MULTI-SCALE PLANNING AND IMPLEMENTATION TO RESTORE FIRE-ADAPTED ECOSYSTEMS AND REDUCE RISK TO THE WILDLAND–URBAN INTERFACE

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ABSTRACT
Multi-scale planning was used in the Upper Arkansas River subbasin and Box Creek watershed to prioritize and plan forest health and National Fire Plan restoration on San Isabel National Forest and Bureau of Land Management (BLM) lands. Restoration alternatives were designed to restore fire-adapted ecosystems, improve forest health, improve native species habitats, and reduce unwanted wildland fire and other hazards to human communities. The Upper Arkansas River subbasin and Box Creek watershed are located in the mountains of central Colorado. National forest and BLM plans and national policies and budgets identified the need to prioritize and plan to achieve effective multi-resource and fire-adapted ecosystem restoration. A consistent and science-based approach was used for mapping and analysis of fire regime condition class, historical regime departure, vegetation, and other resource and social values. Findings from this analysis were used to determine the amount of area to restore, develop the management prescriptions, map operationally restorable outcomes, and conduct effects analysis. The results from the Box Creek watershed restoration project demonstrate a cost-effective and science-based attempt to provide consistent and repeatable risk data for assessment of conditions and development of alternatives. In addition, the interdisciplinary team demonstrated how to identify the full "decision space" available for restoration if an integrated approach to project prioritization, purpose and need, and proposed action formulation is implemented versus accepting the traditional "mitigation spin."

keywords: Colorado, condition class, fire regimes, forest health, fuel management, natural regime, planning, wildland–urban interface, wildlife habitats.

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INTRODUCTION

The Box Creek watershed was identified as a priority for restoration in an assessment of all watersheds in the Upper Arkansas River subbasin of central Colorado (McNicoll et al. 1999). This assessment used a systematic rating system combined with an interview approach for key publics to develop a suite of risk rankings for each watershed. These data were used to rank watersheds for restoration based on departure from the historical (high hazard fire regime; condition class 3) fire regime, uncharacteristic levels of insects and disease, uncharacteristic wildlife habitats, conflicts between user groups, and high wildfire risk to the wildland–urban interface. Uncharacteristic (vegetation or structure) was defined as a vegetation–fuel condition, disturbance behavior or effects determined to not occur within the natural or historical regime, similar to the definition from Hann (*this volume*). For example, an uncharacteristic condition of a vegetation community could be a change from a community dominated by a fire-resistant tree species with a fairly open structure to a more dense structure that would facilitate a crown fire that might result in more severe fire effects to the vegetation versus a previously cooler surface fire. Funding for the planning and restoration implementation came from Forest Health and the National Fire Plan. The framework for the planning process came from Forest Health and the National Fire Plan, which was often referred to as the Cohesive Strategy (USDA 2001); the analysis of options was developed from Hann and Bunnell (2001).

During the Upper Arkansas assessment and Box Creek watershed planning, we hypothesized that an integrated approach was needed to resolve many of the conflicts currently faced by agency leadership (USDA 2001, USGAO 2002). Fire regime condition class, departure from the historical regime, and other science-based risk measures were used as part of this integrated approach to prioritize project areas, develop the project purpose and need, design the proposed action, and involve the public. If understanding and consensus could be achieved with an integrated approach, this could potentially reduce appeals and litigation from external public groups, regain credibility with the public, reduce the need for mitigation (primarily reduction in treated area) to meet environmental laws and regulations (such as Endangered Species Act, Clean Air Act, Clean Water Act, Antiquities Act, Council for Environmental Quality regulations), and reduce the need for mitigation to achieve agency policy (such as Forest and Resource Plan standards and Manual Direction).

This integrated and prioritized process would be quite different from the current standard procedure. Currently, resource staffs identify the project area (often based on limited criteria, inconsistent data, and ease of operations) and describe a conceptual purpose and need. Staffs then propose restoration action focused primarily on operational concerns and cost per acre, irrespective of multi-resource laws, regulations, and policies. In response to this traditional approach, the interdisciplinary team evaluates the proposed action and recommends mitigation (usually reduced treatment area), which then develops into the final preferred alternative. Often the remaining action alternatives emphasize one or more resource items (a “wildlife alternative” or a “watershed alternative”) that are unlikely to be implemented, and presented as a “range of alternatives” to meet requirements of the National Environmental Policy Act (NEPA). In contrast, we felt that the interdisciplinary integrated approach could be used to rank those areas with the highest need for restoration.

Previous scientific assessments have found that most landscapes with high priority for restoration, (e.g., wildland–urban interface risk, fire exclusions, and a history of management not mimicking the historical regime), typically lack high-quality habitat, populations of wildlife and fish species of concern, or old forest (old growth) (Hann et al. 1997, 1998). A consistent and integrated science-based prioritization of areas for restoration will substantially reduce the potential conflict between restoration versus protection of high quality habitats and populations (Rieman et al. 2000). In the Upper Arkansas River assessment, Box Creek was prioritized for restoration to improve habitat for big game, indicator species, and Canada lynx (*Lynx canadensis*), to improve forest health, and to reduce risk to the wildland–urban interface. There was strong need for an integrated restoration project designed to reduce conflicts. An integrated approach should provide rationale for the proposed action and identify the maximum area for treatment that would achieve the greatest and most cost-effective landscape reductions in risks to wildlife habitat, watersheds, wildland–urban interface, and other objectives. All action alternatives would be equal in area and vary according to treatment methods.

For the Box Creek planning process, this nontraditional integrated design of alternatives was directly linked to the purpose and need that set forth the scientific basis for restoration following the framework and assumptions laid out by Hann and Bunnell (2001) for the Cohesive Strategy. Through our examination of the Box Creek case study, we hope to open and stimulate further discussion and work relative to the interdisciplinary integrated restoration approach.

STUDY AREA

The Upper Arkansas River subbasin is located in central Colorado, southwest of Denver and east of Grand Junction. This is a long narrow river subbasin flowing generally north to south between the Sawatch Mountain Range of the Continental Divide to the west and the Mosquito Range to the east. The Box Creek watershed is a 6th code subwatershed located in the northwest corner of the Upper Arkansas River subbasin (Figure 1), to the southwest of the town of Leadville, south of the Halfmoon divide and north of the Twin Lakes divide. This watershed ranges in elevation from about 2,700 m (9,000 feet) where Box Creek flows into the Arkansas River to well over 4,300 m (14,000 feet) at the top of Mt. Elbert, the tallest peak in Colorado. Although high in elevation, this area of the southern Rocky Mountains (approximately 39° latitude) has similar vegetation zonation to elevations ranging from 1,800 m (6,000 feet) to 3,000 m (10,000 feet) in the northern Rocky Mountains at approximately 45° latitude. Lower elevations of the Box Creek watershed along the river and primary stream drainages are subirrigated and covered with willows (*Salix* spp.) and wet meadows. Much of this type of private lands has been converted into hay ground and pastureland. Above these subirrigated lands mountain big sagebrush dominates the Lower Montane Zone (Figure 2). The Montane Zone, currently dominated by lodgepole pine (*Pinus contorta*), was historically dominated by a mixture of lodgepole pine with ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*). As elevations increase and on steep lower-elevation north-facing aspects, Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), lodgepole pine, and subalpine meadows dominate. Above timberline, alpine tundra, talus, and rock occur from about 3,700 m (12,000 feet) and higher in elevation. About two-thirds of the watershed is in federal (National Forest, Bureau of Land Management) ownership and about one-third in private and state ownership. Federal lands are nonwilderness with forest and resource plans emphasizing nonmotorized primitive, big game winter range and wildlife and fish (focus on management indicator species) habitat uses. The project focused on restoration of national forest and Bureau of Land Management lands within the watershed in collaboration with the county soil conservation district, state lands, and private landowners. The watershed is approximately 9,700 ha (24,000 acres) in area with about 7,300 ha (18,000 acres) in federal ownership and about 2,400 ha (6,000 acres) in private and state ownership.

Nomadic Native Americans used the Upper Arkansas for summer and fall camps, hunting, and gathering. Buffalo (*Bison bison*), elk (*Cervus elaphus*), and other large ungulates appear to have been common in the Lower Montane Zones. Fires were common, occurring from both lightning and Native American ignitions, in the extensive fire-maintained sagebrush grasslands and mixed-conifer parklands of the Lower Montane Zones. American and European exploration and settlement entered this area of the Upper Arkansas early in the 1800s (Griswold and Griswold 1996). Some exploration and settlement lower in the Upper Arkansas subbasin (Buena Vista and Salida areas) had occurred earlier from Mexico by Spaniards, but the major influx of nonnative Americans and Europeans occurred after 1850 into the early 1900s associated with the “Mining Era.” During this period extensive and intensive timber harvest occurred with multiple entries for structure logs and mill lumber; road and railroad punching, bridges, and tread; mine timbers; fuel wood for heating and for charcoal pits and kilns; and fuel wood for the large smelters. Historic logging for mine and other large timbers as well as mill lumber and structure logs focused on taking the larger trees (Engelmann spruce, Douglas-fir, ponderosa pine, and lodgepole pine). Focus on fuel wood was less specific regarding species or size.

Essentially the whole Box Creek watershed, which is within an approximate 32-km (20-mile) radius of Leadville, was clearcut with multiple entries from lower to upper forest ecotones—except for a few scattered trees or groups of trees retained for shade or near structures, and a few patches of forest in very hard to access areas surrounded by very steep or rock terrain. At the end of this period fuel wood was in such short supply that roots were pulled with teams of horses and hauled in with any remaining logs left on the ground from earlier entries (Ray Dawson [Leadville, CO], personal communication). In addition, large herds of cattle, sheep, horses, mules, and burros were grazed to support the service industries (food, clothing, and freighting), as well as the mining and logging industries.

The impact from historic activities (burning, logging, mining, charcoal production, and grazing) was severe and extensive to the soil surface resulting in the loss of the surface soil horizon either through mixing with the subsurface on the gentle slopes or erosion into the streams and river on the steeper slopes. Most of the forest tree species seed source was lost as a result of burning and charcoal production except for lodgepole pine cones left on the ground. Since this was a common species and highly adapted to regenerate and grow in a mineral soil environment, lodgepole pine was the only species to regenerate. Very few ponderosa pine and Douglas-fir survived or regenerated in the Box Creek area. Field examinations determined that lack of these tree species was most likely due to the lack of available seed source and not a climatic change, since ponderosa pine appears to be slowly regenerating in the Box Creek area. The remaining ponderosa pine and Douglas-fir were found primarily located on southern exposures, although a limited number (fewer than 50) of mature seed-bearing individuals have been observed within the current stands of lodgepole pine. With the loss of the ground fuel (grasses, twigs, litter, and small wood) and implementation of fire suppression, fires no longer occurred that would thin the lodgepole pine or create small openings. This tree species now covers the landscape like a carpet (Figure 2), but with a steadily increasing load of ground fuel.

The period from the mid-1900s to the present was a transition from a post-mining-era ranching-dominated economy to a “rural” lifestyle based on recreation, water, and ranching economy. Recreational dispersed use, mining, hiking, mountain biking, skiing, hunting, and trail riding are many of the important uses of the public lands. Public fuel wood, post and pole operations, and saw logs are in demand. The Mt. Elbert conduit, Twin Lakes and Turquoise Lake reservoirs, and other water developments provide local irrigation water and water to the Rocky Mountain Front from Denver south to Colorado Springs to Pueblo and east into the Lower Arkansas River subbasins. Considerable subdivision of large ranches has occurred, making the wildland–urban interface a substantial issue. Large fires have effectively been suppressed to date, but increasing fuel accumulation during periods of drought increase fire hazard within the wildland–urban interface.

METHODS

Analysis

The framework for the methods follows the findings from Hann and Bunnell (2001) and methods follow those outlined by Hann (*this volume*). Definitions for natural fire regimes and their condition classes are based on Hardy et al. (2001) and Schmidt et al. (2002) (Tables 1 and 2). Natural fire regimes and potential natural vegetation are the vegetation and disturbance regimes that would occur following removal of modern human influences under the current and future climate. This can be quite different from historical fire regimes and historical natural vegetation, which is based on pre-Euro-American settlement and associated climate. Although an understanding of the natural system under current and future climates is preferred, often the historical must be used as the best proxy due to an inability to predict future vegetation and disturbance regimes. For the Box Creek analysis we used historical as the best proxy for the natural regime. The first step after defining the project area, scope, and objectives was to use available data to map fire regime condition class and historical regime departure, and associated management implications and hazard ratings at a stand scale (4- to 20-ha [10- to 100-acre] polygons). One of the most important map layers needed to achieve this objective was the potential vegetation map (Figure 3), but of equal importance for determining current condition were the cover type and structure layers.

The U.S. Forest Service, U.S. Bureau of Land Management, and Colorado State Forest Service vegetation data were not compatible because of differences in definitions, methods, and lack of complete coverage. The interdisciplinary team (IDT) made the decision to use the 30-m remotely sensed cover type data (LANDSAT) as the base for building a compatible set of potential vegetation, cover type, and structure layers that could cover all lands within the Box Creek watershed. This decision was based on the IDT's agreement that an integrated landscape-planning process required a set of vegetation themes that could be used to determine fire regime condition class, habitat conditions, and other values and be consistent and compatible for all land ownerships across the watershed. The U.S. Forest Service local Resource Information System contained information at the stand level for cover type, habitat type, and structure. This information was used in combination with digital orthophotographs to extrapolate structure to similar stands missing structure attributes.

A very coarse-scale Pike and San Isabel National Forest landtype association map was used as a surrogate for potential vegetation because the national forest did not have a mapped classification for potential vegetation (habitat types). The landtype associations accounted for the main elevation zones of Valley Montane, Lower Montane, Montane, Subalpine, and Alpine, but this map did not account for aspect differences that cause stand-scale changes in potential vegetation. A rule set based on stand elevation and aspect was then developed to map potential vegetation for all ownerships. A key decision was made that identified the 30-m remote sensing cover type map as the "true" or primary layer because it appeared to have finer scale and more accurate mapping. This meant that other attributes (structure and potential vegetation) would be adjusted to provide logical combinations with the cover type map. From this initial combination we conducted ground-reconnaissance transects across elevation gradients to develop rule sets to refine the map attributes and correct illogical combinations of the current cover type, structure, and potential vegetation. At the same time we adjusted the canopy closure and tree size class and assigned all data to the single vegetation map polygon layer.

In reviewing other planning projects we have found that this process of creating a single vegetation map layer with attributes that all IDT members will use throughout the planning process is often a major stumbling block. The time required to create, ground truth, and adjust the map layer (4 weeks) was an important investment and prevents the traditional approach of using "whatever is available." Usually, whatever is available cannot be used across multiple scales, is incomplete (does not describe private or other agency areas within the project boundary), and results in inaccurate and incompatible departure and fire regime condition class calculations, and associated cumulative effects analysis.

A second key step was to simulate the historical regime to determine the average composition of vegetation classes and amounts of disturbance. For this we used the vegetation development dynamics tool (Beukema and Kurz 2000) and the box model framework (Hann, *this volume*). We customized this framework for the potential vegetation types of the Box Creek watershed and conducted ground reconnaissance to determine succession rates, historical vegetation structure and composition, historical area fire frequency, and other disturbance agents (Figure 4, Table 3). The method for determining historical fire frequency and severity used a landscape area return probability for a percentage of the landscape burned, rather than a point or stand return interval, so that the method was integrated with methods for assessment of historical vegetation class composition across the landscape.

In the Montane Zone no live trees could be found with historical fire scars, but many stumps of lodgepole pine cut during the mining era had multiple fire scars and could be aged (Figure 5). A few remaining short snags of ponderosa pine were also found that had multiple scars and could be aged. By conducting a reconnaissance-style watershed fire history combined with sensitivity testing of the simulation model we concluded that the area historically had frequent (approximately 30-year average) fires with highly variable patch size and periodicity in the Montane Zone (Figure 6). Most fires appeared to burn in a pattern of understory (surface) combined with torching out of small patches if ladder fuels existed, forming a mixed fire severity. Rapid and productive growth of grasses in openings that would carry this type of fire, dark surface soils indicative of a grassy understory in areas where soil had not been eroded from the mining-era logging, and observations of current fire behavior in similar vegetation added additional evidence to support this determination. These spatially mixed fires maintained an open forest of scattered individual large ponderosa pine and Douglas-fir intermingled with patches of moderate-sized lodgepole pine. While the ponderosa pine and Douglas-fir could survive many fire scars, the lodgepole pine only appears to have survived up to about three fire scars.

In the Subalpine Zone the lodgepole pine also had multiple fire scars as well as a few single scars on Engelmann spruce. Using a similar process as for the Montane Zone, we concluded that the area historically had infrequent (approximately 60-year average) fire with fires of a larger size ranging from 40 ha (100 acres) to 1,000 ha (2,500 acres) (Figure 6). Contrary to the traditional view of crown-fire replacement in the Subalpine Zone, this area appears to have had mixed fire severity that burned as a surface fire in some areas of the lodgepole pine and torched out patches of lodgepole pine, Engelmann spruce, and subalpine fir where ladder and down fuels existed.

There is little doubt that if we had used the textbook literature on fire frequency and severity, rather than conducting the simulation modeling combined with ground reconnaissance, we would have misclassified both the Montane and Subalpine Zones into the infrequent replacement class, rather than the frequent mixed class for the Montane Zone and the infrequent mixed class for the Subalpine Zone. A similar error would have occurred if we had used a point or stand approach to assessing historical fire frequency and severity, rather than the landscape area approach. A point or stand approach would have resulted in a fire frequency with a much longer return interval (lower return probability) that would not have synchronized with the vegetation class composition. Methods were designed to account for historical fire regimes that changed or maintained the landscape vegetation class composition through a mix of surface, replacement, and missed (no burn) patches across the landscape.

We could find little evidence to classify the fire regime in the Lower Montane sagebrush zone and the Valley Montane riparian zone, because of the extensive and intensive disturbance that has occurred in these areas from the mining era to the current period. The large fine fuel component (grass) that would have occurred historically caused us to assume that the fire frequency was similar or more frequent than that of the Montane Zone and that fire severity was replacement or mixed.

The current composition for cover type and structure were then determined and compared to the historical averages following the methods defined by Hann (*this volume*). Similarity of current to historical, departure, fire regime condition class, management implications, and hazard ratings were calculated and assigned. Other current data for resources, social, and economic indicators, along with operational variables (such as road access, distance to private structures, adjacent fuel hazards) were also summarized for the watershed.

Planning

We used a rating system to compare the integrated planning process used for the Box Creek project against a number of recent project environmental assessments developed using the traditional approach. The rating system was used to assess the strength, continuity, and consistency of prioritization, purpose and need, action alternative formulation, and effects analysis. In addition, we reviewed related project information relative to appeals, outcomes for the final decision, and lawsuits. Informal interviews were conducted with selected agency IDT, environmental, and other involved group members to determine satisfaction, dissatisfaction, and amount of support for the different projects. Similar observations and interviews were conducted during the Box

Creek project in order to make a qualitative comparison of the success of the two different planning processes.

RESULTS
Analysis

We summarized current vegetation information (potential vegetation, cover type and structure) into the successional classes for each potential vegetation type (PVT) as described by Hann (*this volume*) (Tables 4 and 5). In the Montane PVT only 10% was found to fit the stand conditions similar to the historical regime (Table 6). This lack of similarity was caused by mining-era logging, fire exclusion, and the subsequent excessive development of dwarf mistletoe (*Arceuthobium* spp.). The mining-era logging alone would have caused a substantial change in conditions, but if fire had not been suppressed, regenerating lodgepole pine might have been thinned and developed a much higher diversity of size classes, tree groups, and patches. It is likely that in a fire-affected mosaic, ponderosa pine and Douglas-fir could have regenerated, but fire suppression allowed the dense lodgepole pine cover and litter–duff to develop and effectively eliminate ability of these species to regenerate.

Within the characteristic classes a limited number of aspen (*Populus* sp.) stands of small area (<0.5%) occurred in the early-development successional stage (A). Stands in this class were identified as aspen seedlings intermingled with shrubs and herbaceous species. Historically there was about 8% of the Montane PVT in this early stage. The only stands found to be characteristic of the mid-development closed successional stage (B) were closed pole and sapling aspen with shrub, herbaceous, and lodgepole pine seedling understory, which accounted for about 4% of the area, about twice the amount that occurred historically. Only about 1% of the area was found to be in the open (C) stage, all of pole and sapling tree size, also with an aspen–conifer cover type. Historically this class occupied about 16% of the area and was dominated by the lodgepole pine with scattered ponderosa pine and Douglas-fir. The loss of this type has occurred because of loss of historical surface and patch fires that opened up the closed class (B) or thinned regeneration in the early-development class (A).

Approximately 7% of the characteristic open late-development class (D) still occurs with mature size class of lodgepole pine and large scattered ponderosa pine and Douglas-fir, mostly on southerly aspects with dry soils at the southern boundary of the watershed where proximity to Twin Lakes, a historically important recreation area, may have constrained logging activities. In addition these dryer soils appear to have slower regeneration and closure than more moist stands to the north. This area also receives higher winds that may have reduced efficacy of surface fire suppression during the early 1900s. The historical Box Creek montane landscape was dominated by this class (66%), which was maintained by mixed fires that burned on the surface through open areas of larger lodgepole pine that contained scattered ponderosa pine and Douglas-fir, and crowned into the denser tree groups. No stands were currently classified as characteristic of the late-development closed (class E) successional stage of old tree size and age dominated by either aspen or lodgepole pine with scattered ponderosa pine and Douglas-fir. Almost 8% of the Montane PVT occurred in this type historically, generally in the more moist draws where mixed fires were of a more creeping nature that thinned smaller trees, consumed ground fuels, and opened small patches, but retained a closed canopy of larger trees.

Most of the current Box Creek Montane PVT occurs in an uncharacteristic condition (88%) as a result of the mining-era logging followed by fire exclusion and spread of dwarf mistletoe. The major uncharacteristic condition that occurred in this PVT was stands dominated by dwarf mistletoe-infected lodgepole pine mature, pole, and sapling size trees with a lack of understory shrubs and herbs, thin to moderate litter and duff, lack of scattered ponderosa pine and Douglas-fir, and lack of large snags or down logs (class L). However, much of the area (11%) was also classified as uncharacteristic (class I) where dwarf mistletoe has not yet developed excessive levels and the primary effects relate to successional development since the mining-era logging combined with fire exclusion. Most of these stands were closed, pole and sapling lodgepole pine, lacking any substantial litter and duff layer with little understory shrub or herbaceous vegetation. A small portion of the Montane PVT (7%) that had been clearcut harvested in the past was classified as uncharacteristic timber management (class G) not mimicking the natural regime because of a lack of mixed conifer regeneration.

In the Subalpine PVT much more of the area (93%) was in stands characteristic of the historical regime. However, the composition of the characteristic classes was only 40% similar because of a lack of the early-development (A) and late-development open and closed (D) classes, and too much of the mid-development open and closed classes (Table 7). This lack of a similar composition of stand conditions was a result of succession following the late 1800s and early 1900s mining-era logging combined with fire exclusion. Given the impacts of the mining-era logging, this type is productive and would have recovered its natural composition if the mixed fire regime would have been allowed to play its natural role of thinning and creating a salt-and-pepper mosaic of early-, mid-, and late-development open and closed stands. With an approximate 50- to 100-year fire cycle, this type has missed an average of two cycles of mixed fire effects. However, this is too simplistic an approach to view the exclusion of fire from this regime. Although the average interval was determined to be between 50 and 100 years, this type was very variable in fires through time and space with more frequent fires of as short an interval as 20 years to less frequent fires of 130 years. Fires tended to occur more frequently on the southerly aspects, benches, and ridge tops and less frequently on the northerly aspects and in the moist bottoms. Although the gross fire areas in this type may have been fairly large, the areas that actually crowned appear to have been scattered in relation to topography and pre-fire fuel conditions. Exclusion of fire not only resulted in a loss of this salt-and-pepper pattern, but an increase in canopy density, understory tree layers, and down fuels.

A limited number of stands of small area (<0.5%) did occur that fit the characteristic early-development successional stage (A). Stands in this class were identified as Engelmann spruce and subalpine fir seedlings, lodgepole pine, or aspen intermingled with shrubs and herbaceous species. The shortage of this successional stage was a direct result of fire exclusion. An overabundance of stands and area (65% vs. 16%) were found in the characteristic mid-development closed successional stage (B) of closed pole and sapling lodgepole pine or aspen. This excess was directly related to lack of fire that thinned closed stands and created open patches, thus creating open stands with increased growth rates of the larger surviving trees followed by understory regeneration of Engelmann spruce and subalpine fir. In addition there may have been a lack of Engelmann spruce and subalpine fir seed source following the mining-era logging that favored lodgepole pine, and an excess of aspen regenerating on disturbed soils. A similar but less dramatic trend (16% vs. 13%) occurred in the mid-development open (C) stage, all of pole and sapling tree size, dominated by lodgepole pine or aspen. This slight excess appears to be also related to the post-mining-era logging and fire exclusions for similar reasons as the closed stage. A very small number and area of stands (<0.5%) with similar cover types occurred in the late-development open (D) successional stage with mature size class. In contrast, a fair number and area of stands occurred in the characteristic late-development closed (E) successional stage with old tree size and age dominated by aspen or lodgepole pine. The major uncharacteristic condition that occurred in this PVT was stand conditions determined to be beyond the successional maximum due to lack of mixed fire effects (I). These were typically dominated by moderate canopy closure of mature lodgepole pine or Engelmann spruce and subalpine fir that had a deep litter and duff layer with an understory of low- to medium-high shrub or herbaceous vegetation.

The current similarity of the Montane PVT to the historical regime was only 10%, indicating a 90% departure (Table 6). The standard breaks for each fire regime condition class and historical range of variability (HRV) departure class are 0%–33% (classes 1 and low departure, respectively), 34%–66% (classes 2 and moderate departure, respectively), and 67%–100% (classes 3 and high departure, respectively). The results for the Montane PVT placed this type in fire regime condition class 3 with high (H) departure. In contrast the current similarity of the Subalpine PVT to the historical regime was 60%, indicating a 40% departure, which fits in fire regime condition class 2 and historical range of variability (HRV) departure class of moderate (M) (Table 7).

Although ground reconnaissance indicated little evidence that could be used to simulate the historical regime averages for successional stages and disturbances in the Lower Montane sagebrush (*Artemisia tridentata*) PVT we were fairly confident in estimating its similarity to the historical regime at 65% with departure of 35%. Although this PVT was impacted substantially by grazing during the mining era, it appears to have recovered a diversity of native species, sagebrush cover, and a surface soil conducive to herbaceous species. Lack of fire appears to be having a substantial effect in loss of sagebrush and grass patch diversity, sagebrush age diversity, and sagebrush canopy closure; thus our estimate of 35% departure. Our ground-reconnaissance evaluation of sagebrush burns implemented more than 15 years ago suggests that application of fire in this type effectively increases grass and herbaceous diversity for several decades. For the riparian and alpine PVTs, we were confident in estimating that their similarity was approximately 95% and departure only 5%.

Planning Process

Planning for the project to meet the NEPA was organized into five components:

Planning. The framework for planning linked multiple scales: 1) national and regional guidance, such as the Cohesive Strategy and Threatened and Endangered species conservation plans; 2) Forest and Resource Plans and the Upper Arkansas assessment (Figure 1); and 3) project area conditions.

Data. Data were linked between all disciplines and scales so that inconsistencies between data sources did not occur. A key step in this process was the reconciliation of vegetation layers (cover type, structure, potential vegetation) for all land ownerships within the watershed. The base reference data for analyzing risk included the natural fire regime map, the historical regime departure classes, and fire regime condition class.

Desired condition (Figure 7). To develop desired conditions the interdisciplinary team identified three components: 1) key landscape interconnections; 2) operationally restorable treatment units (Figures 8 and 9); and 3) prescriptions and tools.

Alternatives. To develop alternatives the amount of treatment was held constant for all action alternatives, ensuring that all action alternatives met the desired future condition of condition and departure class. Differences among the alternatives were focused on differences in tools (such as fire, mechanical, or mixes of the two) to treat the area required to achieve the desired departure and condition class.

Public support. Engaging the public to support the project took time. Key public individuals and groups had a history of knowledge and involvement in the Upper Arkansas assessment. They were informed of conditions during the assessment and they were interviewed for their knowledge and opinions on conditions and issues in the Upper Arkansas. Consequently, there were no surprises and we generally found agreement that the Box Creek watershed was a high priority for restoration work. Some disagreement existed between those preferring commercial harvest versus those preferring noncommercial mechanical or burning, but these disagreements were resolved as they were involved in the discussion of tools to be used during the restoration operation.

We found that critical components to success of the planning process were the skills of and relationship between the IDT and decision maker. The IDT team leader required multi-resource and ecological knowledge and experience, an understanding of social climate and legal constraints, and capability to interact with specialists regarding selected tools. The IDT core membership was key and was built on the premise that a highly energized, small (fewer than 4 members) core working group that has a good understanding of measures of natural regime departure, disturbance regimes, and multi-ecosystem functions was most effective. The IDT workshops were condensed (4 to 5 days at a time) versus 1- or 2-day meetings spread out over 6 months to a year. This approach proved most effective in maintaining team energy, problem solving, and production. From both IDT and decision-maker perspective it was critical that the purpose and need focused on restoration based on the analysis process and not on a predetermined acre, volume target, or type of treatment.

One of the outcomes of public involvement in the process was assistance provided to us in finding historical photos and documentaries of conditions in the Box Creek watershed and the Upper Arkansas River subbasin. There was much more interest in this aspect than in providing input on purpose and need, alternatives, or effects.

The interdisciplinary team developed the range of prescriptions with a focus on achieving the desired conditions for different operational situations (Table 8). Twenty-four prescriptions were developed that were mapped to each polygon within the project area. Prescription designs for reducing risk to wildland–urban interface involved much more than assignment of a fuels reduction (thinning) prescription in the proximity of subdivision structures. The 275-m (300-yard) fuel breaks would do little to protect these structures from running crown fire brands that would occur with high winds coming from the west. The landscape west and northwest of the subdivision area, for the width of the watershed, was given a mix of prescriptions that would shift fire behavior from a crown to a mixed or surface fire that would move slower, have lower intensity, and be much easier to contain.

To improve ecosystem and wildlife habitat conditions the IDT designed a watershed-wide mosaic of prescriptions that would generally reduce departure from the historical regime. In addition, the team developed prescriptions designed to promote or protect old growth, big game winter range, black-backed woodpeckers (*Picoides arcticus*), yellow-bellied sapsuckers (*Sphyrapicus varius*), marten (*Martes americana*), and Canada lynx to assure these management concerns were addressed. In addition treatments were scheduled and designed to reduce the negative effects of roads and improve overall watershed conditions.

Action alternatives developed into three differing mixes of tools (Table 9). Proposed or preferred action, harvest (mechanical) emphasis, and fire emphasis. All three alternatives treat similar amounts of area, but the harvest emphasis uses mechanical and commercial harvest where possible, while the fire emphasis uses fire wherever possible. In contrast, the preferred or proposed action mixes fire and harvest in what the interdisciplinary team agrees best achieves the risk-reduction objectives. Part of each alternative is an aggressive plan to protect quality aspen stands and old forest and trees and create conditions where natural process, such as windthrow following treatment by fire, will result in quality wildlife habitat (i.e., no post-treatment salvage). An additional component of all alternatives was to maintain areas previously treated to reduce dwarf mistletoe and improve structural diversity. The spatial arrangement of this mix of tools were developed and tested against the landscape connection criteria established to reduce risk to wildland–urban interface, to ecosystems, and to habitats (Figure 10).

A review of other similar planning projects that used the traditional single purpose with operation focus resulted in the emergence of several key issues:

Opportunities. Most traditional planning project areas were prioritized first on operational opportunities. The operational opportunities typically did not rigorously consider Forest, Resource, or Land Management plan standards and objectives, Agency Manual, or environmental law (NEPA, Endangered Species Act, Clean Air Act, Clean Water Act, etc.) regulations. The consequences that a proposed project would go against previous decisions and environmental regulations were a loss of credibility between the IDT leader–decision maker and environmental groups, regulatory agency staffs, and the public. Freedom of Information Act (FOIA) requests, appeals, and lawsuits can result from such a loss of credibility and use up substantial agency and IDT energy. Mitigation of the proposed action alternatives typically through reduction of treatment area, or complete failure of the project frequently followed.

Perceptions. Most traditional planning project areas were prioritized and developed the purpose and need based on philosophical, conceptual, or subjective perceptions of fire regime condition class, forest health, fire, or other risks. The consequence was a lack of consistent and quantifiable information that could be used to provide context to broader extents (such as nation, region, state, ecoregion, or subbasin). In addition, communication among IDT, the decision maker, and the publics were difficult because of lack of definitions. Publics at a broader local scale (e.g., county or subbasin) were not interviewed and felt left out. Similar consequences

(FOIA, appeals, and lawsuits) frequently occur that result in mitigation or project failure.

Rationale. Most traditional planning projects did not provide rationale for the priority, purpose, or need that carried directly into the formulation of the action alternatives and analysis of effects. The consequences were a feeling by the public that the people leading the projects were "tinkering" without full knowledge of objectives and outcomes.

In contrast, we found that the integrated and prioritized approach used in the Box Creek planning process generally resolved these issues by developing internal and external confidence. It was equally important for decision makers not to predetermine the acre or volume target or the action alternative. The involved decision makers waited until the Upper Arkansas assessment was completed to prioritize Box Creek as a restoration project. Following this step they waited to assign targets or consider the proposed alternatives until after the IDT with public involvement completed the analysis of fire regime condition class and departure, wildlife habitat and watershed conditions, resource and social values, estimated area needed to treat to restore, and developed management prescriptions, and subsequent preliminary proposed action alternatives. This allowed the IDT and involved publics to integrate and design the most effective combination of treatments to achieve the purpose and need.

DISCUSSION

Analysis

Results for each PVT were summarized for the Box Creek watershed as a whole (Table 10). In order to achieve an objective of condition class 1 with low historical regime departure over the total project implementation period we calculated that we would need to treat approximately 1,550–1,650 ha (3,800–4,000 acres) within the Montane PVT, 700–800 ha (1,700–2,000 acres) in the Subalpine PVT, and 900–1,000 ha (2,200–2,500 acres) in the Lower Montane PVT. This resulted in a total of approximately 3,300–3,400 ha (8,100–8,400 acres) of treatment to achieve the objectives. Subtracting the desired departure from the current departure and multiplying times the area within the PVT calculated the area to treat to achieve the desired condition. A higher desired departure (20%) was allowed for the Montane PVT for this first phase of restoration because the IDT did not feel a much larger area could be treated with fire or harvest and be economical or accepted socially. However, this desired departure was lower than that used by Hann and Strohm (2003) in order to move the PVT well into the middle of condition class 1, rather than just at the boundary between condition classes 1 and 2. A fairly low desired departure (5%) was selected for the Subalpine PVT because it was perceived to be operationally achievable, would put a large component of the landscape in a maintenance condition, and would achieve habitat objectives for Canada lynx and other species of concern.

Most of the treatments in the Lower Montane sagebrush grass PVT could be accomplished as part of broadcast burning in the adjacent montane forest types or upon implementation of a fire use plan. The objective of 5% desired departure was used to calculate the amount of area for treatment to achieve and objective of condition class 1. This may appear quite high compared to the values used by Hann and Strohm (2003). However, one of the operational problems that exist in the Box Creek watershed was the mosaic of Lower Montane with Montane stands that would make it difficult to burn one independently from another. In addition there was the problem in the Montane PVT of the total lack of some of the characteristic early-seral and late-seral classes with the continuity of the uncharacteristic classes that are a residual pattern from the extensive and intensive mining-era logging. This creates a continuous uncharacteristic condition that could be broken up by burning mosaic sagebrush units to create a mosaic. In order to move the whole landscape to a more characteristic mosaic pattern, it is important to recruit more of the late-seral open and closed stages, and reduce the severe levels of dwarf mistletoe and mountain pine beetle (*Dendroctonus ponderosae*) risk; substantial area of both PVTs needs to be set in a parallel motion through treatment.

Planning

Critical to the success of this integrated approach is the consistent and systematic approach to the planning framework and use of data. Additionally, calculation and classification of historical regime departure and fire regime condition class was designed to indicate hazards (wildland–urban interface, ecosystem and wildlife habitat). In particular, the early establishment of the interdisciplinary and integrated Upper Arkansas assessment, continuous public involvement with key individuals and groups, Box Creek prioritization, and design of prescriptions and action alternatives aided in avoidance of the “mitigation spin.”

For any project on federal public lands, the actual decision space generally falls within an area defined by the intersection of legal–policy limits, operational limits, and some measure(s) of land management objectives (Figure 11). For this project we will call these measures “fire regime risk” and “urban interface risk.” In Figure 11 this overlap area of decision space has an x-section pattern and is titled “interdisciplinary prioritized design.” If agency leadership directs through policy and education that this integrated approach be implemented then these risks can be substantially reduced (40% to 60%). However, during recent history and currently, most agency projects eventually end up in the mitigation spin. This typically occurs when the project is prioritized and designed from a narrow, noninterdisciplinary traditional management view, such as from just fire, fuels or timber, to achieve primarily operational and target area considerations, with conceptual statements of risk reduction, but little emphasis on science-based measures of risk. Other disciplines then must react with mitigation to reduce the negative effects to their resource and meet legal and policy requirements. The final mitigated action alternative may often only treat half or less of the proposed treatment, and only reduce the actual science-based risk measure to urban interface and ecosystems by one-tenth. This same mitigation spin can also occur as a result of social pressures to not treat the amount of area needed to improve condition or habitats. This social pressure can come from a lack of confidence in achieving project outcomes, objectives that conflict with improving condition or habitats, or a lack of understanding of the ecosystems.

In summary, the results from the Box Creek watershed restoration project demonstrate a cost-effective and science-based attempt to provide consistent and repeatable data for assessment of conditions and development of alternatives. In addition, the interdisciplinary team demonstrated how to identify the full decision space available for restoration if an integrated approach to project prioritization, purpose and need, and proposed action formulation is implemented versus accepting the mitigation spin.

MANAGEMENT IMPLICATIONS

Implications for Restoration

Findings from this project have wide applicability to accomplishment of National Fire Plan, Cohesive Strategy, land management analysis and planning processes, threatened and endangered species conservation strategies, and general land management objectives.

Current restoration management implications for the Montane PVT would be to manage to recruit the early-development (A) and late-development closed (E) classes, reduce the mid-development closed class (B), retain and recruit the late-development open class (D), and reduce the uncharacteristic classes (G, I, and L). The early-development class could be fairly easily recruited through mechanical, fire, and planting treatments in the uncharacteristic classes (G, I, and L) by mimicking the mixed fire regime and managing for lodgepole pine, ponderosa pine, and Douglas-fir regeneration. If enough of the early-development class (A) were created, this would result in an increase in the mid-development closed or open classes (B and C) within a fairly short time period (20–40 years). The closed stands (B) could then be thinned to produce more of the open stands (C) and promote growth of larger trees to late-development stands that could be maintained in an open condition (D) with thinning or underburning. Thinning, planting, and underburning in uncharacteristic classes with mature trees (L and I) could recruit the late-development open class (D). The late-development closed class (E) could be developed within a somewhat longer time frame (30–50 years) after developing the late-development open class (D) and allowing development of moderate to closed canopies, multiple layers, and old trees. Terrain plays an important role in the location of these late-development closed stands. These types of conditions historically were in the bottoms and northern-aspect cooler conditions where the mixed fires typically burned around or crept through the litter and duff resulting in very low mortality of understory trees and only small gaps from torching of ladder fuels or windthrow.

The current high departure (90%) in similarity to the historical regime and the large amount of uncharacteristic stand conditions (88%) result in substantial hazards. These include potential for uncharacteristic wildfire that could cause negative effects to both ecosystems and threaten the wildland–urban interface. The large area of uncharacteristic habitats that lack composition, patch, structural, and snag and down log diversity have resulted in a lack of both quantity and quality wildlife habitats for management indicator species. The low diversity of plant species, depauperate understory, lack of down logs, and closed stand conditions result in high tie-up of nutrients in the stagnated tree canopies taking away nutrients from the soil system. The epidemic levels of dwarf mistletoe in lodgepole pine have created a “forest that is defenseless” (J. Worrall, U.S. Forest Service, personal communication) without the natural fire regime. The historical regime contained patches of endemic dwarf mistletoe that added to the natural diversity. However, the current epidemic levels dwarf mistletoe dominate the forest processes and reduce natural diversity.

Current restoration management implications for the Subalpine PVT would be to manage to recruit the early-development class (A), retain and recruit more of the late-development closed class (E), and reduce the mid-development classes (B and C) and the uncharacteristic class (I). Recruitment of class A could be accomplished by mechanical, fire, and regeneration treatments for Engelmann spruce, subalpine fir, aspen, and lodgepole pine in the mid-development closed class (B) or the uncharacteristic class (I) that mimic the historical regime. Similar reductions of the mid-development closed class (B) and the uncharacteristic class (I) through thinning and underburning could result in more of the late-development open class (D) within a 20- to 30-year time frame that could subsequently be allowed to close canopy and develop the multiple layers of a class E.

The current moderate departure (40%) in similarity to the historical regime and the relatively low amount of uncharacteristic stand conditions (7%) give this PVT substantial opportunity for rapid restoration and maintenance of relatively good conditions. Most departure is due to a lack of balance in composition of the characteristic classes A through E, particularly the lack of early-development (A) and late-development closed and open classes (E and D) rather than a large amount of uncharacteristic types. Because of the lack of balance in composition of characteristic stand conditions, severe effects and risks to the wildland–urban interface may occur from wildfires. This lack of balance also results in a lack of quality wildlife habitats, particularly for Canada lynx and its prey (snowshoe hare [*Lepus americanus*] and red squirrel [*Tamiasciurus hudsonicus*]). Negative effects to soils and forest health occur at a moderate level to the overall landscape level, but not so much at the individual stand level. Thus the fire regime condition class is a 2 as compared to 3 for the Montane PVT, and the HRV departure class is moderate compared to high.

Implications for Analysis

We have demonstrated an interdisciplinary and integrated approach to analysis that provides consistent, science-based measures of fire regime condition class, historical regime departure, wildlife habitat, and other vegetation and resource values that can be used to prioritize projects at multiple scales and to develop a linked purpose and need, action alternatives, and effects analysis.

The methods for project- and watershed-scale fire regime condition class and historical regime departure can be used to determine a landscape-scale status, but should not be used at single stand scales. At single stand scales risk ratings of low, high, or moderate should be used to identify the contribution of that stand to overall landscape risk. Management implications of reduce, retain, or recruit can also be assigned at the stand scale.

This project has demonstrated the value of integrating the set of potential vegetation, cover type, and structure vegetation themes for use by all IDT members. This improves accuracy, credibility, and communication during the analysis and planning process.

In the Box Creek project area the “textbook” assumption that the lodgepole pine cover type infers a crown fire replacement regime would have substantially misled the analysis and planning process. Each landscape project is usually unique in its ecosystem or history and deserves on-the-ground investigation.

Implications for Planning

We have demonstrated an interdisciplinary approach to prioritization and design of purpose and need and proposed action that can aggressively achieve action objectives and reduce risk to wildland–urban interface, ecosystems, forest health, watershed, and wildlife habitats within operational and legal–policy limitations. This approach has been tested and recommended by a number of other investigations (Quigley et al. 1996, Reiman et al. 2000, Hann and Bunnell 2001, Hann and Strohm 2003).

Traditional fire or resource single objective project identification and design that focus on conceptual or philosophical objectives and operational limitations, with little focus on interdisciplinary design to achieve legal–policy requirements or science-based measures for objectives do not have the rationale to garner support, and must either be mitigated or fail altogether.

A traditional approach results in mitigation that substantially reduces size of treated areas (Figure 11). Lack of science-based and natural regime rationale combined with legal–policy conflicts result in a loss of credibility with the public, regulatory agencies, and congress.

Land-management agency leadership currently does not provide the direction, the training, or consistent policy on integrated risk data to achieve aggressive widespread change in direction that would actually implement interdisciplinary prioritization and design combined with science-based rationale. Without active agency leadership direction to change from the mitigation spin to interdisciplinary decision space combined with training and an integrated data policy, it is unlikely that the National Fire Plan and other land management emphasis areas, which require active treatment, can be successfully implemented.

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Table 1. Natural fire regime classes from Hardy et al. (2001) and Schmidt et al. (2002) as interpreted by the authors for modeling landscape dynamics at project and watershed scales.

Fire regime class	Frequency (Fire return interval)	Severity	Modeling assumptions
I	0–35+ years, frequent	Surface mixed	Open forest, savannah, or patchy structures maintained by frequent fire; often includes a mosaic of different age post-fire open forest, early- to mid-seral forest structural stages, and shrub- or herb-dominated patches (generally <40 ha [100 acres]). Interval can range up to 50 years.
II	0–35+ years, frequent	Replacement	Shrub or grasslands maintained or cycled by frequent fire; fires kill nonsprouting shrubs such as sagebrush that typically regenerate and become dominant within 10–15 years; fires remove tops of sprouting shrubs such as mesquite and chaparral that typically resprout and dominate within 5 years; fires typically kill most tree regeneration such as juniper, pinyon pine, ponderosa pine, Douglas-fir, or lodgepole pine. Interval can range up to 50 years.
III	35–100+ years, infrequent	Mixed	Mosaic of different age post-fire open forest, early- to mid-seral forest structural stages, and shrub- or herb-dominated patches (generally <40 ha [100 acres]) maintained or cycled by infrequent fire. Interval can range up to 200 years.
IV	35–100+ years, less infrequent	Replacement	Large patches (generally >40 ha [100 acres]) 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	>100–200 years, rare	Replacement	Large patches (generally >40 ha [100 acres]) of similar age post-fire shrub- or herb-dominated structures, or early- to mid- to late-seral forest cycled by infrequent fire.

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 natural or historical range of variability at project and watershed scales. Historical Range of Variability (HRV) is the variability of regional or landscape composition, structure, and disturbances, during a time period of several cycles of the common disturbance intervals, and similar environmental gradients, referring to a period prior to extensive agricultural or industrial development in the United States. Natural Range of Variability (NRV) is 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 (synthesized from Morgan et al. 1994, Swanson et al. 1994, Hann et al. 1997, Landres et al. 1999, Swetnam et al. 1999). For the Box Creek watershed we used HRV.

Condition class	Departure from NRV or HRV	Description
1	None, minimal, low	Vegetation composition, structure, and fuels are similar to those of the historical regime and do not predispose the system to risk of loss of key ecosystem components. Wildland fires are characteristic of the historical fire regime behavior, severity, and patterns. Disturbance agents, native species habitats, and hydrologic functions are within the historical range of variability.
2	Moderate	Vegetation composition, structure, and fuels have moderate departure from the historical regime and predispose the system to risk of loss of key ecosystem components. If wildland fires occur they are moderately uncharacteristic compared to the historical fire regime behaviors, severity, and patterns. Disturbance agents, native species habitats, and hydrologic functions are outside the historical range of variability.
3	High	Vegetation composition, structure, and fuels have high departure from the historical regime and predispose the system to high risk of loss of key ecosystem components. If wildland fires occur they are highly uncharacteristic compared to the historical fire regime behaviors, severity, and patterns. Disturbance agents, native species habitats, and hydrologic functions are substantially outside the historical range of variability.

Table 3. Box model class descriptions from Hann (*this volume*) with additional description and interpretations.

Class	Class description	Process	Forest and woodland	Shrubland and grassland
A	Characteristic; post-replacement; early development	Post-replacement disturbance; young age	Single layer; <10% tree canopy cover; standing dead and down	Fire-response forbs; resprouting shrubs; resprouting grasses
B	Characteristic; mid-development; closed	Mid-successional; mid-age; competition stress	One to two upper-layer size classes; >40% canopy cover; litter–duff; standing dead and down	Upper layer shrubs or grasses; <15% canopy cover
C	Characteristic; mid-development; open	Mid-successional; mid-age; disturbance maintained	One size class in upper layer; <40% canopy cover; fire-adapted understory; scattered standing dead and down	Upper layer shrubs or grasses; >15% canopy cover shrubs
D	Characteristic; late development; open	Late successional; mature age; disturbance maintained	Single upper canopy tree layer; one to three size classes in upper layer; <40% canopy cover; fire-adapted understory; scattered standing dead and down	Upper layer shrubs or grasses; <15% canopy cover
E	Characteristic; late development; closed	Late successional; mature age; competition stress	Multiple upper canopy tree layers; multiple size classes; >40% canopy cover; shade-tolerant understory; litter–duff; standing dead and down	Upper layer shrubs or grasses; >15% canopy cover shrubs
G	Uncharacteristic timber management not mimicking natural regime	Timber harvest, stand improvement, and tree planting is not similar to natural regime	Commonly involves cutting of large trees and leaving small trees; timber thinning to systematic single tree spacing rather than group trees with variable spacing; planting higher density or different species composition than natural, or off-site stock; high density road system enhancing invasive plant spread, rerouting of water and sediment, and animal displacement–harassment	
I	Uncharacteristic succession and fuels	Natural disturbance frequency is beyond maximum	Usually associated with change to larger patch size and loss of patch mosaic with more contiguous heavy fuels	Usually associated with change to larger patch size and loss of patch mosaic with more contiguous upper layer fuels
L	Uncharacteristic insect–disease invasive or more severe	Invasive insects or disease, such as blister rust; or epidemic or level of extent not similar to natural regime	Commonly occurs following uncharacteristic timber harvest of large trees leaving small insect–disease-susceptible trees	

Table 4. Descriptions of cover types and structures for vegetation–fuel classes that currently occur in the montane potential vegetation type of the Box Creek watershed.

Class	Vegetation type in Box Creek
A	LP–DF–PP [a]; shrub tree seedling herb
	PP; shrub tree seedling herb
	QA–CO; shrub tree seedling herb
B	QA–CO; pole–sapling tree closed [b]
C	LP–DF–PP; pole–sapling tree open
	LP–DF–PP; pole–sapling tree moderate
	QA–CO; pole–sapling tree moderate
	PP; pole–sapling tree moderate
D	LP–DF–PP; mature tree open
	PP; mature tree open and moderate
	PP; old tree
	QA–CO; mature tree moderate
E	QA–CO; old tree
	LP–DF–PP; old tree
G	LP; shrub tree seedling herb clearcut with no PP or DF regeneration
I	LP; mature tree moderate with very deep litter–duff and heavy down fuels
L	LP; pole–sapling closed, moderate, and open with severe mistletoe infestation
	LP; mature tree closed, moderate, and open with severe mistletoe infestation

[a] Cover type tree species: CO, conifer; DF, Douglas-fir; LP, lodgepole pine; PP, ponderosa pine; QA, quaking aspen.
[b] Canopy closure classes: closed, ≥60% canopy cover; moderate, ≥40% and <60% canopy cover; low, <40% canopy cover.

Table 5. Descriptions of cover types and structures for the vegetation classes that currently occur in the Subalpine potential vegetation type of the Box Creek watershed.

Class	Vegetation type in Box Creek
A	ES–SA [a]; shrub tree seedling herb
	LP; shrub tree seedling herb
	QA–CO; shrub tree seedling herb
B	LP; pole–sapling closed [b, c]
	QA–CO; pole–sapling closed
	ES–SA; pole–sapling closed
C	LP; pole–sapling moderate
	LP; mature tree moderate
	LP; mature tree open
	QA–CO; pole–sapling moderate and open
D	QA–CO; mature tree open
	LP; mature tree moderate
E	QA–CO; old tree
	QA–CO; mature tree moderate
	QA–CO; mature tree closed
	LP; old tree
I	LP or ES–SA; mature tree closed with very deep litter–duff and heavy down fuels

[a] Cover type tree species: CO, conifer; DF, Douglas-fir; ES, Engelmann spruce; LP, lodgepole pine; PP, ponderosa pine; QA, quaking aspen; SA, subalpine fir.

[b] Canopy closure classes: closed, ≥60% canopy cover; moderate, ≥40% and <60% canopy cover; low, <40% canopy cover.

[c] Tree size classes: seedling; sapling; pole; mature; old.

Table 6. Summary of comparison of current to historical for the Montane potential vegetation type for current similarity, percent difference, restoration implication, and risk to ecosystems. The central tendency (average) of the historical (natural) range of variability was used as the measure for comparison to current in order to provide a similarity and departure between 0 and 100%. Current restoration implication of "recruit" was assigned where percent difference was less than –25% and none occurred currently, "retain–recruit" where some occurred currently and difference was less than –25%, and "reduce" was assigned where difference was greater than +25%.

Box model class	Historical (natural) regime average (%)	Current amount (%)	Current similarity (%)	Percent difference [a]	Current restoration implication	Current risk to ecosystems
A	8	0	0	–100	Recruit	High
B	2	4	2	+33	Reduce	Moderate
C	16	1	1	–88	Retain–Recruit	High
D	66	7	7	–81	Retain–Recruit	High
E	8	0	0	–100	Recruit	High
G	0	7	0	–100	Reduce	High
I	0	11	0	–100	Reduce	High
L	0	70	0	–100	Reduce	High
Total	100	100	10			

[a] Percent difference = (current amount – historical average)/(current amount + historical average) × 100.

Table 7. Summary of comparison of current to historical for the Subalpine potential vegetation type for current similarity, percent difference, restoration implication, and risk to ecosystems. The central tendency (average) of the historical (natural) range of variability was used as the measure for comparison to current in order to provide a similarity and departure between 0 and 100%. Current restoration implication of “recruit” was assigned where percent difference was less than –25% and none occurred currently, “retain–recruit” where some occurred currently and difference was less than –25%, “reduce” assigned where difference was greater than +25%, and “maintain” assigned where within ±25%.

Box model class	Historical (natural) regime average (%)	Current amount (%)	Current similarity (%)	Percent difference [a]	Current restoration implication	Current risk to ecosystems
A	12	0	0	–100	Recruit	High
B	16	65	16	+60	Reduce	High
C	13	16	13	+10	Maintain	High
D	12	0	0	–100	Recruit	High
E	47	11	11	–64	Retain–Recruit	High
I	0	7	0	+100	Reduce	High
Total	100	100	40			

[a] Percent difference = (Current amount – Historical average)/(Current amount + Historical average) × 100.

Table 8. Summary of the 24 treatment prescriptions developed for the Box Creek watershed restoration plan.

Rx ID	Tree species [a]	Tree size [b]	Desired future condition	Treatment prescription [c]	Tool [d]
	LP	MT	Candidate old growth	Thin to advance structure. Retain largest diameter size classes and all snags >12-in. (30.5-cm) DBH	H/NH
	LP	SA	Lodgepole pine	Sanitize if needed; protect advanced growth	H/NH
	LP	SA	Mixed conifer	Sanitize if needed; plant with Douglas-fir–ponderosa pine; protect advanced growth	H/NH
	LP	SA	Mixed conifer	Sanitize for mistletoe; thin to 250 trees/acre; plant with Douglas-fir–ponderosa pine; protect advanced growth	H/NH
	LP	PT	Candidate open mature/old	Thin; protect advanced structural stage	H/NH
	LP	PT	Candidate mature/old	No thinning; protect advanced structural stage	H/NH
	LP	PT	Sanitize for mistletoe	Sanitize; thin	F/H/NH
	LP	PT	Aspen	Regenerate	F/H/NH
	LP	PT	Seedling spruce; lynx habitat, spruce size class diversity	Regenerate; no thinning of conifer regeneration until crowns are 6 feet (1.8 m) above ground (lynx foraging habitat)	F/H/NH
0	LP	PT	Mistletoe control for regen.	Regenerate	F/H/NH
1	LP	PT	Ponderosa pine, open, mature, fire maintained	Remove lodgepole pine understory; retain all ponderosa pine w/o mountain pine beetle larvae; retain all snags >12-in. (30.5-cm) DBH	F/H/NH
2	LP	PT	Big game forage; conversion to winter range; enhance aspen	Reduce basal area to 20 to 120 basal area; remove <12-in (30.5-cm) lodgepole pine; maintain open understory with periodic fire; plant ponderosa pine in microsites (optional)	F/H/NH
3	LP	PT	Burned snag patches	Mixed severity fire; mechanical pre-treatment; no post-burn removal of burned trees	F
4	LP	Any	Mixed conifer	Reduce lodgepole pine to encourage other conifer; maintain thermal and security cover	H/NH
5	AC	Any	Aspen–conifer mix	Protect where possible	None
6	AC	Any	Young age class; aspen clones	Regenerate; if using fire, follow historic burn pattern	F/H/NH
7	ES	OT	Old growth	Protect	None
8	ES	MT	Candidate old growth	Retain	None
9	ES	Any	Seedling spruce, spruce size class diversity; cavity nesters	Regenerate; no thinning of conifer regeneration until crowns are 6 feet (1.8 m) above ground (lynx foraging habitat); follow historic burn pattern; retain all burned snags	F
0	ES	Any	Aspen expansion	Regenerate aspen	F/H/NH
1	SB	Any	Maintain early seral stage	Regenerate	F
2	Any	Any	Not Applicable	None	None
3 WUI [e]	Any	Any	Maintain condition class 1 fuel break; mistletoe control; pine beetle control	Retain larger diameter size class; treat activity fuels pile/burn or lop and scatter; minimum 300-yard (274-m) fuel break where possible; sanitize for dwarf mistletoe and mountain pine beetle where possible	H/NH
4	Any	Any	Variable	Retention	None

[a] Tree species: AC, aspen–conifer mixture; ES, Engelmann spruce; LP, lodgepole pine.
[b] Tree size: MT, mature; OT, old growth; PT, pole; SA, sapling.
[c] Abbreviation: DBH, diameter at breast height.
[d] Tools: F, fire; H, harvest; NH, noncommercial thin.
[e] Abbreviation: WUI, wildland–urban interface.

Table 9. Summary of alternatives designed for restoration of the Box Creek watershed. In the no-action alternative the 235 ha of patch cuts conducted as part of previous projects would be maintained through thinning of lodgepole pine, but no other areas would be treated. In the proposed-action alternative the most effective combination of fire and harvest were combined with protection and maintenance to achieve the objectives. For the harvest- and fire-emphasis alternatives the tool of emphasis was used wherever operationally possible.

	Alternative			
Tool	No action (ha)	Proposed action (ha)	Harvest emphasis (ha)	Fire emphasis (ha)
Fire	0	2021	1815	2754
Harvest	0	1073	1328	141
Protect	0	404	404	404
Maintain	235	235	235	235
No treatment	7314	3815	3766	4015
Total area	7549	7549	7545	7545

Table 10. Summary of potential vegetation types in the Box Creek watershed with an estimate of the amount of area to restore to achieve desired condition and departure class objectives. Montane and subalpine potential vegetation types were assessed quantitatively through ground reconnaissance and simulation modeling. In order to address the total landscape the lower montane, alpine, and riparian potential vegetation types were mapped and percent departure, condition class, and departure class were estimated. The desired departure and desired condition class were selected by the interdisciplinary team as the desired outcome following restoration. A desired departure of 20% was selected for the montane type with an objective to restore condition class 3 to class 1. A desired departure of 5% was selected for the subalpine and lower montane types with an objective to restore condition class 2 to class 1. The amount of area to treat is to restore to condition class 1.

			Departure (%)		Fire regime condition class			Historical (natural) regime departure class			
Potential vegetation type	Indicator species	Area (ha)	Current	Desired	Class	Current	Desired	Current	Desired	Desired departure (%)	Amount of area (ha) to treat [a]
Montane	Lodgepole pine, ponderosa pine, Douglas-fir	2,308	90	20	Frequent Mixed	3	1	H	L	20	1,615
Subalpine	Engelmann spruce, subalpine fir, lodgepole pine	1,316	60	5	Infrequent Mixed	2	1	M	L	5	778
Lower montane	Mountain big sagebrush	3,117	35	5	Frequent Replacement	1	1	L	L	5	935
Alpine	Tundra species	334	5	5	Rare Mixed	1	1	L	L	5	0
Riparian	Willows	374	5	5	Infrequent Replacement	1	1	L	L	5	0
Total		7,449									3,329

[a] The amount of area to treat was determined using the formula [(Current Departure – Desired Departure)/100] × Area.

Figure 1. Map of Upper Arkansas assessment indicating Box Creek watershed has a high priority for restoration based on high departure from the historical (natural) vegetation and fire regime (condition class 3), uncharacteristic levels of insect and disease, uncharacteristic wildlife habitats, and high wildfire hazard to the wildland–urban interface. Much of the departure and uncharacteristic conditions result from the combination of mining-era (late 1800s and early 1900s) logging and wood cutting combined with fire exclusion.

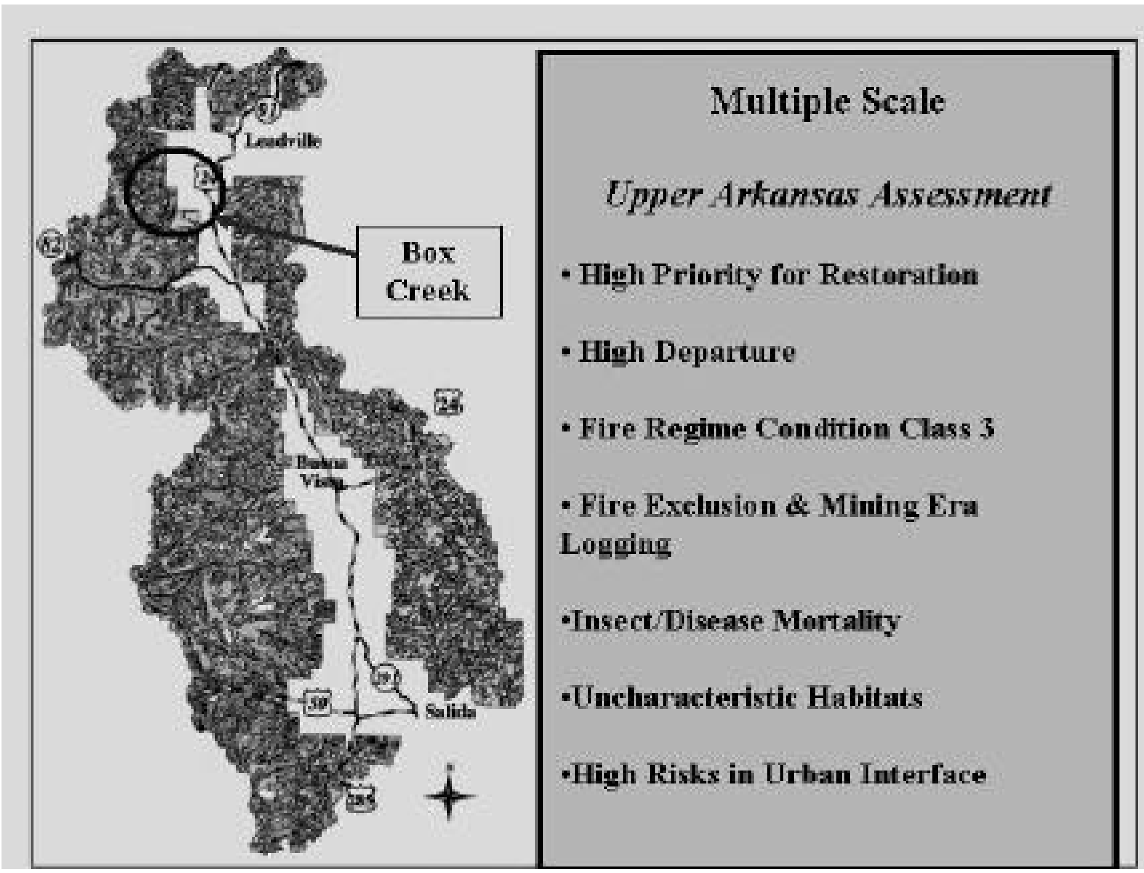

Figure 2. The Box Creek watershed looking from the east with Mt. Elbert on the left (south) and Halfmoon Creek and the southern ridge of Mt. Massive on the right (north). Photo is warped to emphasize elevation and aspect differences. Lower southerly slopes, benches and ridges are sagebrush–grass, lower northerly slopes and mid-elevation ridges, benches and slopes are mixed conifer, upper-elevation timbered slopes are subalpine fir and spruce, with the alpine meadow and rock zone above.

Figure 3. Potential vegetation types for the Box Creek watershed. Potential vegetation types were mapped through combination of use of landtype mapping with current cover type maps and ground truth. Potential vegetation is the endpoint of succession usually named by the understory tree, shrub, and herbaceous species that best indicate the moisture, temperature, and soil regime. For example, presence of subalpine fir in the understory of a lodgepole pine–spruce cover type would indicate the mountain subalpine potential vegetation, rather than mountain montane potential vegetation.

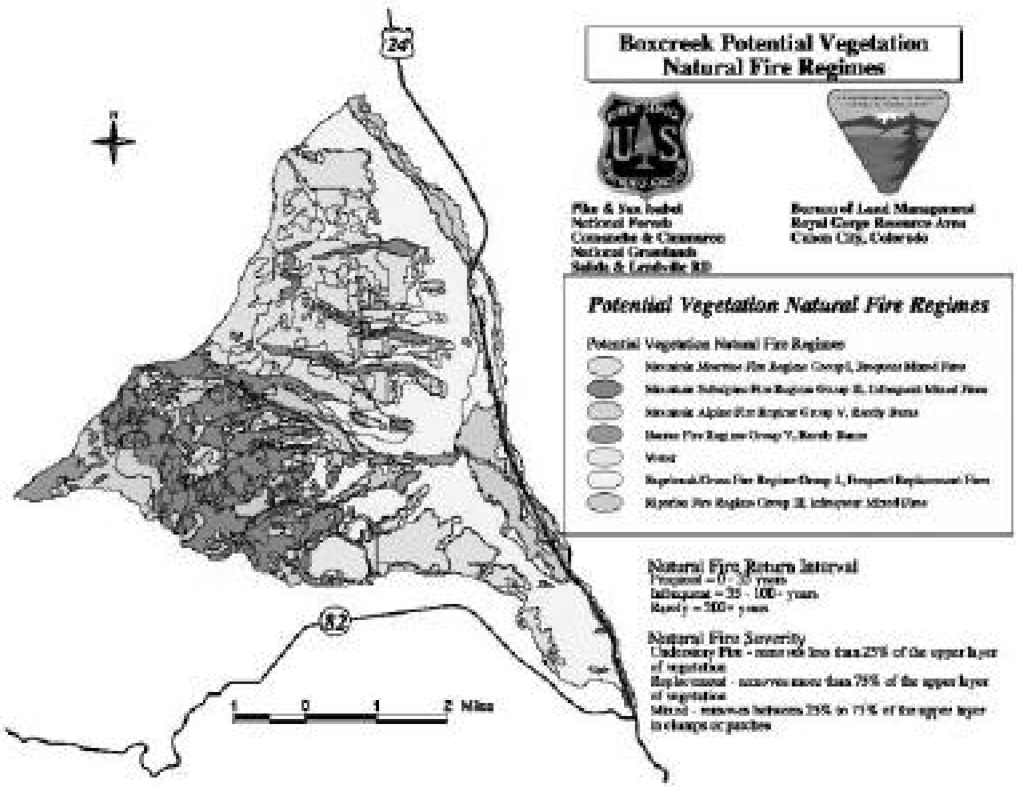

Figure 4. Framework of succession and disturbance computer model used for modeling historical (natural) average and range of variability for vegetation and fire regimes in the Box Creek watershed. Successional times between classes and probabilities of disturbance were developed from ground sampling, review of the literature, and expert judgment.

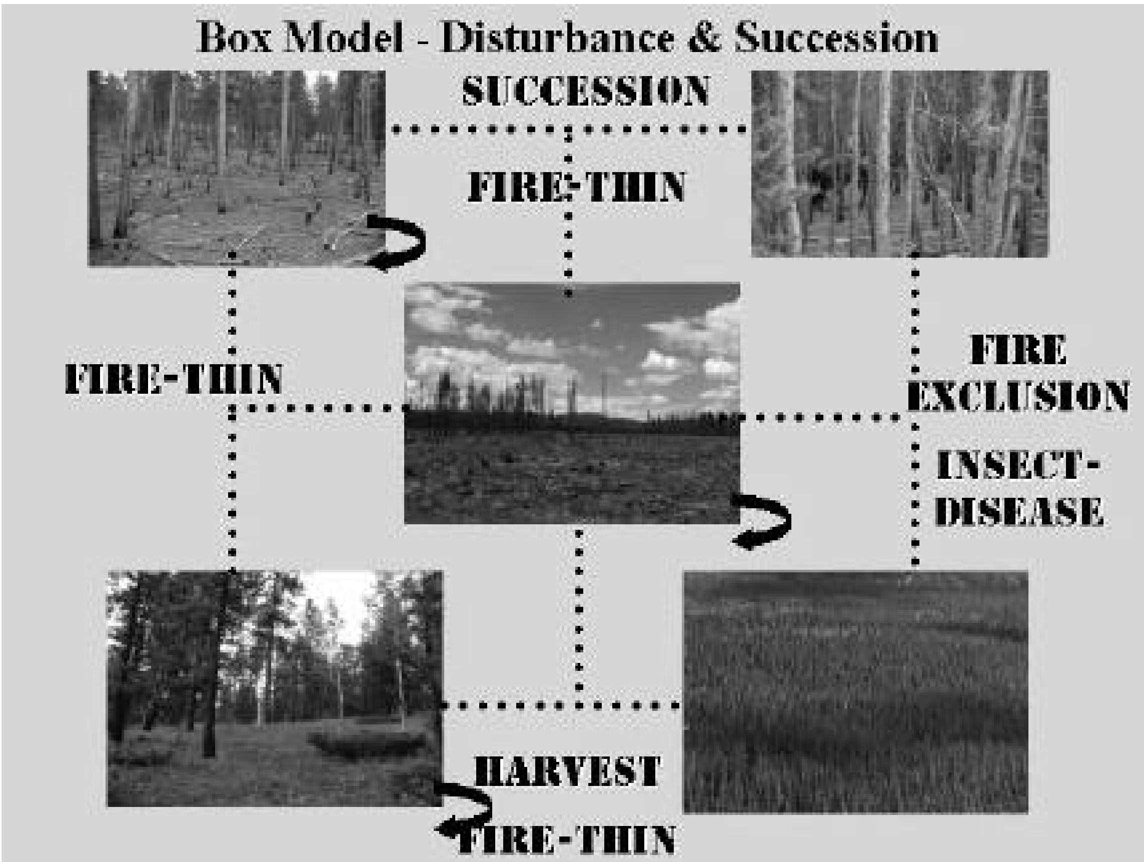

Figure 5. On-the-ground reconnaissance was used to estimate historical (natural) vegetation composition based on stumps, root wads, and logs of ponderosa pine, Douglas-fir, and lodgepole pine in the montane potential vegetation type. Fire scars from stumps indicated that the area had frequent small fires with mixed surface and patches of trees torching, maintained an open, but variable structure with a productive layer of grass, forbs, and low- to moderate-height shrubs.

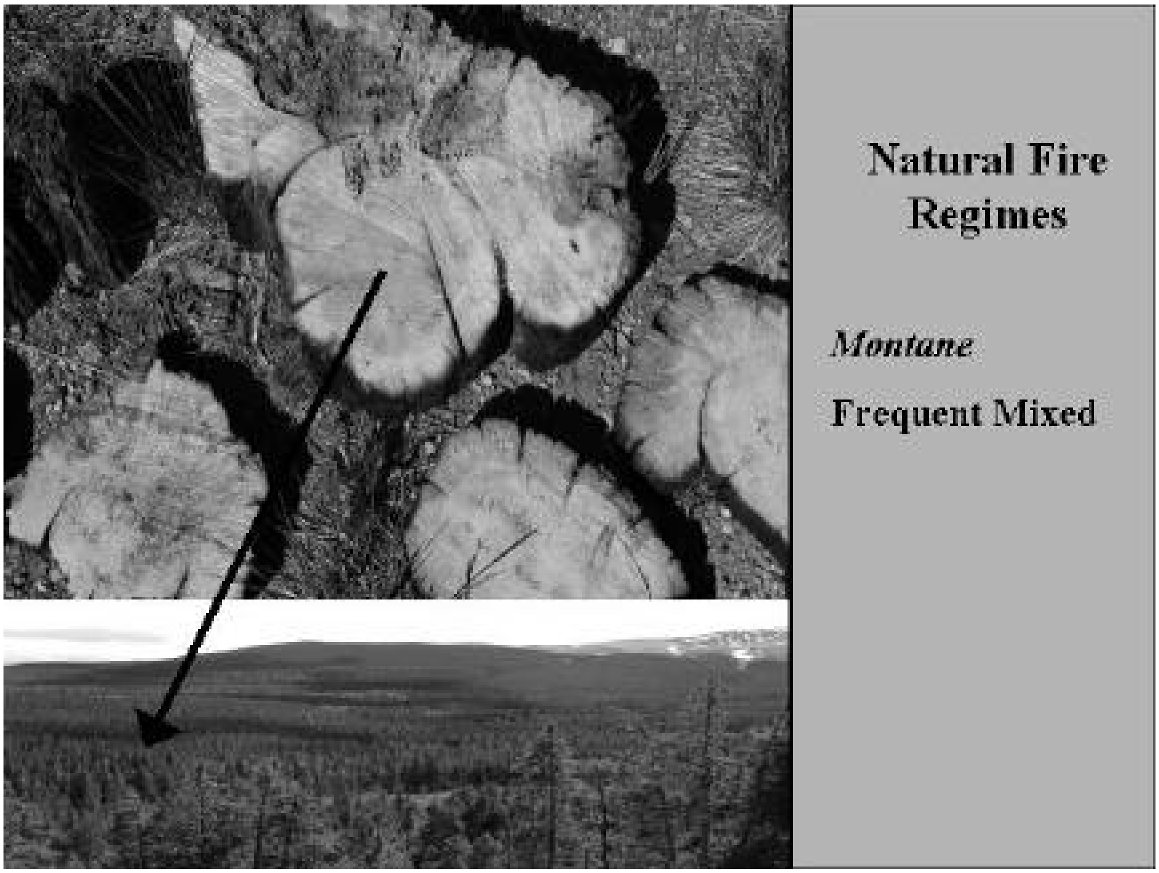

Figure 6. Map of fire regimes developed from the combination of ground reconnaissance, potential vegetation type mapping, and succession and disturbance modeling. Preliminary expert judgment, the literature, and the coarse-scale fire regime mapping (Hardy et al. 2001, Schmidt et al. 2002) indicated a predominance of infrequent replacement regime typical for lodgepole pine. On-the-ground reconnaissance resulted in findings that indicated the historical (natural) vegetation of the montane zone was mixed conifer (ponderosa pine–Douglas-fir–lodgepole pine) with a frequent mixed fire regime.

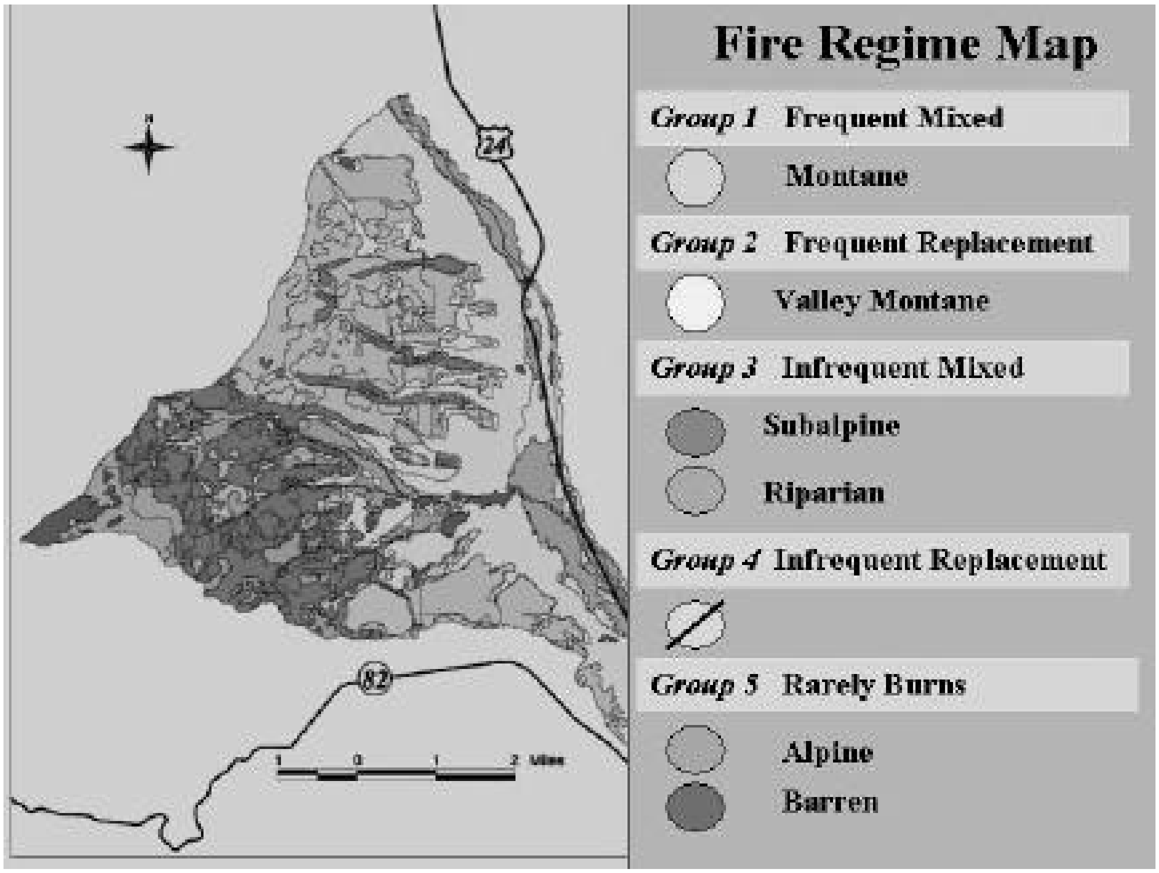

Figure 7. Desired future conditions for the Box Creek Watershed were based on reducing uncharacteristic wildfire (shifting current crown fire hazard to surface–mixed fire behavior), changing forest structure and composition, reducing hazard to wildland–urban interface, and restoring habitats (creating black snags for woodpeckers and nesting holes for bluebirds).

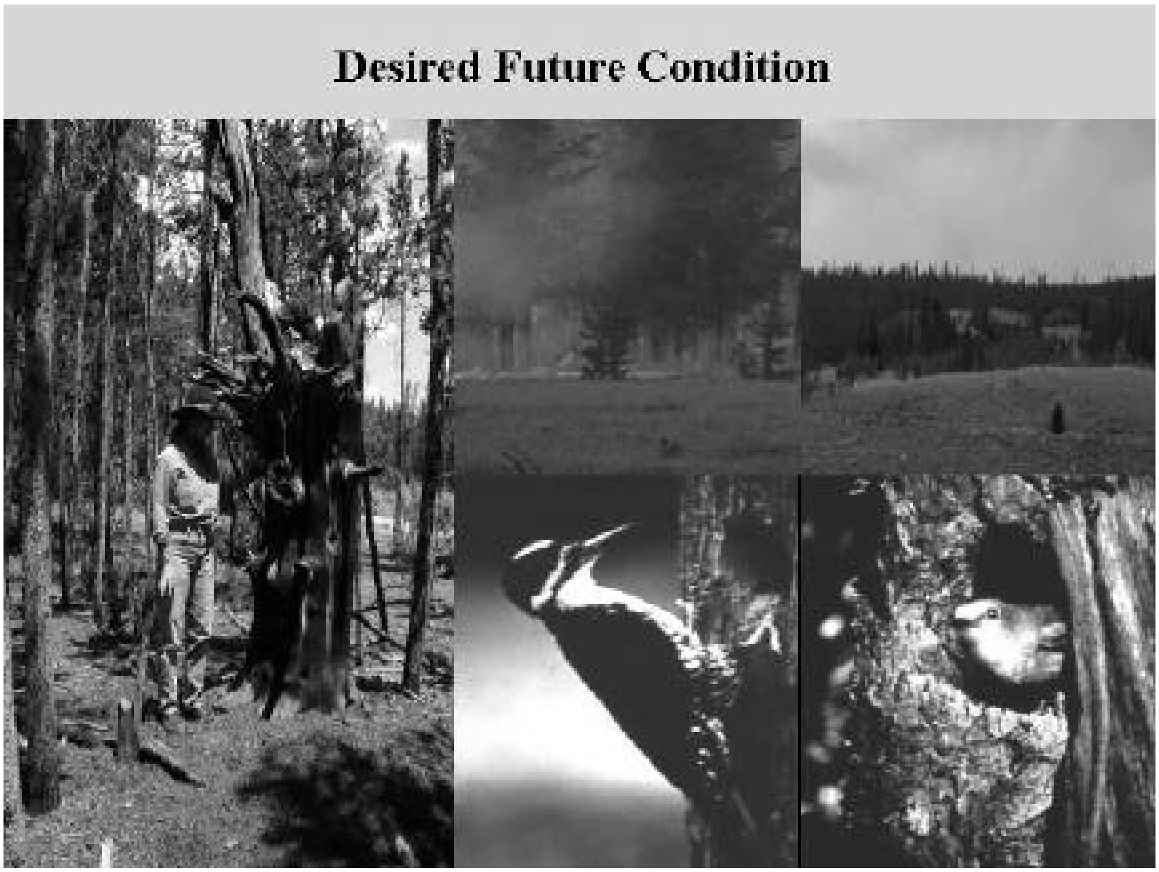

Figure 8. Operationally restorable stands and treatments were identified and designed to achieve the desired future conditions. This included initiating succession to increase composition of large ponderosa pine and Douglas-fir in the mountain montane type. In addition, snags and down wood were retained in the surface–mixed fire regime, while thick lodgepole pines with heavy down fuels (fuel model 10) were managed to initiate early-seral regeneration. An important component of restoration was identifying and designing the restoration of Canada lynx prey (snowshoe hares and red squirrels) habitat. Through an interdisciplinary approach this was accomplished in a way that resulted in the treatment of more area for restoration than originally designed based on traditional fire and timber management objectives.

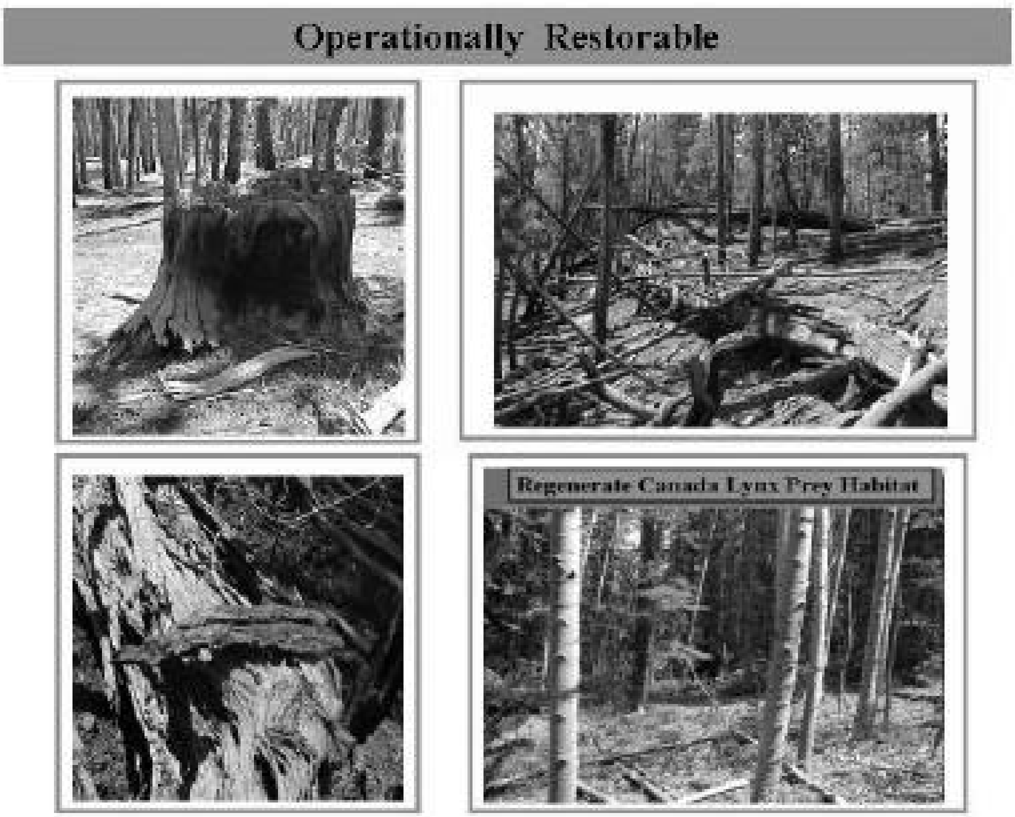

Figure 9. An important treatment was the design of protection options to assure that candidate old-forest aspen stands, as well as other types of characteristic old-forest conditions, were retained since they were at low levels compared to the historical (natural) regime.

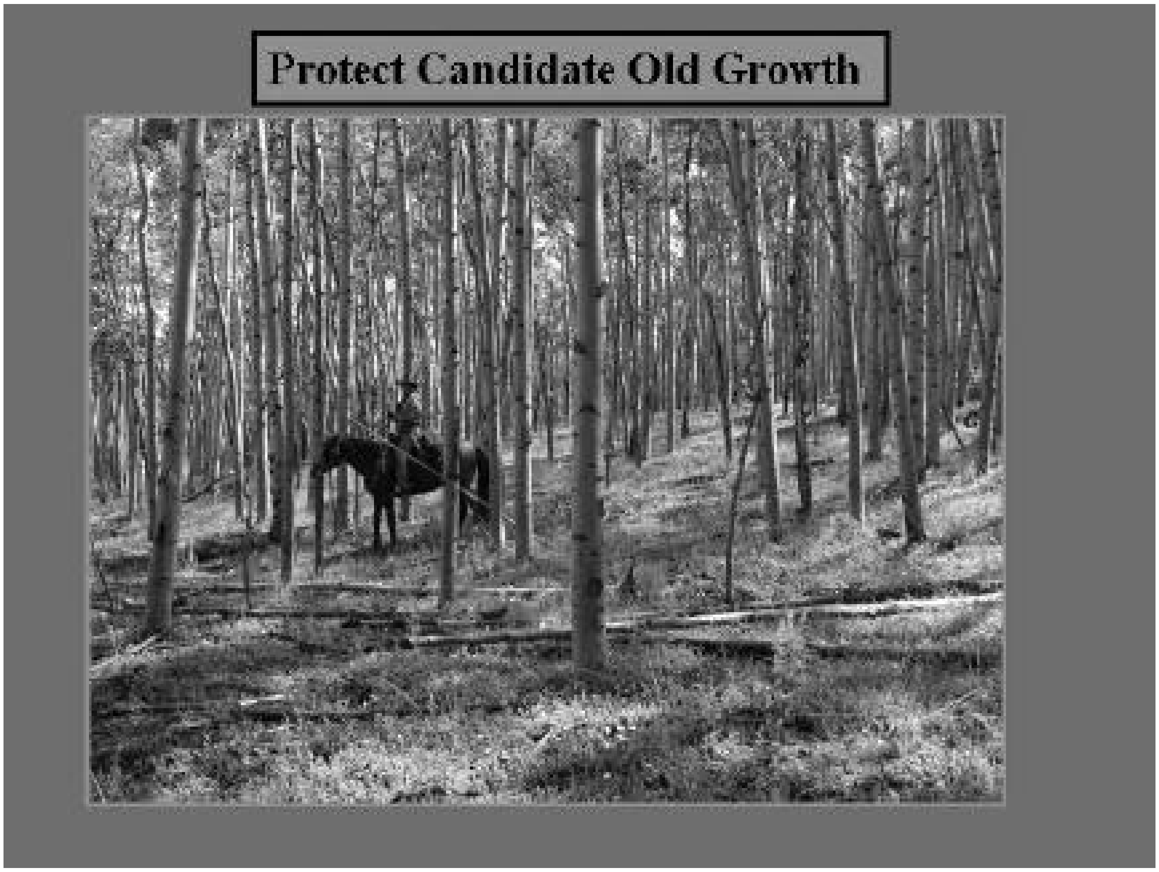

Figure 10. Treatment tools were identified for stands that were operationally restorable based on consideration of current conditions, access, soils, fuel hazards, historical (natural) regime departure, fire regime condition class, wildland–urban interface hazard, and uncharacteristic habitat conditions.

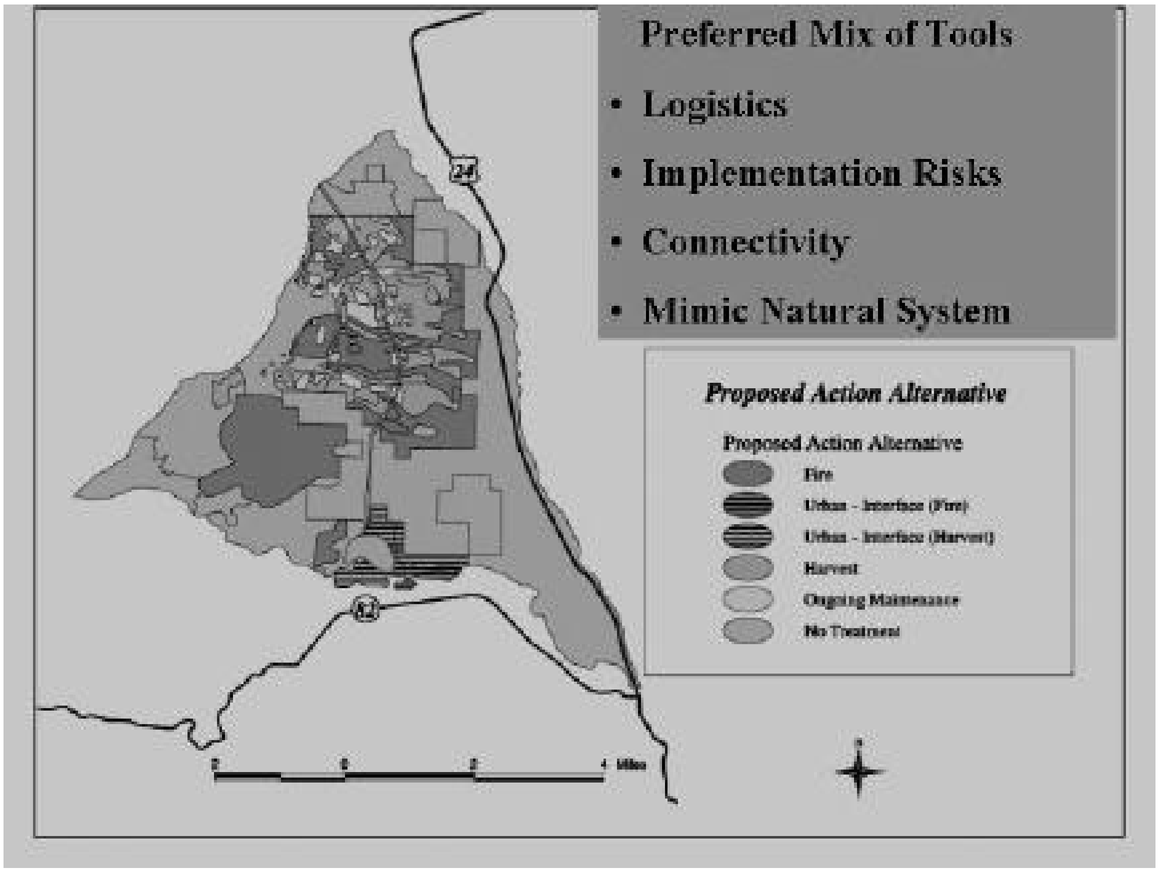

Figure 11. Decision space available for operational restoration to reduce risk of uncharacteristic disturbances (such as wildfire, insect, and disease) to the wildland–urban interface and ecosystems (fire, fuels, resources) is lost as a result of lack of up-front interdisciplinary prioritization, identification of the project purpose and need, and project design. The intersection of the operational space with the natural regime departure that contributes to wildland–urban interface and ecosystem hazard with the legal–policy constraints identifies the decision space that an interdisciplinary team can prioritize and design within. This decision space is substantially reduced when traditional fire and timber management projects are designed primarily to achieve operational and traditional objectives without up-front integration of legal–policy, reference to the natural regime, and science-based hazard measures.