPVT 4</u> High Elevation Mixed Conifer - Aspen
  Natural fire regime group III – infrequent mixed fires
  Ponderosa pine-Douglas fir-aspen-lodgepole pine-spruce
  Upper elevation: >8300 feet on north slopes; >8700 feet on south slopes
  Montane/all aspects
  25,628 hectares (63,302 acres)
- <u>FRPVT 5</u> Riparian Valleys
  Natural fire regime group IV –infrequent replacement fires
  Valleys w/ meadow vegetation-willow-spruce – all elevations
  2124 hectares (5246 acres)
- <u>FRPVT 6</u> High Elevation Grasslands
  Natural fire regime group II – frequent replacement fires
  High elevation grassy meadows with scattered ponderosa pine

Expansive meadow area specifically in the Woodland Park-Divide area
2252 hectares (5562 acres)

- URBAN
  Those areas of urban influence such as shopping areas, industrial lots, parking lots, irrigated golf courses, etc. The key is that these types do not have sufficient vegetation-fuel to carry a wildfire nor to threaten structures. Housing developments with trees and lawns that do have sufficient vegetation-fuel to carry a wildfire or to threaten structures were attributed as "Urban Interface" and included in the appropriate FRPVT.
  311 hectares (769 acres)
- LAKES 55 hectares (135 acres)

Model Historical Range of Variation (HRV)

Historical range of variation was modeled and summarized for FRPVT 1through 4. FRPVT 5 and 6 were not modeled because there was no expected restoration or maintenance in these types. Compositions of HRV vegetation-fuel classes, fire interval, and amount of replacement and surface fire were summarized (tables 3, 5, and 8). Using this data each of FRPVT 1 through 4 was classified into a fire regime group (figure 1) and cross checked with the field reconnaissance classification. FRPVT 1 on gentle slopes with a replacement of 24% was very close to the boundary between a surface and mixed regime, while FRPVT 2 on the steeper south slopes fell well within the mixed regime. Both had fire intervals that appear to average about 20 years, while FRPVT 3 on the north aspects was at the upper end of both the fire interval class and amount of replacement for the frequent mixed group. FRPVT 4 at the higher elevations was fairly different from the other FRPVT in that it fell well within the infrequent mixed group (58, 62) with a fire interval and replacement levels both at about 60. These average fire intervals appear to be somewhat more frequent than the average fire intervals identified by Kaufmann et al. (2000a, b). This may be because we underestimated the role large herb-shrub patch size with lack of seed source or competition from grasses and shrubs in comparison to the role of fire in slowing succession back to

Table 8—Summary of vegetation-fuel departure (Veg-Fuel Dep.) and fire interval-severity departure from the central tendency measure of the HRV average for FRPVTs in Trout West watersheds.

FRPVT Code	Description	Area (hectares) (acres)	Veg-fuel dep.	Fire interval	Fire interval departure	Replacement fire %	Fire severity departure	Fire interval -severity departure
1	Gentle ponderosa pine	16,662 41,173	53	21	79	24	73	76
2	Low elevation south aspect ponderosa pine	4788 11,832	39	20	80	30	67	74
3	Low elevation north aspect ponderosa pine -Douglas-fir	2934 7,251	73	30	70	66	27	49
4	High elevation ponderosa pine –aspen -Douglas-fir –spruce -lodgepole pine	25,617 63,301	55	58	42	62	31	37
Sum		123,558	54	40	60	47	48	54

dominance for forested vegetation. Or it may be because the Trout West watersheds are in somewhat more gentle terrain with soils that produce more grass and thus might have had a higher amount of fire. Given that condition class 1 includes plus or minus 33% variation around the estimate of central tendency for the HRV, and the difference for departure contribution, abundance, and management implication classes includes plus or minus 25%, the disagreement with Kaufmann et al. (2000a, b) did not have substantial influence on condition class or associated variable ratings.

Assess Current Conditions

Summary of the current conditions indicate only about 67% of FRPVT 1 area is in characteristic vegetation-fuel classes, which was similar to the amount for FRPVT 2 (tables 9 and 10). However, FRPVT 3, the north aspect ponderosa pine – Douglas-fir type had the lowest amount of characteristic types with only 28%, while FRPVT 4 had 45% characteristic types. Most of the uncharacteristic vegetation-fuel conditions in FRPVT 1 and 2 were a result of succession continuing past maximum fire return intervals and generating structures that did not occur in the historical landscape. Uncharacteristic insect and disease mortality was not a substantial factor in FRPVT 1, 2, or 4, but was substantial (17%) in FRPVT 3. Vulnerability of stands to epidemic levels of insect and disease mortality occurred because natural fire exclusion by suppression activities combined with historic timber harvest to reduce ponderosa pine and allowed Douglas-fir to dominate. FRPVT 1 and 2 appear to be too dry to have much Douglas-fir, while in FRPVT 4 much of the vulnerable or dead Douglas-fir has been removed in past harvest or salvage. Much of the area appears to have been affected by uncharacteristic harvest, burning, and livestock grazing activities that occurred during the late 1800s and early 1900s mining era. This may have contributed substantially to reduction in

Table 9—Each FRPVT was summarized for area, vegetation-fuel condition class (Veg-Fuel CC), HRV vegetation-fuel departure class, fire interval-severity condition class (CC), the HRV fire interval-severity departure class, the fire regime condition class and the HRV departure assignments. Condition classes were assigned as 1 for low HRV departure from central tendency, considered to be within the HRV, and 2 and 3 for moderate and high departure, considered to be increasingly outside the HRV.

FRPVT code	Description	Area (hectares) (acres)	Veg-fuel CC	HRV veg-fuel departure class	Fire interval-severity CC	HRV Fire interval-severity departure class	Fire regime condition class	HRV departure class
1	Gentle ponderosa pine	16,662 41,173	2	Moderate	3	High	3	High
2	Low elevation south aspect ponderosa pine	4788 11,832	2	Moderate	3	High	3	High
3	Low elevation north aspect ponderosa pine-Douglas -fir	2934 7,251	3	High	2	Moderate	3	High
4	High elevation ponderosa pine-aspen -Douglas-fir -spruce -lodgepole pine	25,617 63,301	2	Moderate	2	Moderate	2	Moderate
Sum		123,558	2	Moderate	2		2	Moderate

Table 10—Summary of current vegetation-fuel class conditions to compare amount of characteristic to uncharacteristic conditions. Characteristic vegetation-fuel classes were those considered to have composition and structure that occurred during the HRV, while uncharacteristic classes were considered to be those that did not occur during the HRV.

FRPVT code	FRPVT description	Area hectares (acres)	A-E composition %	F-L composition %
1	Gentle ponderosa pine	16,662 (41,173)	67	33
2	Low elevation south aspect ponderosa pine	4788 (11,832)	68	32
3	Low elevation north aspect ponderosa pine -Douglas-fir	2934 (7,251)	28	72
4	High elevation ponderosa pine –aspen -Douglas-fir –spruce -lodgepole pine	25,617 (63,301)	45	55
Sum		50,002 123,558		

ponderosa pine dominance and increase in small tree regeneration density (McNicoll and Hann 2003).

The closed late development class dominated FRPVT 1 (31%), with open late development also played a strong role (20%). This relationship was reversed in FRPVT 2 where the open late development was dominant (45%), with the closed late development only having 19 percent. Succession appears to be much slower on the south aspects that are much dryer and have more coarse and well-drained soils than on gentle terrain. Closed (12%) and open (13%) late development had similar amounts in FRPVT 3 apparently because insect and disease mortality had opened many of the previously closed stands. FRPVT 4 was dominated by the closed late development class (21%) with only half as much open late development (12%). This type receives more moisture and has cooler temperatures causing more rapid canopy closure. Past harvest and salvage was the primary causal agent in creating the open late development classes.

FRPVT 1 was the only type with substantial early development (8%) vegetation. This was primarily grass and some shrub, apparently maintained in this stage by heavy competition from the grass that limits tree seedling regeneration. FRPVT 1 and 4 were the only types having substantial mid development closed conditions (5 and 7% respectively). In the gentle low elevation ponderosa pine type, this appeared to be related to thick "dog hair" stands created from some past hot fire or excessive livestock grazing disturbance that maximized regeneration. In the higher elevation type, these stands were primarily the result of past harvest followed by tree planting. None of the types contained substantial open mid development conditions.

Compare Current Vegetation-fuel Conditions With HRV

FRPVT 3 had the highest departure in vegetation-fuel conditions (figure 2, 73%). In contrast FRPVT 2 had the lowest, with only 39% departure. This is

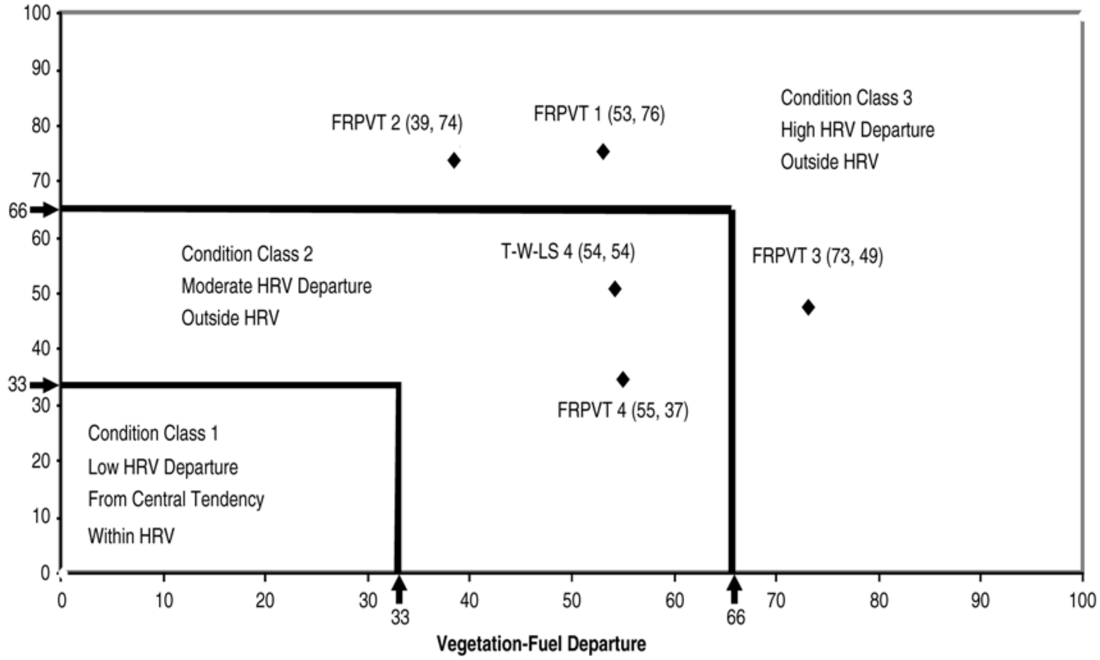


Figure 2. Graphical representation of fire regime condition class boundaries for inputs of vegetation-fuel departure and fire interval-severity departure showing the x and y axis intersects of FRPVT 1 (53, 76), 2 (39, 74), 3 (73, 49), 4 (55, 37) and the Trout West landscape (T-W-LS as a whole (54, 54). Condition class 1 can contain plus or minus 33 % variation around the estimate of central tendency for the natural or historical range of variability. This allows for a 66% range in variation. Condition class 2 and 3 are considered to be outside the natural or historical range of variability in successively higher levels.

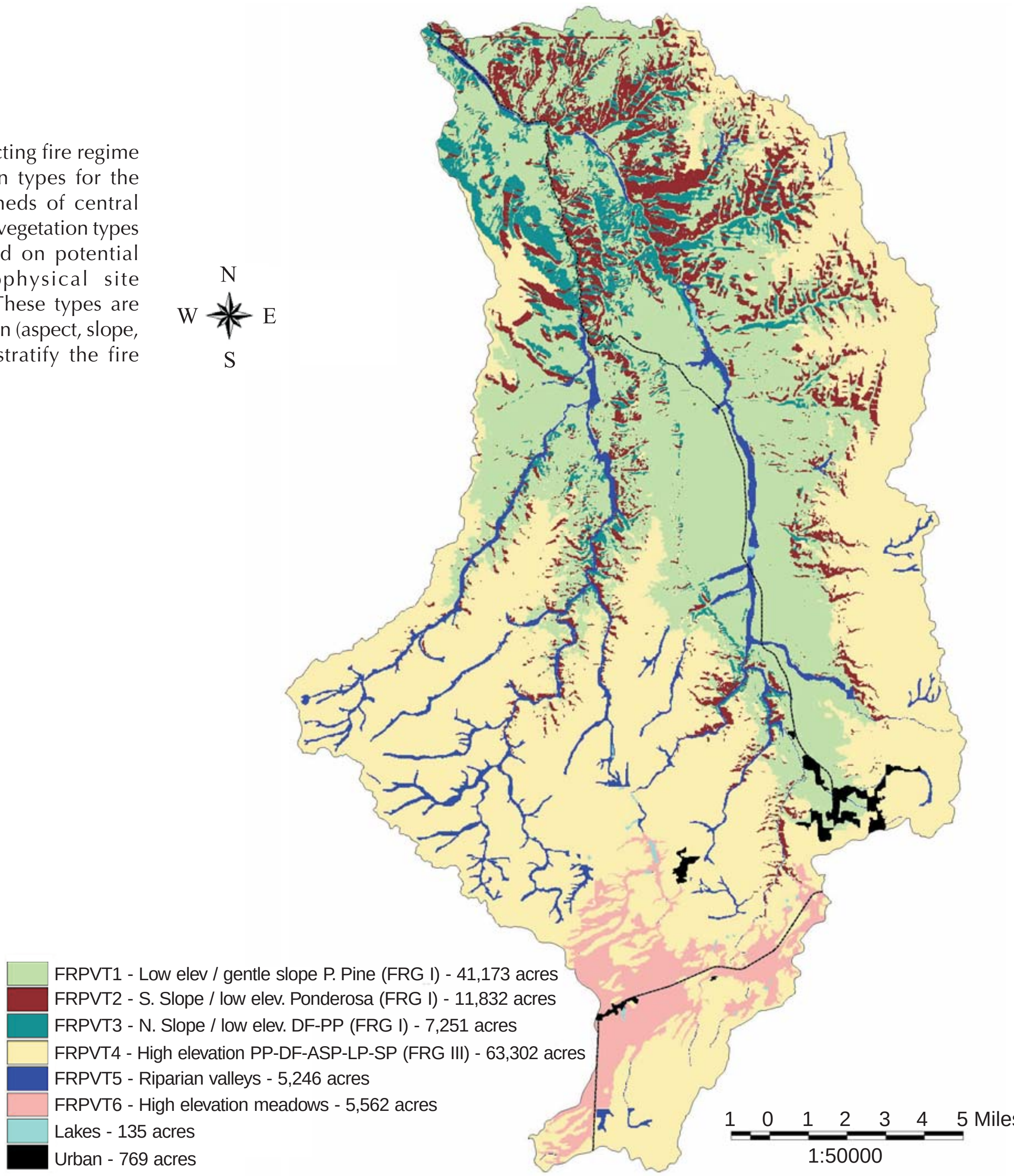
interesting given these two types are on contrasting slopes. In general the south slope has the least change because of dryer conditions that have slowed uncharacteristic succession, with the north aspect slopes showing the greatest departure because of moist conditions that allow fairly rapid uncharacteristic succession combined with a lack of past harvest due to the steep terrain.

FRPVT 1 and 4 had intermediate departures (53% and 55% respectively) that were similar to the landscape average for Trout West (figure 2, T-W-LS 54%). Departure in FRPVT 1 was somewhat less because of fairly slow uncharacteristic succession due to grass competition with tree regeneration and some past prescribed fire and harvest treatments. Although succession may be faster in FRPVT 4, the departure was slower because natural fire intervals are infrequent as compared to the more frequent interval in FRPVT 1 (figure 3). In addition, past harvests, salvage, and prescribed fire reduced departure to some degree.

Compare Current Fire Interval and Severity with HRV

In contrast to vegetation-fuel conditions, FRPVT 1 had the highest departure in fire interval-severity (figure 2, 76%). FRPVT 2 had almost as high a departure level with 74%. This is a logical relationship since both types are in a frequent fire regime and the primary causal agent of departure is fire exclusion. Past excessive livestock grazing in the late 1800s and early 1900s could have also been a related factor by reducing fine fuels, thus increasing the natural fire interval even prior to the active fire suppression efforts initiated in the 1920s and ‘30s. These causal factors may be interacting with increased fire ignitions from mining-related burning that occurred during that time and with decreased fire ignitions from Native American burning. However, given

Figure 3. Map depicting fire regime potential vegetation types for the Trout West watersheds of central Colorado. Potential vegetation types are classified based on potential lifeform and biophysical site indicator species. These types are then split using terrain (aspect, slope, and elevation) to stratify the fire regime.



the amount of lightning in the Trout West area, the lack of fine fuel from excessive livestock grazing would likely be the driving force in increasing the fire interval, as compared to changes in amounts of cultural burning.

FRPVT 3 and 4 had lower levels of fire interval-severity departure (figure 2, 49% and 37% respectively). This follows with these types having less frequent fire intervals. Although FRPVT 3 classified into the frequent fire regime, the average (table 8, 30 years) is very close to the upper boundary for the frequent regime. The range in variability of this type would take it into the infrequent regime for some cycles.

One of the key effects of the departure in fire interval-severity appears to be related to native plant diversity. The understory of mid and late development stands and of the early development stands appears to have very low diversity of native herb and shrub species. Many of these species are fire adapted or fire associated in terms of regeneration mechanisms. Even though the vegetation-fuel class conditions may allow for these species, the lack of regenerative fire effects precludes their development.

Summarize Fire Regime Condition Class for each FRPVT

FRPVT1 had the highest departure (76%) in fire interval-severity, but only moderate departure (53%) in vegetation-fuel class composition (figure 2) thus classifying as a condition class 2 for vegetation-fuel conditions, 3 for fire interval-severity conditions, and overall a fire regime condition class 3 for combined conditions (tables 8 and 9). FRPVT 4 had the lowest departure in both components (55%, 37%) with a moderate departure and overall condition class 2 assignment. FRPVT 3 had the highest departure in vegetation-fuel class composition (73%), only a moderate departure in fire interval-severity (49%), and thus an overall class 3 assignment.

FRPVT 1 and 2 have sufficient departure in fire interval and severity to classify as condition class 3 although the vegetation and fuel departure would classify as condition class 2. This would likely have implications that this regime may lack natural fire effects and have lost composition of fire associated species. FRPVT 3 has sufficient departure in vegetation and fuel to classify as condition class 3 although fire interval and severity departure would classify as condition class 2. This would have implications for high fuel loading and loss of natural cover type and structure diversity. FRPVT 4 classified as condition class 2 for both types of departure and because of its large area extent caused the average departure for Trout West as a whole to classify in condition class 2.

Summarize Area to Treat and Maintain

One scenario for the Trout West watersheds was to treat and maintain enough area to change the condition to a class 1 in a landscape pattern that would reduce risk to the urban interface. Additional secondary options included reducing potential large fire suppression costs and reducing ecosystem risks to air, water, native species habitats, and sustainability. Given that fire interval-severity outcomes are very difficult to measure and evaluate, it appeared that the vegetation-fuel condition class would be the most useful indicator to estimate area to treat and maintain, and to monitor relative to achievement of an option. Focusing on an option resulted in the need to calculate the area to treat and maintain based on the option of changing the Vegetation-fuel condition class from 2 to 1 for FRPVT 1, 2, and 4, and from 3 to 1 for FRPVT 3. This focus on vegetation-fuel condition class does not de-emphasize the need to focus on the fire interval-severity condition class and departure. The fire interval-severity condition class was identified as a focus for identification of type of treatments, particularly prescribed fire as a tool for treatment and maintenance of polygons in FRPVT 1 and 2.

Summary of the area to treat indicated approximately 10,000 hectares (76,000 acres) in order to achieve the condition class option (table 5). In addition about 2100 hectares (5200 acres) would need to be maintained during a typical project implementation period. A little over half would be focused at FRPVT 4, about one third to FRPVT 1, with the rest in FRPVT 2 and 3. Given that 2 and 3 are located on the steeper slopes with less road access, a strategy may be developed to treat these with prescribed fire or wildland fire use following treatment of surrounding areas in FRPVT 1 and 4 with mechanical and prescribed fire, and only emphasizing mechanical or hand treatment where FRPVT 2 and 3 polygons abut urban interface areas. Treatment polygons would be focused at reducing high and moderate departure (figure 4) and maintaining low departure. Given there is much more high and moderate departure (45,593 hectares, 112,663 acres) than needed to achieve the outcome, polygons would be prioritized based on most effective design to reduce risks of wildfire to urban interface and ecosystems combined with operational considerations (such as access, soils, terrain, and visuals). Treatment and maintenance prescriptions can be focused at those needed to reduce certain types, recruit other types, and maintain low departure conditions.

Fuel Model Mapping

Fuel models in themselves do not indicate potential for uncharacteristic wildfire behavior and effects, fire regime condition class, or departure from natural (historical) conditions (Hann and Bunnell 2001). However, the combination of an indicator of departure such as in figure 4 with fuel models (figure 5) has considerable value. Fuel model 2 (open grassy forest) would have been the most common fuel model in the natural (historical) regime. This fuel model can have rapid rates of spread in grassy fuels, but typically does not crown, have potential for blowup fire behavior, have severe fire effects, throw mass firebrands, and spread with long distance spotting fires. This fuel model still exists in scattered polygons (figure 5) but has been replaced in most polygons with fuel models 8, 9, and 10. Fuel model 8 (closed short needle single and multi-layer young forest without heavy ground fuels) in a moist or cold forest setting does not have high potential for ignition, spread, and crown fire. However, this fuel model would be uncharacteristic in a forest setting that is subject to drought conditions. In this kind of setting this fuel model can exhibit extreme crown fire behavior and long distance spotting (1.5-3 km, 1-2 miles), such as occurred during the fire seasons of 1988, 1994, and 2000. Fuel model 9 (closed long needle forest with litter-duff) can display even more extreme fire behavior than fuel model 8 in the dry forest setting. Fuel model 10 (closed forest with heavy ground and ladder fuels) typically displays the most extreme fire behavior and long distance spotting. The current vegetation-fuel conditions in the Trout West watersheds produce fuel model 8-9-10 complexes that are associated with high departure and uncharacteristic vegetation-fuel conditions.

Fuel models have shifted from the historical dominance of fuel models 2, 9, 1, and 8 to the current dominance of fuel models 8, 9, 2, and 10. This has resulted in a fire behavior shift during severe fire weather conditions from what were historically fast moving, but low intensity mixed and surface fires to current fast moving, but high intensity crown replacement fires and mixed fires. One of the biggest additional differences that affect landscape scale fire behavior is the current lack of non-forest fire maintained herbaceous-shrub (grass, forb, shrub) patches that were interspersed between the forested patches where fire would drop to the ground (Kaufmann et al. 2000a, b).

Map Wildfire Occurrence Risk

The wildfire occurrence and uncharacteristic fire risk indicates that the likelihood of current and near future ignitions, rapid rates of spread, and resistance to initial attack and wildfire containment would occur in the northern portion of the Trout West watersheds in the more rugged terrain (figure 6, moderate and high classes). The low class is strong to the southerly area of the watersheds indicating a lower likelihood that wildfires would initially ignite, be difficult to control, and spread from these areas. However, based on the departure map (figure 4), once a wildfire ignited and spread from inside or from adjacent watersheds uncharacteristic behavior (rapid rates of spread, crown fire, potential blowup fire behavior, mass firebrands, and long distance spotting) would be just as severe in the southerly end of the watersheds as in the

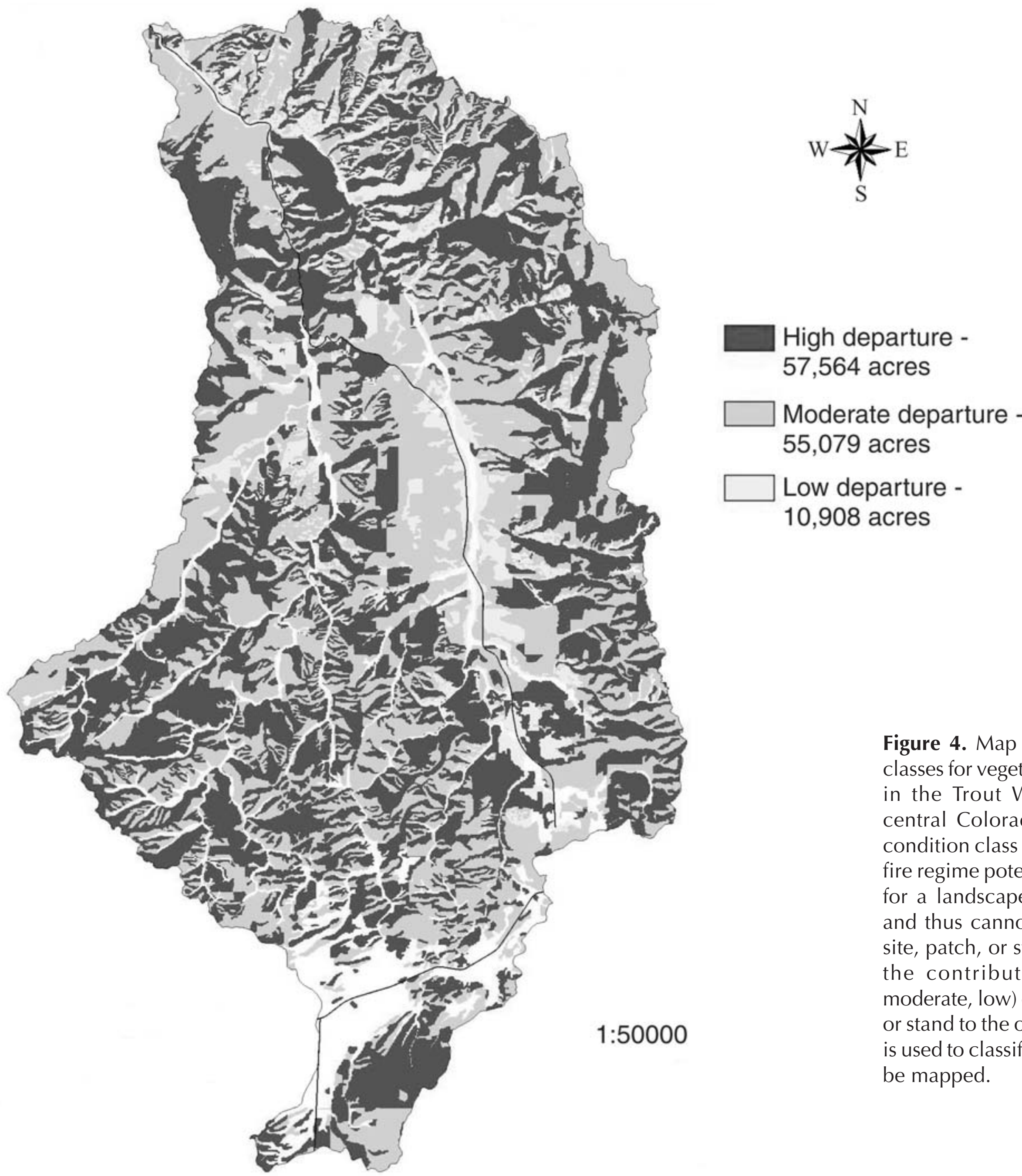
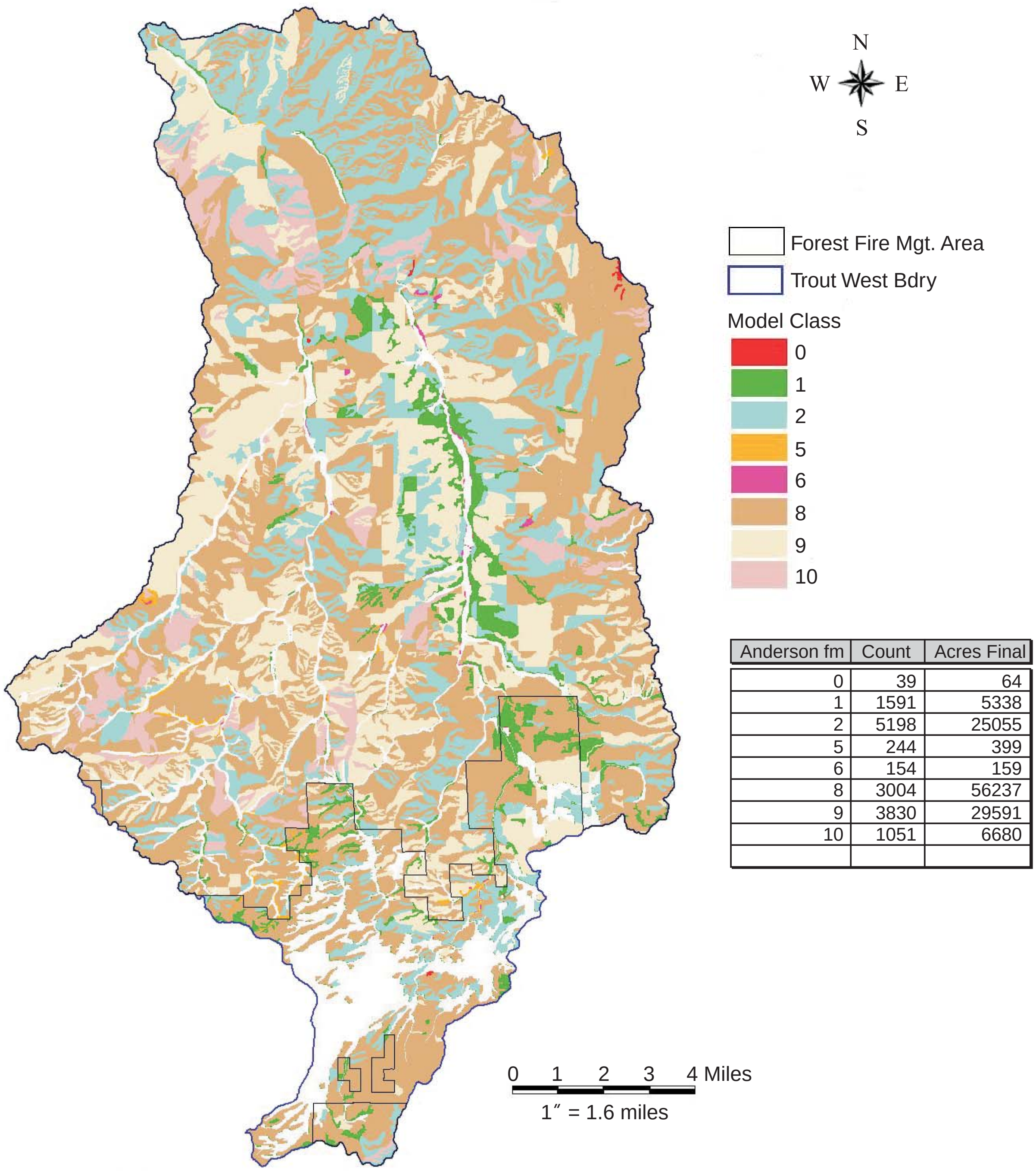


Figure 4. Map depicting departure classes for vegetation-fuel conditions in the Trout West watersheds of central Colorado. The fire regime condition class is determined for the fire regime potential vegetation type for a landscape or watershed area and thus cannot be mapped to the site, patch, or stand level. However the contribution or risk (high, moderate, low) of a given site, patch, or stand to the overall departure that is used to classify condition class can be mapped.

northern area. Amount of wildland fire ignitions or fuel flammability were found to not limit the current wildland fire occurrence. Initial attack to suppress wildland fires was found to be the primary cause of reduced fire occurrence compared to historical fire occurrence.

The high wildfire risk associated with uncharacteristic vegetation-fuel conditions occurs in a dry forest environment that is subject to cumulative multi-year drought and windy conditions with a high probability of ignition and spread from the northerly end of the watersheds or adjacent watersheds. The ignition and initial fire spread could come from the northerly portion of the landscape, from the landscape to the west or from the landscape to the east, driven by westerly or northwest winds, or Rocky Mt. Front easterly winds. The



Anderson fm	Count	Acres Final
0	39	64
1	1591	5338
2	5198	25055
5	244	399
6	154	159
8	3004	56237
9	3830	29591
10	1051	6680

Figure 5. Map depicting fuel models for the Trout West watersheds of central Colorado. Fuel models descriptions come from Anderson (1982) and are used along with weather and patch or stand canopy and structure attributes for modeling fire behavior (Andrews and Chase 1989, Finney 1998).

landscape as a whole, and in the context of adjacent landscapes, presents a high risk of eventually having a large wildfire event that could consume 60 to 80% of the watersheds, similar to the Buffalo Creek fire that occurred to the north in 1994.

Map the Wildland Urban Interface

The map of the wildland urban interface (WUI) indicates most of this area is in the southerly end of the watersheds on the higher elevation benches of

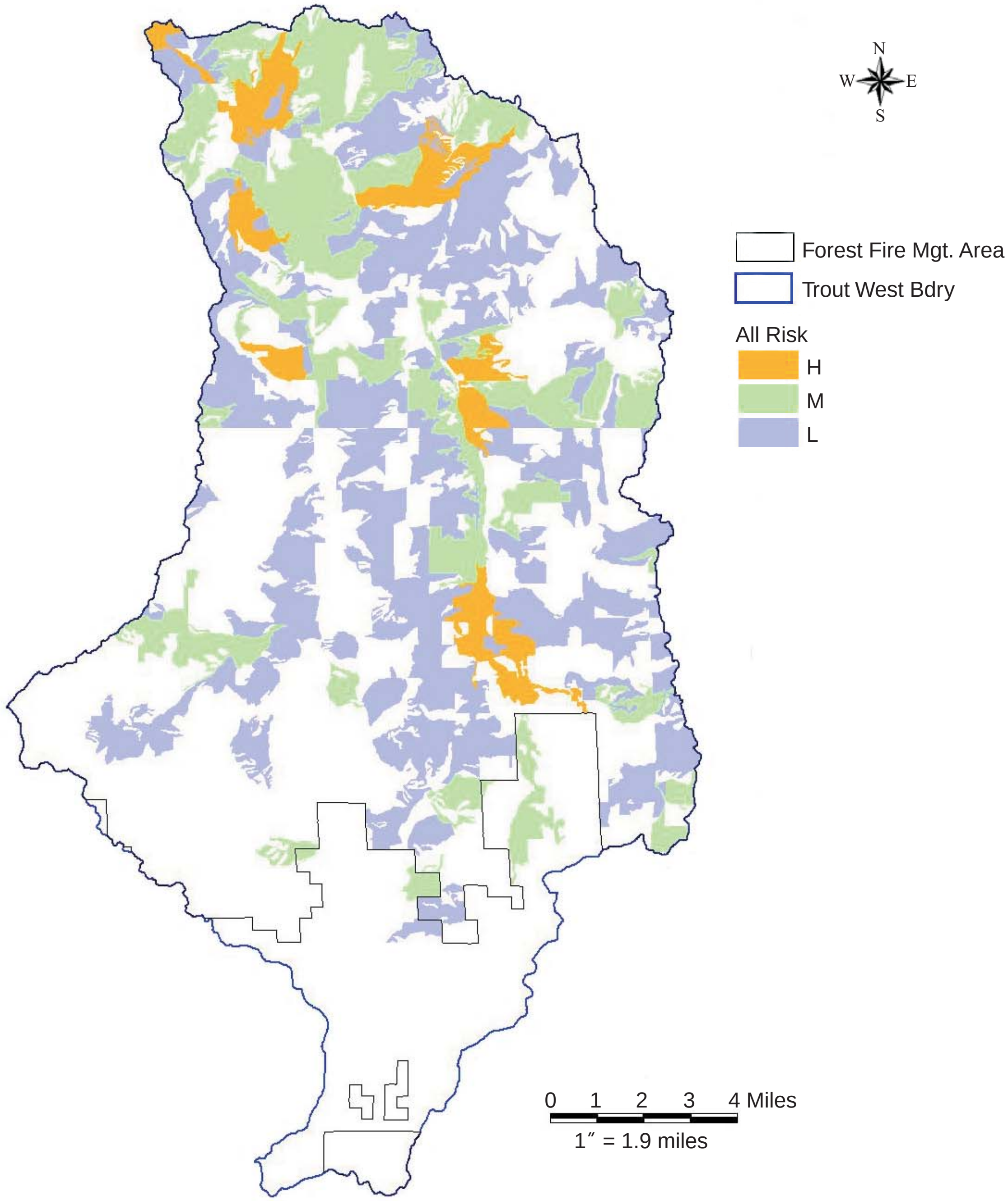


Figure 6. Map depicting wildfire occurrence risk for the Trout West watersheds of central Colorado. Relative risk levels were calculated using recent wildland fire occurrence data for the Pike and San Isabel National Forests. Numbers of wildland fires were summarized across this larger area, the Trout West area, by watershed, and by stand scale departure contribution class to calculate and classify relative risk of wildland fire occurrence during the fire weather season.

the watersheds with some area extending to the north down the primary stream valleys (figure 7). The one-mile buffer indicates about 17,000 hectares (42,000 acres) of public land are adjacent to the WUI. Most of the WUI is associated with the high or moderate departure uncharacteristic vegetation-fuel conditions. Very little is associated with low departure conditions. This is consistent with findings of Hann et al. (1997) in an area as far away as the northwestern U.S. (Interior Columbia Basin).

No Treatment, WUI Focus, and Landscape Focus Scenarios

An initial view of risk to WUI (figure 7) may falsely conclude that if most of the interface and buffer area were treated to reduce fuels and uncharacteristic fire behavior, objectives for change in overall condition class and WUI risk reduction could be achieved. However, large wildfires in contiguous uncharacteristic fuels would not be substantially slowed with this type of treatment (Finney and Cohen this volume). Nor would risk to urban interface be substantially reduced. In the most probable outcomes there is not much difference in risk between no action and a WUI focus option. A large wildfire event would spread as depicted in figure 8; most probably starting in the north end or coming from adjacent west or east landscapes and spreading to the south, initially pushed by winds from the west, north, or east, and then pushed by its own fire pre-heating and drying green and dead fuels, then burning at even higher intensities, and developing its own wind. Until the weather changes with rain or cooler temperatures and a drop in winds, fire behavior would be severe, of potential blowup nature, and spreading through long distance spotting. Fire suppression crews would be unable to attack this fire at the head even if the urban interface buffer areas had been treated for crown fire and fuel risk reduction, because of the mass fire brands raining into the area and fire jumping lines constructed by dozer or hand crews. Mass firebrands would potentially ignite many vulnerable structures causing most of the suppression resources to focus on protecting structures rather than on fire suppression. Although the WUI focused fuel treatments may not substantially change landscape level fire behavior, these treatments would somewhat reduce the severity of post-fire effects. Where fuels had been treated in the WUI buffer zone the severity of fire effects would be reduced to a more characteristic level within the interior of the treated polygons. However, the exterior of the treated polygons would be subjected to extreme heating from the fire in adjacent uncharacteristic fuels.

There is a different design option that can reduce wildfire risk to WUI and have the added benefit of reducing risk to ecosystems at landscape scales. This would be a landscape design. This type of design would involve treatment and maintenance to achieve the condition class 1 landscape option across the Trout West watersheds to change large wildfire behavior and effects. This option would focus on treatment of high departure and maintenance of low departure polygons throughout the watersheds in a pattern most effective at slowing large wildfire spread and reducing risk of negative ecosystem effects (Finney and Cohen this volume; Hann and Bunnell 2001). The first set of treated polygons could focus on mechanical and prescribed fire treatment of operationally accessible high departure polygons and maintenance of low departure polygons inside the line depicted in figure 7. The line generally surrounds both the urban interface and the higher risk areas from a landscape perspective. The second set of treatments would tie in the intermingled less operationally accessible high departure polygons through use of hand cutting and prescribed fire by being able to anchor into the first set of treatments. In addition, prescribed fire with minimal mechanical or hand treatment could be used outside the line and in a relatively small adjacent portion of the landscape to the west, which is primarily roadless and wilderness, to reduce the potential for uncharacteristic fire spreading from or to that area. This would allow wildland fire use or prescribed fire to be effectively used within the core of the adjacent roadless and wilderness area. Similar treatments and maintenance could be used outside the line and in the landscape to the east, which is a mosaic of WUI and non-WUI, similar to Trout West. This would reduce the potential

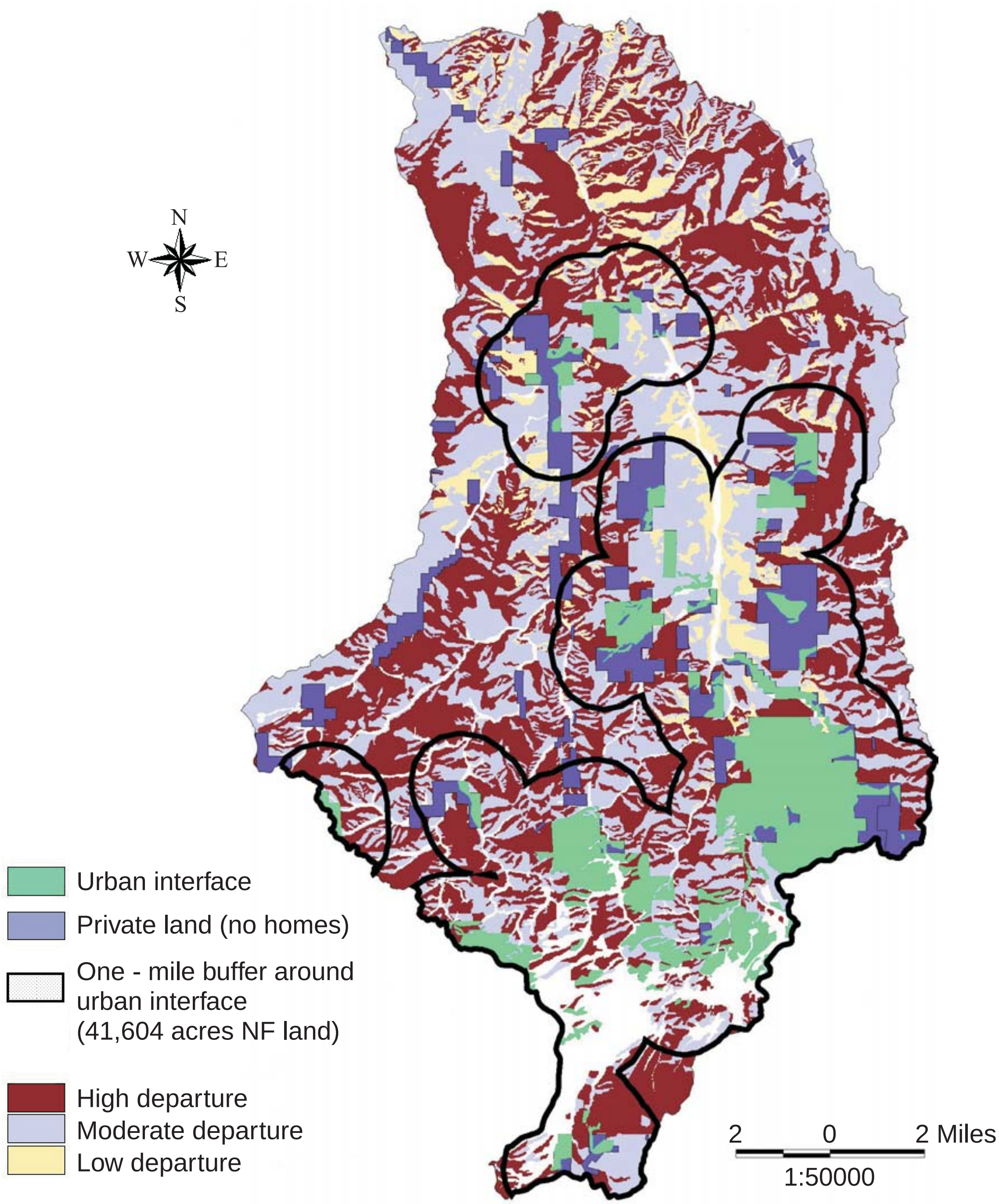


Figure 7. Map depicting urban interface, a one mile buffer around urban interface, and associated risks of uncharacteristic wildfire (high, moderate, low departure) for the Trout West watersheds of central Colorado. The urban interface was considered to be the area with one or more structures per 16 hectares (40 acres).

for uncharacteristic fire spread from that landscape to the Trout West watersheds or vice versa. In addition, the design could take into account ecosystem objectives for reducing risks to air, water, native species habitats, and sustainability; in essence achieving risk reduction for multiple benefits at the same cost.

This landscape type of treatment would substantially change the behavior and effects of a large wildfire run originating from within the Trout West watersheds or from adjacent landscapes. Wildfire from any of these sources

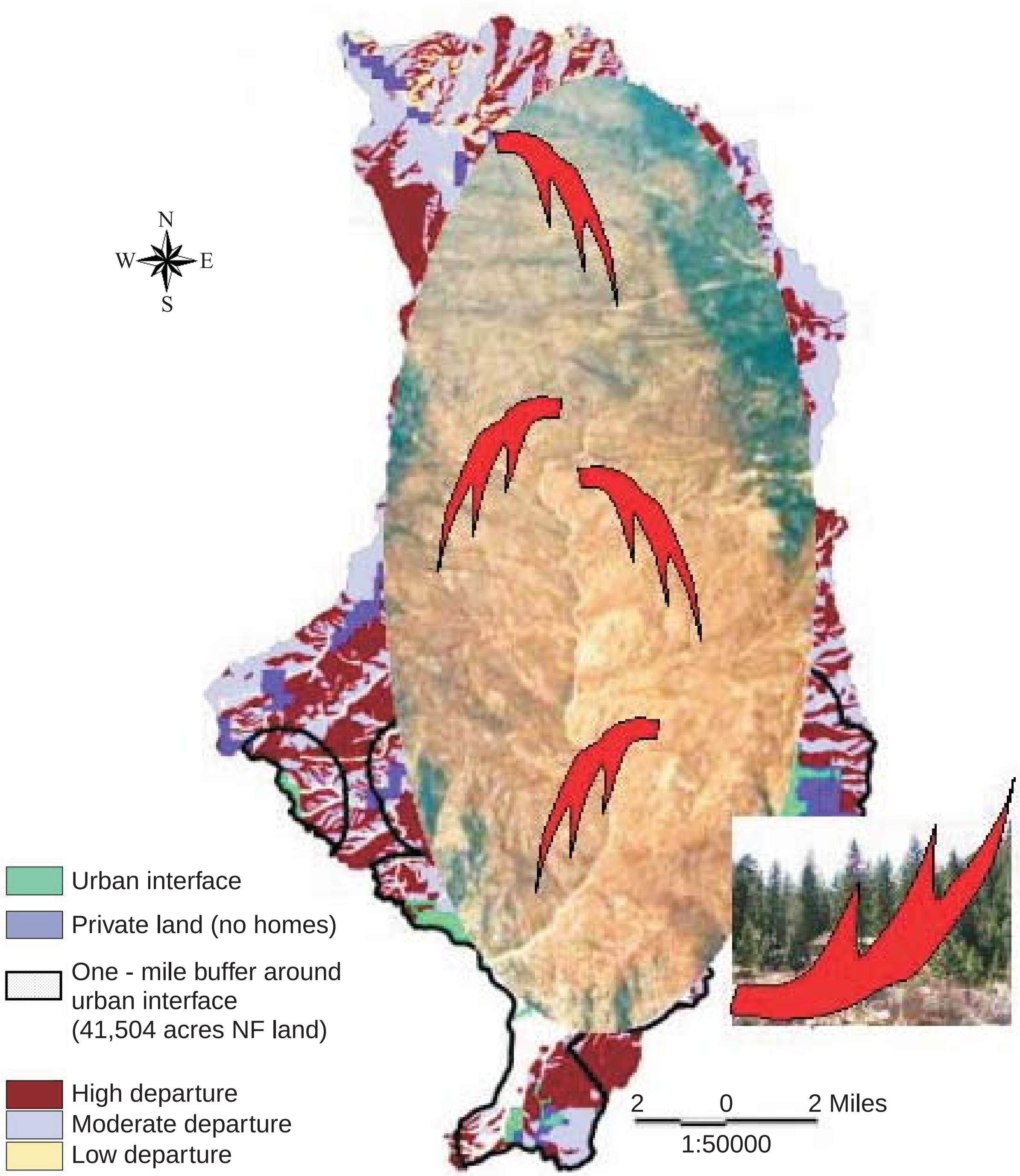


Figure 8. Map depicting the outcome of a Buffalo Creek type wildfire event upon the Trout West watersheds of central Colorado. This type of fire behavior spreads through mass long distance spotting across the urban interface, one mile buffer around urban interface, and into adjacent areas. Treatment of just the urban interface or a narrow buffer does little to improve management options for effective fire suppression and protection of wildland urban interface values.

would still spread fairly rapidly in grass and shrub surface fuels, but would have low risk of torching and spotting and little risk of sustaining a running crown fire. Initial attack would have a much higher chance of containing the fire and if the fire escaped initial attack suppression efforts could contain the fire using hand or dozer lines anchored across strategic areas. There would be little spotting into urban interface structures, thus reducing risk to both vulnerable and non-vulnerable structures. We again emphasize that the vulnerability of structures primarily exists within the narrow zone of the structure and surrounding area that typically is in the ownership of the structure owner (Cohen 2000, Finney and Cohen this volume). However, by substantially reducing firebrands and changing fire behavior from crown to surface, the risk even to vulnerable structures becomes less. This type of wildfire behavior could be managed within the availability of typical suppression resources without having to redirect most of the resources to protection of structures. We have generally found that even in communities with high awareness of wildfire risks and ability of structure owners to reduce these risks with mitigation of structure vulnerability and fuel management, there is at best only about half of the structure owners that will take action. Some redirection of suppression resources would probably be necessary to protect vulnerable structures in areas with torching, but this would be for a small number of areas compared to the WUI wide vulnerability that exists under the no treatment or WUI focus options. Costs of suppression would be much less under this scenario than the no treatment or WUI focus scenario and damage to resources would be minimal.

We think it is important to emphasize that restoration of the WUI area should not be a small area (donut hole) treated to reduce crown fire and fuel risks, within a surrounding landscape (donut) of untreated area. This can result in wildfire behavior in the surrounding donut that presents just as high a risk to the WUI. In a similar sense if the WUI publics also consider visual, air quality, water, and habitat values to be important, this type of donut hole treatment will do little to reduce the risk of loss of these values from wildfire. The key to design of successful restoration and maintenance is to reverse the relationship, such that the WUI area and surrounding landscapes present little risk of sustaining a running crown fire with high severity effects. High risk fuel conditions are generally relegated to operationally inaccessible polygons that are embedded within low risk conditions with a substantial distance to WUI areas.

Cost Comparison of Mapping and Analysis and Treatments

Costs of mapping and analysis were estimated to total about $10,000 (table 11). For the total area of 54,775 hectares (135,352 acres) this cost an average of $.18 per hectare ($.07 per acre). This information for the total landscape can be used to identify the treated acres, assess effects over the whole area for future planning and other resource planning efforts, and edge-matched with adjacent landscapes for broad-scale assessment to support Forest or Resource plans. Even if the total cost is paid for by the project area to be treated to meet the condition class 1 option (12,528 hectares, 30,953 acres), this only averages $ .80 per hectare ($ .32 per acre). This is a low cost compared to the typical costs of treatment in WUI of $200 per hectare ($500 per acre) and $120 per hectare ($300 per acre) in non-WUI, to have information to prioritize and plan what, where, when, and associated scenario outcomes.

We compare the costs of treatment for the three different scenarios of no treatment, WUI focus, and landscape WUI and ecosystem focus including the potential cost of large wildfire suppression (table 12). We developed restoration treatments costs of $988 per hectare ($400 per acre) for the WUI focus and $494 per hectare ($200 per acre) for the landscape focus using similar methods for estimation as from Hann et al. (2001). When assessing the amount of WUI buffer in different risk classes, we estimate that about 6070 hectares (15,000 acres) would be treated in this scenario as compared to 10,117 hectares (25,000 acres) for the landscape scenario. A similar approach was used to

Table 11—Estimated costs for Trout West watersheds fire regime condition class mapping and analysis. Vegetation data (cover type, size class, canopy closure) for Forest Service lands were already available in the resource information system (RIS). Some data correction was necessary and other public and private lands data was obtained through photo interpretation.

Task	Person days	Cost ($)
Coordination and design	10	2,000
Field reconnaissance	10	2,000
HRV modeling	12	2,400
Current maps and GIS analysis	18	3,600
Total	50	10,000

* $200 per person day = $10,000

assess the costs and amount treated for maintenance (table 12). We assumed that wood product values could be produced from about half of the restoration treatments with no product values produced from the maintenance treatments. Based on Hann et al. (2001) we estimated the average product value return to be about $247 per hectare ($100 per acre). Suppression costs were estimated at $500 per acre (Hann et al. 2001) for this area without treatment, with a size of 4048 hectares (10,000 acres) for a typical large fire size in central Colorado. Some benefit (10% reduction) in reduction of average suppression cost was applied for the WUI focus treatment scenario, but the gross size was assumed to be similar to the no treatment scenario. Both reductions in average suppression cost and in wildfire size were applied to the

Table 12—Estimate of costs for planning and implementation of Trout West watersheds restoration and maintenance comparing three different scenarios: 1) no treatment, 2) WUI focus, and 3) landscape WUI and ecosystem focus. The cost estimates include cost estimates for a large wildfire during severe fire weather conditions for each scenario.

Cost item	No treatment $	WUI focus $	WUI area treated hectares (acres)	Landscape WUI and ecosystem focus $	Landscape area treated hectares (acres)
Restoration		6,000,000	6,070 (15,000)	5,000,000	10,117 (25,000)
Maintenance		500,000	1012 (2,500)	500,000	2,023 (5,000)
Product Value		- 750,000	3,035 (7,500)	-1,250,000	5059 (12,500)
Suppression	5,000,000	4,500,000	4,047 (10,000)	500,000	4,047 (10,000)
Property	2,000,000	1,800,000		200,000	
Burn Rehabilitation	175,000	140,000	1,619 (4000)	35,000	405 (1000)
Total	7,175,000	12,190,000		4,985,000	

Restoration – WUI focus $400 per acre average; Landscape focus $200 per acre average.
Maintenance – WUI focus $200 per acre average; Landscape focus at $100 per acre average.
Product values - $100 per acre for 50% of restored acres.
Suppression - $500 per acre; 10% reduction WUI focus; 90% reduction for Landscape focus.
Property - 10 structures $200,000 each; 10% reduction WUI focus; 90% reduction Landscape focus.
Burned area evaluation and rehabilitation – No treatment results in 50% severe damage with rehabilitation costs of $35/acre; WUI focus results in 40% severe damage with rehabilitation costs of $35/acre; Landscape focus results in 10% severe damage with rehabilitation costs of $35/acre.

landscape scenario for a combined 90% decrease. A typical large fire loss of 10 structures was assumed with a value of $200,000 each for the no treatment scenario, with a 10% and 90% reduction in risk for the WUI focus versus landscape focus, respectively. The net sum cost for the three scenarios was approximately 7, 10, and 5 million dollars, respectively. Sensitivity testing of the estimated costs and assumptions on area indicate that even with major changes the no treatment will still be similar to the WUI focus and the landscape focus will consistently be substantially lower than the other two scenarios.

Design of Treatments to Achieve an Option

A problem that has emerged with many types of urban interface and ecosystem risk reduction restoration and maintenance treatments has been the application of measures that do not address the issue (Hann et al. 2001). Because of the history of timber management and silviculture in our forest ecosystems, measures such as crown closure, stand density, size, and basal area are commonly used to design treatments to reduce risk of uncharacteristic wildfire behavior and effects. In a similar vein the history of range management in rangeland ecosystems has resulted in common measures such as canopy cover, basal cover, density, and utilization. Because of this history, many treatments in forest ecosystems, with objectives for reducing risks to communities and ecosystems, continue to be focused on a tree growth, crown closure, basal area, or stand density measure, which may not achieve the objectives. Similarly many treatments in rangeland ecosystems with objectives for reducing risks to communities and ecosystems become focused on shrub or herb canopy cover or density. Measures of canopy biomass distribution, canopy depth, canopy base height, number of tree clumps, and surface fuel and ecosystem characteristics may be much more applicable for assessing and designing treatments to reduce crown fire potential, uncharacteristic fire behavior and effects, and coarse-filter approach to sustaining ecosystems (Finney 1988; Hann et al. 1997 and 1998; Keane et al. 1998; Reinhardt et al. 1997; Scott and Reinhardt 2001).

In addition to selection of applicable measures, projects designed to sustain ecosystems should avoid systematic “rules of thumb” or “one size fits all” prescriptions across all treated polygons (Hann et al 2001). Treatments with objectives that are very prescriptive in specifying numbers of trees by size, snags, down logs, and distance from riparian areas without allowing for natural variation can create a systematic landscape that does not allow for the fine scale variation needed by the diversity of native organisms and processes. Treatments designed to represent the range of historical or natural variability or even a median range of variability must be implemented in a way that allows for that variability. This can be achieved by prescribing variation, which may in itself constrain natural variation. A more useful technique may be to remove the desired amount of woody biomass and then use variation in prescribed fire effects to create the variation in polygon features such as shape, size, numbers of dead standing and down, litter and duff reduction, and species response. The response should be monitored and assessed against the understanding of natural variation. As implementation proceeds, the prescribed fire prescription should be adjusted to shift variation in effects.

Textbook or coarser scale mapping applied to project area site-specific fire regime and condition class can result in the greatest error in outcomes. We consistently find that these coarser scale results are not appropriate for fine-scale project design. More often than not, the lodgepole pine type is a mixed or surface fire regime rather than a replacement fire regime. In a given area, the sagebrush type may be a mixed regime, rather than a replacement fire regime. The coarse scale infrequent fire regime may be a frequent interval regime at the finer scale.

These potential errors also apply to restoration and maintenance of the Trout West watersheds. To avoid error in selection of measures we developed methods focused at fire regime condition class and fuel model, combined with cover type, canopy closure, and size class. To avoid prescriptive numbers without variation we used broad classes of canopy closure and size and focused on the fire regime, condition class, potential fire behavior and effects, and urban interface relationships to wildlands. To avoid the textbook or coarser scale fire regime condition class mapping implication that “all ponderosa pine types are frequent surface fire regimes,” we developed and applied methods to develop site-specific fire regime condition class.

Management Implications and Recommendations

Methods

In retrospect, it would have been advantageous to have used the standard RIS density classes (habitat structural stage) of 10-40%; 40-70%; and 70%+ canopy closure. This would have fit in better with existing vegetation data. It is critical that the canopy closure density classes used as a basis for modeling HRV be the same as those used to describe current vegetation conditions. In this case, existing RIS density data was lacking in over half of the NF polygons, and an additional 25,000 acres of private land had no vegetation data. Since we had to do such a major renovation of the RIS tabular data to utilize it as a depiction of current conditions, we opted to develop our own set of density classes. This resulted in a tedious and complicated process. It is important to note that the breakpoint for canopy closure for open versus closed in the “box” model HRV structural stages is relatively flexible for two reasons: 1) estimates of canopy closure from historical photographs and stand reconstruction have high variability; and 2) ecosystems vary in what is considered naturally open versus closed (Hann 2003). Consequently, the canopy closure classification should be one standardized for the current vegetation, and cross-referenced to the open and closed categories for the “box” model structural stages.

We again emphasize that the FRCC map depicts the departure contribution across the entire FRPVT and does not apply to any one individual stand. The natural HRV landscape includes amounts in each of Classes A-E. In the Trout West area, FRPVT 1 has a central tendency for about 12% in Class E (closed mature/mid-mature forest). Currently, Class E comprises 31% of the area, nearly three times as much. It is only possible to show this entire existing Class E component as contributing moderately towards the FRPVT departure class (this is categorized as “moderate” departure because the difference between current and HRV is >25% and <75%). It is not possible to ascertain that any particular Class E stand is in moderate departure, because it would have been expected to occur with a range around the central tendency of 12% of the landscape naturally. This gives the manager the option of deciding how much of the existing 33% in Class E should and should not be treated based on operational accessibility.

A “priority treatment” map may be a useful venue to display those areas contributing significantly to overall departure that are likely most in need of fuels reduction treatments. This would only depict those areas with Moderate or High departure contributions *and* associated "Reduce" management implications or "High" abundance. It may be helpful to distinguish between those areas contributing to substantial departures because of underrepresentation across the landscape, and those that are overrepresented. Our departure or "risk" map (figure 4) depicts the entire area by low, moderate and high departure or "risk" contributions. While an important analysis product, this may be difficult to translate into on-the-ground implications. This is because the moderate classes are categorized as such because they are either overrepresented or underrepresented across the landscape, and thus may need to be either reduced or recruited. Only the overrepresented moderate class that may need active management would be depicted on the priority treatment map. The low departure contributions would not show up in the "Priority Treatment" map, as these are classified as "maintain" or "similar." However, we would also caution that this could result in managers not expending enough effort in developing restoration options for "recruitment" that would grow large trees, produce large snags and logs, regenerate to a different species composition, or maintain what currently has low ecological sustainability risk and is similar to the HRV.

While stratifying WUI polygons into low, moderate, and high housing or population densities may be helpful as a means of further prioritization of the Urban Interface zone, we found it to be less critical than the initial attribution as urban interface. The most accurate method of determining housing densities would be a housing map with precise point locations. A density function could then be applied to quantify home densities to meet varying definitions. This data, however, was not available for our analysis area. One county had no GIS housing data at all. The other county could display private parcels and identify how many homes were on each parcel, but could not depict the homes spatially. GIS maps of planned housing developments would also have been helpful, but did not exist. As an alternative, housing density for all RIS polygons meeting the minimum of one house in 16 hectares (40 acres) was attributed through aerial photo interpretation. The drawback to tying this attribute to a polygon is that the size of the polygon determines the minimum threshold. For example, an 80 hectare (200 acre) lodgepole pine polygon may have 4 houses, but it does not meet the WUI classification, as it represents only one house in 50 acres. Where the vegetation was more dissected, the polygons would be smaller and the houses would likely meet this minimum threshold. Acknowledging this limitation, these WUI data were infinitely more detailed and useable than the previously available data source that depicted very broad housing density zones. For our purposes, it worked very well. Because of the unique patterns of land use and housing development that occur for different areas, the housing density classification and wildland urban interface buffer distance may need to be locally defined. We recommend further research and assessment in other areas with different patterns of land use and housing development before standardization of methods.

There was little doubt that use of the "box" model with standardized definitions of HRV stages, succession, and disturbances greatly reduced the time and costs of analysis and resulted in much greater consistency between models for different FRPVT(s). Although we have no way of determining accuracy without an independent comparison, there was general consensus among the interdisciplinary team that use of this type of standardized model limits the variation to that of the ecosystem rather than to model framework, and thus reduces potential for errors. Allowing development of models with unconstrained successional paths and disturbances would have resulted in substantial variation between and within FRPVT(s). This would be a result of "splitters versus lumpers" as well as lack of understanding to attribute detailed succession and disturbance probabilities. The five conditions (A-E) and limited succession and disturbance pathways were scaled at about the same level of the understanding we could achieve from reading the local literature and conducting ground reconnaissance.

Findings

We summarize five implications from the results of this work:

1) Standardized methods for fire regime condition class that has a context to the national definitions can be cost effectively and consistently applied at project and landscape scales across all land ownerships.

2) These methods differ substantially from those applied at the coarse scale by Hardy et al. (2001) and Schmidt et al. (2002) because the scale of landscape composition and structure, and associated management implications, are much finer.

3) Fire regime condition class can and should be developed from the same basic vegetation data that are used for other resource management analyses and implications. This results in more consistent and logical outcomes in analyses and project design.

4) The analysis of no treatment, WUI focus, and landscape focus scenarios indicates that the typical approach to focusing on WUI and buffer areas may not be a viable option to reducing risk to communities. In contrast, a landscape focus reduces risk to communities and ecosystems with a more effective expenditure of funds.

5) Potential errors in design and implementation of treatments to achieve objectives for reduction of wildfire risk to communities and ecosystems can occur. These are typically associated with: a) choosing traditional forest or range management measures versus those focused on fuels, fire behavior and effects, and ecosystem characteristics; b) using fixed or "one-size-fits all" treatment prescriptions at a polygon level, rather than designing for variation in polygon outcomes across the landscape; and c) application of textbook or coarser scale fire regime condition class findings for fine-scale project design.

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