Cheesman Lake—A Historical Ponderosa Pine Landscape Guiding Restoration in the South Platte Watershed of the Colorado Front Range

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Abstract—An unlogged and ungrazed ponderosa pine/Douglas-fir landscape in the Colorado Front Range provides critical information for restoring forests in the South Platte watershed. A frame-based model was used to describe the relationship among the four primary patch conditions in the 35-km^2 Cheesman Lake landscape: (1) openings, (2) ponderosa pine forest, (3) ponderosa pine/Douglas-fir forest, and (4) persistent old growth. Each condition is possible over time at any nonriparian site, with fire and tree recruitment the primary processes causing changes from one condition to another. The Forest Vegetation Simulator model was used to estimate forest conditions at Cheesman Lake in 1900, prior to fire suppression effects. These results and 1896 Cheesman Lake photographs indicate that more than 90 percent of the historical landscape had a crown closure of 30 percent or less, compared with less than 50 percent of current nearby forests affected by logging, grazing, tree planting, and fire suppression. The historical fire regime was mixed severity, and passive crown fire was probably more common than active crown fire. Currently, surrounding forests have almost no openings, little old growth, high tree density, and increased Douglas-fir. Fire behavior has switched to a crown fire regime with sometimes catastrophic results. Historical Cheesman Lake forest landscape conditions are being used to guide restoration of surrounding forests.

Introduction

Restoration of ponderosa pine forests to ecologically sustainable conditions requires knowledge of historical conditions and processes that shaped natural landscapes. Until recently, studies from the Southwestern United States provided the majority of scientific literature describing ponderosa pine stand and landscape structure and the natural processes affecting these forests (Cooper 1960; Covington and Moore 1994; Fulé and others 1997; Mast and others 1999; Moore and others 1999; Pearson 1933; Swetnam and Baisan 1996; Swetnam and others 1999; White 1985; Woolsey 1911). Pine forests in the Southwest historically were characterized by a low-intensity surface fire regime, with fires typically occurring over large areas every 2 to 10 years or more. Stands were described as open and parklike, with productive grassy understories and few small trees. Several reports suggest that the fire frequency in other regions was lower but maintained similar open stands in less productive northern systems (Arno and others 1995; Goldblum and Veblen 1992). Reconstructions of historical stand structures in both the Southwest and other regions have been attempted, but little information on structure of historical ponderosa pine forests at a landscape scale has been available.

Research is being conducted on a 35-km^2 forest area at Cheesman Lake in the Colorado Front Range. Land around Cheesman Lake, a reservoir owned by Denver Water, has never been logged and has been protected from grazing since 1905, when the dam for the reservoir was completed. This research provides a description of a ponderosa pine landscape that evolved with a mixed severity fire regime (Brown and others 1999; Kaufmann and others 2000a,b). Mixed severity fires differ from the frequent low intensity surface fire regime of the Southwest in that individual fire events generally are less frequent and have a patchy crown fire component along with surface fire. They differ from crown fire regimes because the crown fire component is smaller and much more patchy. The Cheesman Lake climate appears to be less influenced by the El Niño pattern and is drier than the climate in the Southwestern United States. Fire history data at Cheesman Lake span eight centuries, with the earliest fire scar sampled dating to 1197 (Brown and others 1999). Maps of fire scar locations shown by Brown and others and additional unpublished data of other fire scar locations indicate that large fires (5–10 km^2 or larger) occurred in 1496, 1534, 1587, 1631, 1696, 1723, 1775, 1820, 1851, and 1880. The only significant fire since 1880 was in 1963, when a fire in the southeast portion of the Cheesman Lake landscape was suppressed after reaching a size of around 25 ha. A moderate number of more localized fires occurred between the larger fires. In addition, extensive studies of tree age and size indicated that tree recruitment occurred in pulses, each about 10 years long (Kaufmann and others 2000b). The recruitment pulses tended to coincide

In: Vance, Regina K.; Edminster, Carleton B.; Covington, W. Wallace; Blake, Julie A. comps. 2001. Ponderosa pine ecosystems restoration and conservation: steps toward stewardship; 2000 April 25–27; Flagstaff, AZ. Proceedings RMRS-P-22. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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with the larger fires; most of the major fires occurred during these pulses, but not necessarily in a cause and effect sequence.

Kaufmann and others (2000a) suggested that relatively infrequent fire and gaps between tree recruitment pulses reflect unfavorable interim climatic conditions for both production of herbaceous vegetation (needed for fuel) and tree seed germination and establishment. In many of their plots, the age of the oldest tree at specific locations in the Cheesman Lake landscape indicated that all trees postdated certain fires identified in the study area by the fire history analysis (Brown and others 1999). Similar results were observed in western Montana (Arno and others 1995). These data strongly suggest that the crown fire component of past fires killed all trees in certain areas and created openings. The current oldest trees reflect the dates trees were recruited into each opening. An expansion of this analysis is given in another paper in these proceedings (Huckaby and others).

Fire and tree recruitment patterns are key processes affecting landscape structure and change over time in the Cheesman Lake landscape. In this paper we describe the four primary types of forest patches that make up the upland landscape. These four components are interchangeable in that they potentially can occur at any upland site over time. The components are useful for describing not only the historical landscape, but also forests that were altered following European settlement. While riparian areas are critical components occupying 1–2 percent of the landscape, they are separate from the upland sites and are not included in our analysis of the upland areas.

We use a frame-based model to discuss the factors that cause transitions of the upland conditions from one state to another (Starfield and others 1993). In addition, we use a forest growth model to "degrow" the Cheesman Lake landscape to assess its condition prior to the effects of fire suppression during the 20th century. These "degrown" conditions are compared with historical photographs of the Cheesman Lake landscape. Finally, we discuss implications of presettlement fire behavior and landscape structure on current restoration activities in the South Platte watershed.

Primary Upland Components

Ponderosa pine forests in the historical Cheesman Lake landscape and elsewhere in the Colorado Front Range are relatively simple in that only two species, ponderosa pine and Douglas-fir, comprise the vast majority of trees (Jack 1900; Kaufmann and others 2000b; Peet 1981; Veblen and Lorenz 1986). While fire suppression during the last century is believed to have increased forest density at Cheesman Lake (discussed later), diversity in age and diameter class distributions, tree density, proportions of the two species, and patch size make the landscape structure very complex, driven by both topography and natural disturbance history. In an adjacent logged landscape, other species (Colorado blue spruce, aspen, narrow-leaf cottonwood, and Rocky Mountain juniper) are more significant, especially in lowland areas (Kaufmann 2000b). We mapped and classified the entire 35-km^2 landscape using an overstory classification template created from extensive plot data (data summarized in Kaufmann and others 2000b) in conjunction with 1:6000 color infrared photographs. Over 3,000 polygons in the historical landscape were classified by percent crown closure in six distinct diameter distribution classes. While polygon characteristics are still being analyzed in GIS, the mapping and classification effort provides a basis for understanding landscape dynamics discussed here.

Examination of plot and polygon data and extensive field observations indicate that four basic stand conditions are found in the Cheesman Lake landscape (fig. 1). These are roughly based on stand development stages and successional trajectories. The conditions are (1) openings vegetated primarily with grasses and shrubs, (2) patches that are pure or nearly pure ponderosa pine, (3) patches having both ponderosa pine and Douglas-fir, and (4) patches having very old trees, which we term "persistent old growth." Openings presently existing in the Cheesman Lake landscape have coarse woody debris dated to 1851, a year in which a large fire occurred (Brown and others 1999). Only one opening of 49 was found having no coarse woody debris (Tobler 2000), indicating that nearly all openings are a transient patch condition in the landscape. The pine and pine/Douglas-fir patches have a specific characteristic distinguishing them from persistent old growth: a cap or upper limit on the age of the oldest trees in the patch. This suggests that they developed following a stand-replacing natural disturbance, most likely fire (Kaufmann and others 2000b). The oldest trees may be quite old (more than 400 years), but even the oldest trees in these patches postdate known fires. In contrast, the persistent old-growth patches appear to be regulated primarily by microscale disturbances that kill only one or a few trees at a time, such as heartrot, insect attack, windthrow, or very small fires. Trees in these patches have a wide age distribution (some may be more than 500 years old), with varying states of health, and a large amount of coarse woody debris is common.

Frame Model of Landscape Components

Model Description

The relationships among the forest patch conditions shown in figure 1 and the key processes affecting the transitions between them are shown in a frame-based model, where each frame represents a potential condition that can exist on a site (fig. 2). Extensive field data on fire history and tree recruitment indicate that the following processes affect transitions among states. First, tree recruitment converts openings created by fire to forest (fig. 2, arrows with small trees). Ponderosa pine patches develop when recruitment is limited to this single species. Age data for a large number of field plots suggest that historically, pure ponderosa pine stands developed on most east, south, and west slopes. In contrast, mixtures of ponderosa pine and Douglas-fir trees often were recruited on north aspects. Tree age data indicate that in the 1900s (during which fire suppression occurred), patches became much more dense, and many pure ponderosa pine patches were converted to mixed patches through ingrowth of Douglas-fir.

Figure 1—Four major patch components of the ponderosa pine/Douglas-fir landscape of the South Platte watershed in the Colorado Front Range. (Upper left) openings; (lower left) persistent old growth; (upper right) ponderosa pine; and (lower right) ponderosa pine/Douglas-fir. Each condition may occur on all upland sites. Parameters of each component are found in table 1.

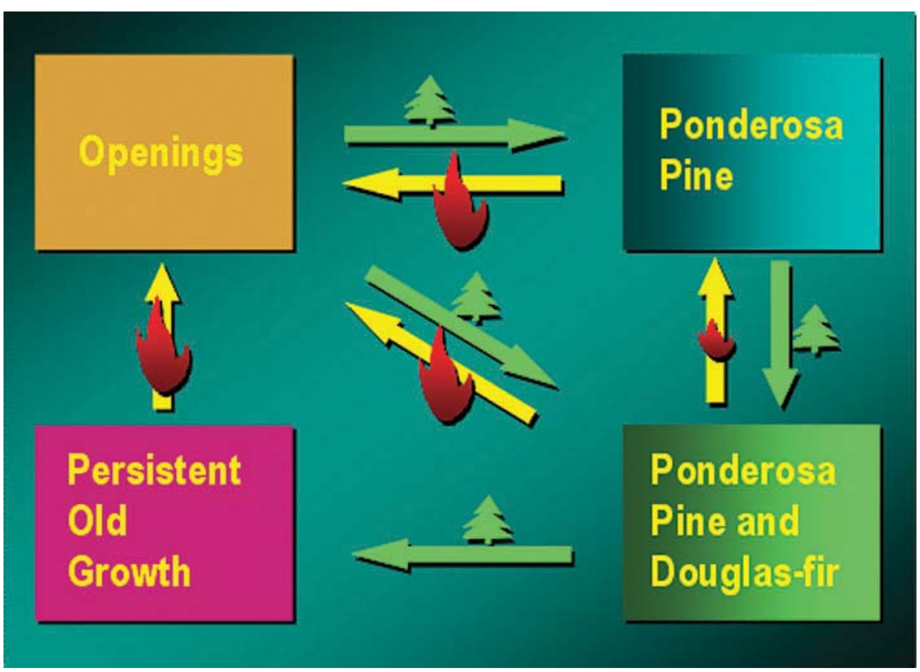

Figure 2—Frame model showing the interrelationships among openings and patches of ponderosa pine, ponderosa pine/Douglas-fir, and persistent old growth in the South Platte watershed of the Colorado Front Range. Arrows with trees represent tree recruitment processes, and arrows with flames represent either crown fire creating openings or surface fire reducing ingrowth of Douglas-fir.

Persistent old-growth patches in our model require very old trees, which we define to be the condition in which trees die predominately from natural causes other than stand-replacing fires. Recruitment occurs where small openings provide enough resources for new trees to be incorporated into the stand. While the oldest trees generally are ponderosa pine, older Douglas-fir trees are found in many persistent old-growth patches (Huckaby and others, this proceedings). We have observed a few pine trees more than 600 years old, some over 500, and many exceeding 400 years. Trees recruited after the fire in 1496 could be 500 years old, and we are not confident in suggesting that these trees reflect recruitment after a stand-replacing fire in 1496 because many trees die for reasons other than fire before reaching an age of 500 years. We are more confident suggesting that trees postdating the 1531 fire reflect a stand-replacing event (Huckaby and others, this proceedings). A caveat in suggesting that polygon reforestation postdates specific fires, however, is that there always is the possibility that older trees predating the indicated fire may have died of other causes. Nonetheless, extensive data over a large portion of the landscape suggest that age caps related to stand-replacing fires are common, and these age caps are useful for understanding landscape dynamics (Arno and others 1995; Kaufmann and others 2000a,b; Huckaby and others, this proceedings).

Fire is almost certainly the primary process creating openings of 1 ha or more in the landscape (fig. 2, arrows with flames). There is little likelihood that other natural disturbance factors such as insects, disease, or wind could have resulted in complete mortality in this system (Kaufmann and others 2000b). Stand-replacing fires were probably more common in ponderosa pine and pine/Douglas-fir forest patches and less common in persistent old growth. Characteristics of stand-replacing fires in the historical Cheesman Lake landscape are discussed later. All fires undoubtedly had a surface fire component, and under certain conditions surface fires may have reduced ingrowth of younger Douglas-fir, thereby converting mixtures of pine and Douglas-fir back to pure or nearly pure ponderosa pine.

Model Parameters

Tree age, density, species composition, and fire history data provide insight into probabilities of changes among components in the frame model shown in figure 2. Table 1 provides criteria we have adopted to distinguish among the four patch conditions. We believe these criteria are suitable for most of the ponderosa pine forest area of the South Platte basin. Openings are defined as areas that have 10 percent or less crown closure. We distinguish between pure ponderosa pine and ponderosa pine/Douglas-fir patches based upon basal area or density of trees. Patches having more than 10 percent of the basal area or more than 20 percent of the trees breast height or taller in Douglas-fir are considered ponderosa pine/Douglas-fir patch types.

Information about the fire and tree recruitment processes that change the condition from one patch type to another is summarized in table 2. This information reflects data for 4 centuries before Euro-American settlement, which occurred in the late 1800s. Current analyses indicate that large fires (more than 5 km^2, listed in the introduction)

Table 1—Characteristics of patches in ponderosa pine/Douglas-fir forests in the unlogged Cheesman Lake and adjacent logged Turkey Creek landscapes. Patch types are those shown in figure 1. BA = basal area.

Patch type	Crown closure	Condition	Tree age structure
Openings	≤10 percent	May be mixed species	Few, generally young
Ponderosa pine	>10 percent	≤10 percent BA Douglas-fir, and ≤20 percent of trees Douglas-fir	Age cap evident May be old growth
Ponderosa pine/Douglas-fir	>10 percent	>10 percent BA Douglas-fir, or >20 percent of trees Douglas-fir	Age cap evident May be old growth
Persistent old growth	>10 percent	Mixed ponderosa pine and Douglas-fir	No age cap evident Very old

Table 2—Fire and tree recruitment characteristics affecting changes in ponderosa pine/Douglas-fir patch structure in the Cheesman Lake landscape. Processes are those depicted by arrows in figure 2. Data summarized from Brown and others (1999), Kaufmann and others (2000b), and additional analyses of fire scars and tree ages.

Process	Mean interval	Range
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Fires >5 km^2 in 35-km^2 landscape, 1496–1880	42.7 ± 12.7	27–65
Fires in 0.5-2 km^2 areas, 1496–1880	50.0 ± 17.2	29–83
Tree recruitment, 1588–1885	45.3 ± 23.5	18–82

occurred with a mean interval of about 43 years in the 35-km^2 landscape. This estimate is shorter than the 59 years estimated by Brown and others (1999) because it includes three fires (1775, 1820, and 1880) not included in the earlier analysis. These fires were included here based upon additional evidence of fire scars not available earlier. When the fire scar sampling area was divided into 11 smaller areas of 0.5-2 km^2 each based upon sampling clusters and topography, the mean fire interval for all areas was 50 years, with a range of 29 to 83 years. Studies are under way to assess fire intervals in other portions of the South Platte watershed.

Tree age data for a 4-km^2 portion of the Cheesman Lake landscape were obtained by dating cores collected 30–40 cm above the ground, and correcting the pith age for the estimated time required after germination to reach the coring height (Kaufmann and others 2000b). These data indicated that most tree recruitment occurred in pulses lasting about a decade each (see fig. 6 in Kaufmann and others 2000b). For a 421-year period between the 1560s and 1980s, half of the surviving trees in 25 0.1-ha plots in the Cheesman Lake landscape were recruited in these pulses, which accounted for only one-fourth of the time. The mean interval between recruitment pulses was about 45 years, which agrees closely with the MFI for the area (table 2).

Current and Historical Landscape Crown Closure

A frame model is useful for assessing how important processes and conditions affect patch dynamics over time and space at a landscape scale. We are addressing the application of a frame model at a landscape scale by examining landscape structure at several points in time. At the initial stages of this application, we are focusing on diameter class distribution and crown closure, which we can estimate using 1:6000 color infrared photographs. The infrared photographs cannot be used to map and classify patches based upon species composition, but they provide a basis for mapping by diameter class distribution and crown closure. The map of percent crown closure in figure 3 (left) was developed from photographs taken in 1996. This map indicates that current crown closure varies widely, with many areas having very open forest (10–30 percent crown closure) and others dense forest (more than 45 percent).

A tree growth model, Forest Vegetation Simulator (FVS, USDA Forest Service 1999), was used with polygon data on tree diameter class distribution and density to "degrow" patches back to 1900, the time just before fire suppression efforts may have begun on the landscape. FVS cannot be run backward in time; however, through a trial and error process

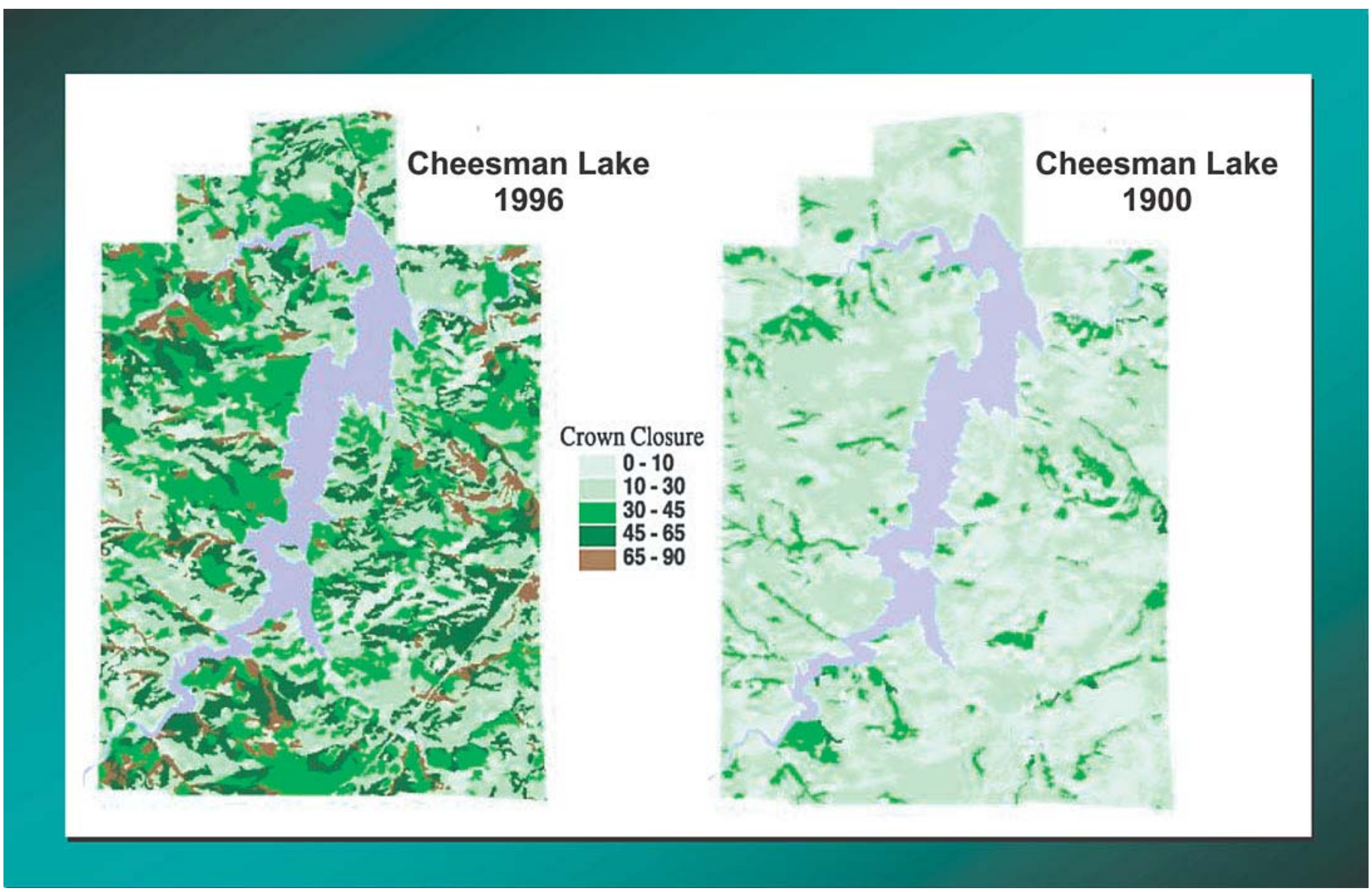

Figure 3—Crown closure percent for the Cheesman Lake landscape. The 1996 map was developed from 1:6000 color infrared photographs and a patch classification template based on plot data. The 1900 map was developed using the Forest Vegetation Simulator to estimate conditions that, projected forward, yielded conditions observed in 1996.

average stand conditions can be identified for earlier periods that, when grown forward, are comparable to current stand conditions. Stand conditions for 1900 were accepted when FVS projections to 1996 agreed well with current (1996) estimates of stand size class distributions and densities. While a number of simple assumptions about tree recruitment rates and mortality will be reexamined, an initial version of the landscape condition in 1900 derived from these calculations is shown in figure 3 (right). Differences between 1996 and 1900 are dramatic, yet the very low forest densities estimated for 1900 agree very well with age structure data for plots with 20th century trees removed and with the open forest structure shown in historical photographs.

Historical photographs taken in 1896 near the site being selected at the time for the Cheesman Lake dam (Denver Water archives, Denver, Colorado) augment our understanding of forest structure at several locations in the Cheesman Lake landscape prior to the effects of 20th century fire suppression. While some grazing undoubtedly had occurred late in the 19th century (primarily along the river), effects on forest structure in the photographed areas are believed to be negligible. Nor was logging a factor, based upon archived records of logging history in the area (South Platte District Office of the Pike/San Isabel National Forest). However, fire suppression limited burning to a single wildfire smaller than 100 ha in 1963. The photograph in figure 4 includes an area in the foreground known to have burned in the 1880 fire, probably resulting in the dead trees on the ground. Across the valley (which is presently part of the reservoir), the far left background shows openings that we believe were created by a fire in 1851. The area in the center across the valley presently has many old trees, indicating it was largely free of stand-replacing fire for at least several centuries, even though fires occurred there in 1631, 1696, 1820, and 1880 (Brown and others 1999). Figure 4 and other historical photographs of unlogged areas show a generally very low historical forest density, a limited number of small trees, and an understory dominated by grasses and shrubs.

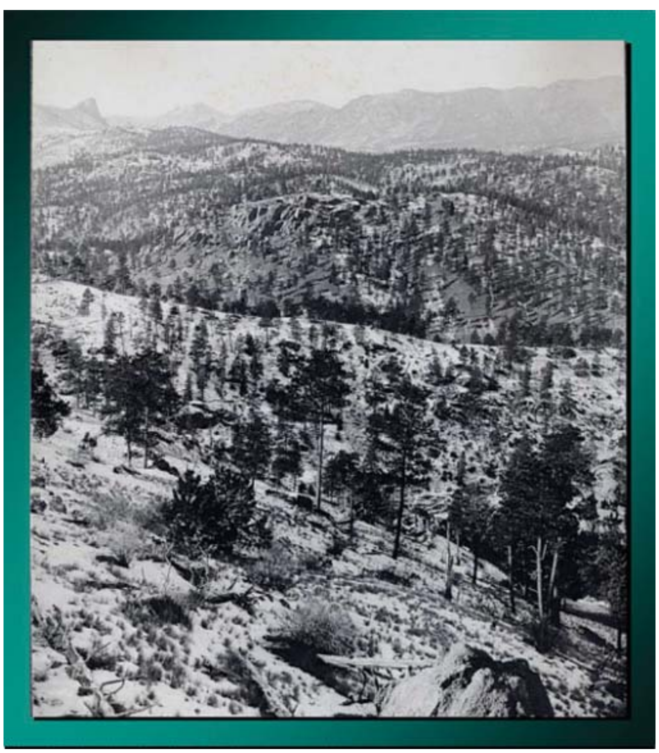

Figure 4—Historical photograph illustrating forest density of the unlogged Cheesman Lake landscape in 1896. Photograph from archives of the Denver Water Department.

Since fire suppression, however, stands have become denser both in the Cheesman Lake landscape and in all nearby areas where logging and grazing occurred. Ingrowth of Douglas-fir is common on all aspects and has converted many ponderosa pine stands into mixtures of the two species. Paired photographs in the Cheesman Lake landscape from 1903 and 1999 (fig. 5) illustrate the change in forest density and loss of openings (right background) along the South Platte River just below the Cheesman Lake dam. A notable exception to the increased forest density in the Cheesman Lake landscape is the area burned in 1963. This area, which had previously burned in 1851, was thinned dramatically by the 1963 fire, leaving a forest structure similar to that found in figure 4.

Polygon crown closure data were compared in GIS for the 1996 Cheesman Lake and adjacent Turkey Creek landscapes, and for the Cheesman Lake landscape degrown to 1900. The Turkey Creek polygon data were for a 4-km^2 study area just outside the historical landscape. This landscape was logged in the 1890s and typifies other forests in the South Platte watershed, though other areas logged earlier may be denser. The landscape area for low, medium, and high crown closure is shown in figure 6. These data suggest that in 1996 only 55 percent of the Cheesman Lake landscape and 47 percent of the Turkey Creek landscape had crown closures of 30 percent or less. However, we estimate that in 1900 over 90 percent of the Cheesman Lake landscape had crown closures no greater than 30 percent. The amount of the landscape having a crown closure of 30 percent or less is significant, because at these tree densities fires usually do not spread from crown to crown. Though preliminary, these estimates and historical photographs support the widely held view that earlier ponderosa pine forests in the Colorado Front Range were much less dense than presently found.

Frame Model Component History

The proportion of the overall landscape we estimated to be occupied by each of the four patch conditions in figures 1 and 2 is shown in figure 7. The upper portion (Historical to Settlement) depicts proportions that we believe occurred the last several centuries before the effects of settlement. The illustration refers only to upland areas and does not include riparian areas (1–2 percent of the landscape) or meadows existing along the South Platte River before the reservoir was completed. The proportions are based on examinations of tree ages for ponderosa pine and Douglas-fir trees over a range of topographic conditions and over a large portion of the landscape (Kaufmann and others 2000b; Huckaby and others, this proceedings). As noted earlier, data indicate that

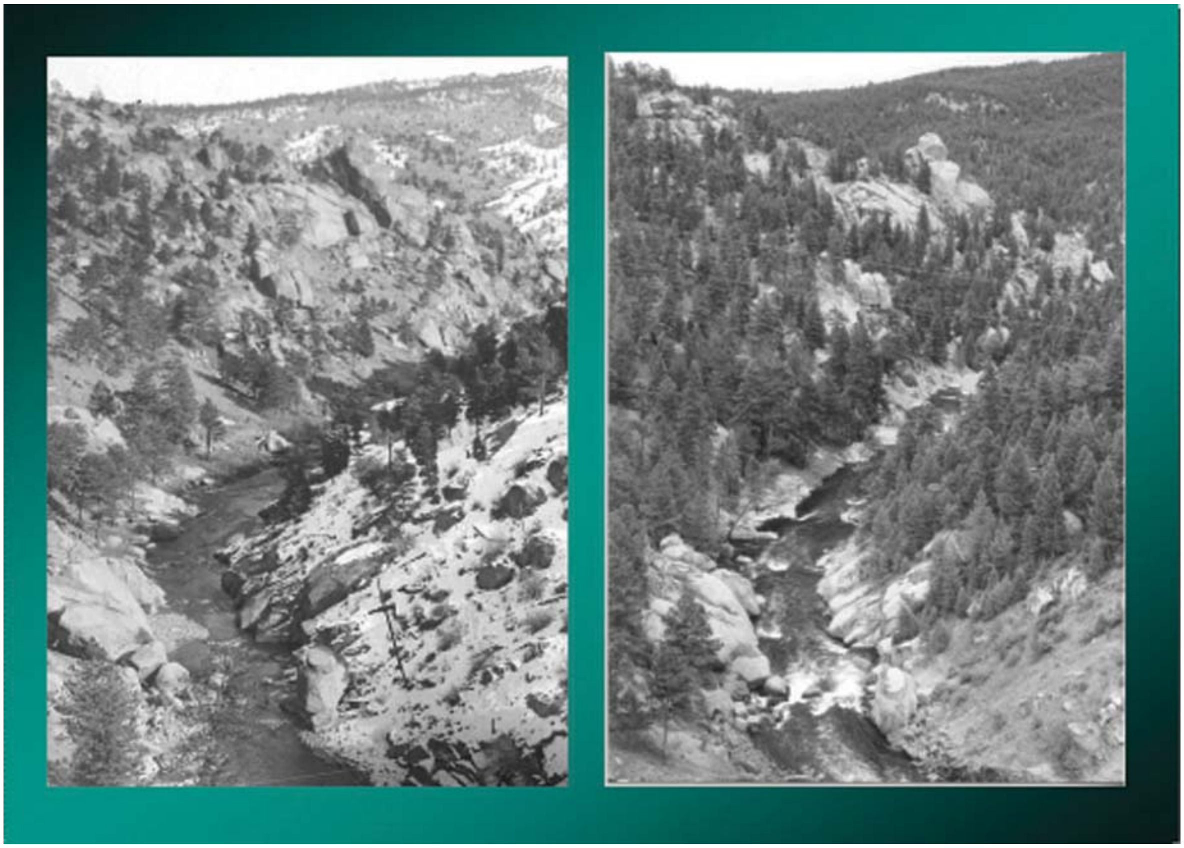

Figure 5—Paired photographs showing forest condition along the South Platte River just below the Cheesman Lake dam in 1903 (left) and 1999 (right). The 1903 photograph is from archives of the Denver Water Department.

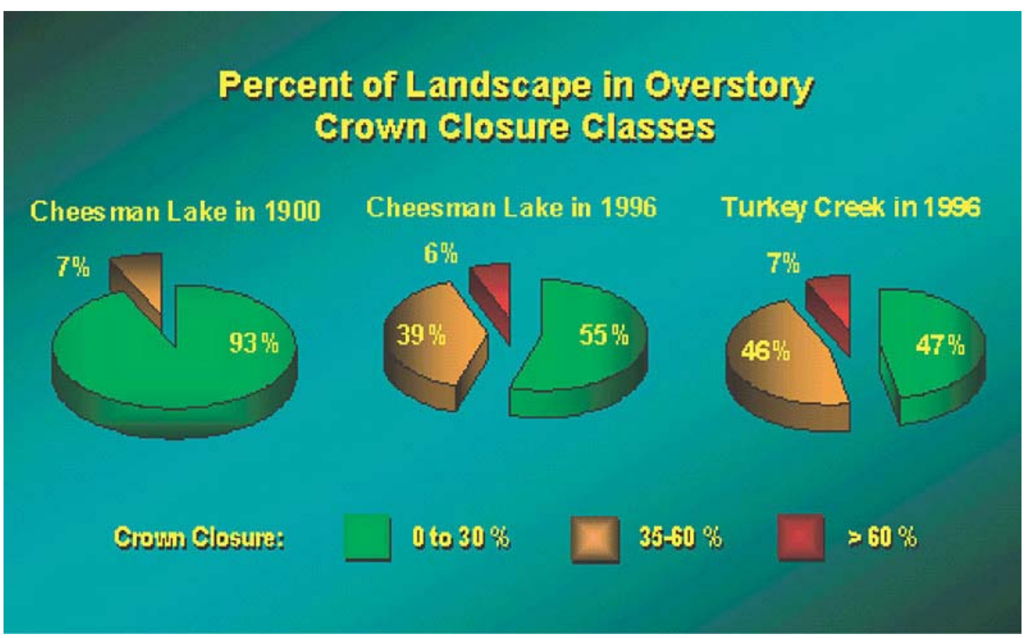

Figure 6—Proportion of the landscape covered by forest in crown closure classes, showing dramatic increases in crown closure since 1900. Cheesman Lake data for 1900 and 1996 are the same as shown in figure 3. Turkey Creek data for 1996 are for a logged area adjacent to the Cheesman Lake landscape.

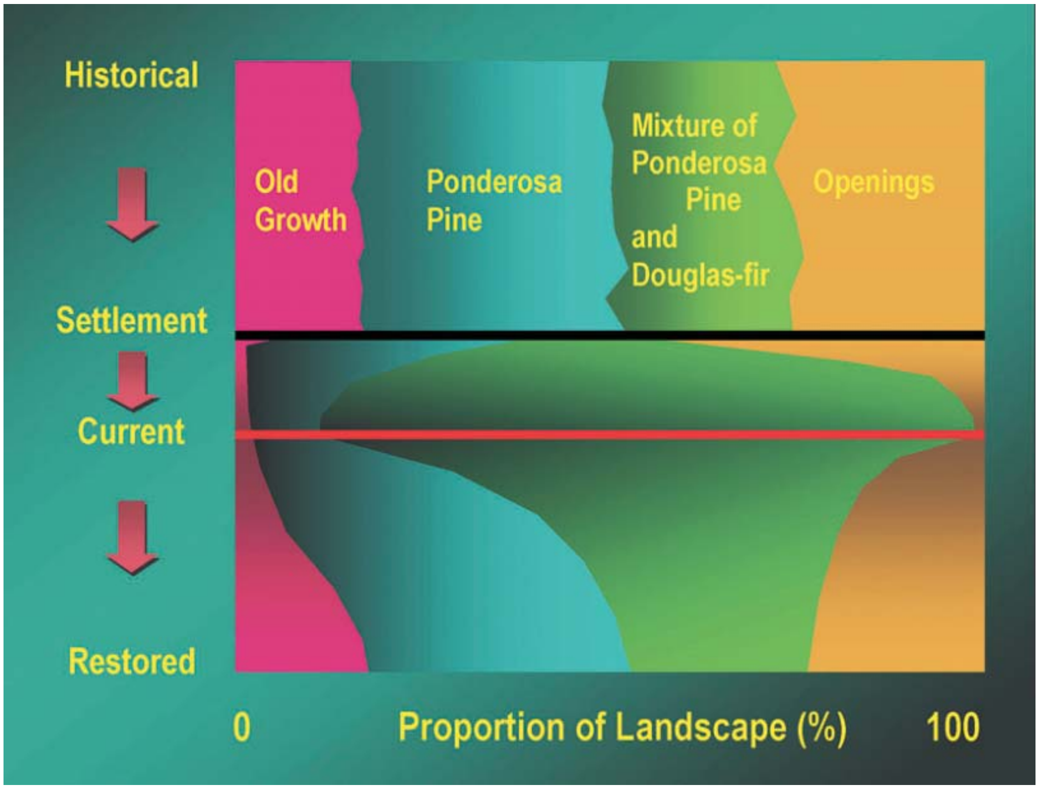

Figure 7—Estimated proportions for the four components of the ponderosa pine/Douglas-fir forest landscape in the South Platte watershed. The period from Historical to Settlement reflects information from Cheesman Lake in the absence of logging, grazing, or fire suppression effects. The period from Settlement to Current reflects changes in forest conditions found in much of the logged and grazed South Platte watershed. The period from Current to Restored reflects landscape changes that might occur under a restoration scenario.

before settlement most trees on east, south, and west slopes were ponderosa pine, whereas Douglas-fir and ponderosa pine occurred in roughly equal proportions on north slopes.

We estimate that about 15 percent of the landscape had persistent old-growth patches (fig. 7). Pure ponderosa pine patches (see table 1 for characteristics) probably accounted for 35–50 percent of the landscape, primarily on east, south, and west slopes. Ponderosa pine/Douglas-fir patches on north slopes and portions of upper ridges may have accounted for 20–30 percent of the landscape, and at least 25 percent of the landscape was open, with no more than 10 percent tree crown closure. Undoubtedly these proportions varied over time, especially when fires created openings, reduced tree densities, or killed young Douglas-fir trees invading patches. Furthermore, tree densities (represented by shading in fig. 7) and the amount of Douglas-fir are likely to have increased within each category as time since fire increased.

The middle portion of figure 7 indicates general shifts we estimate occurred in the forest components of areas outside the historical landscape. These estimates are based on measurements in the adjacent logged Turkey Creek landscape and on observations of forest structure throughout the South Platte watershed. The shifts in patch proportions reflect the effects of logging, grazing, fire suppression, and transplanting, all of which are likely to increase forest density. Logging decreased the amount of persistent old growth. Grazing probably reduced understory competition and allowed the establishment of new seedlings, and the lack of fire allowed the seedlings to survive. The result was a sharp increase in forest density, expansion of the area having a significant Douglas-fir component, and the loss of most openings that temporarily increased during logging. The Current to Restored portion of figure 7 is discussed below.

Implications About Fire Behavior

The current condition of ponderosa pine/Douglas-fir forests in the Colorado Front Range favors a crown fire regime, with a high risk of catastrophic stand-replacing fires. The Buffalo Creek fire in 1996, about 10 miles north of Cheesman Lake, burned 4,800 ha (11,900 acres), of which 3,000 ha (7,500 acres) was a crown fire that traveled 11 miles in $4\frac{1}{2}$ hours. Forest conditions here are similar to those throughout much of the West, with high tree densities favoring crown fires (Covington and Moore 1994).

Strong evidence suggests that the historical fire behavior at Cheesman Lake followed a mixed severity fire regime, which is characterized by a combination of surface fire and patchy crown fire occurring within the fire perimeter. Data suggest that many forest patches have an age cap, indicating regeneration following a stand-replacing disturbance (fire), while other patches nearby retained much older trees (Huckaby and others, this proceedings; Kaufmann and others 2000b). We originally hypothesized that the mixed severity fire pattern creating the openings resulted from long intervals between fires, during which stand density and fuel ladder conditions increased. These conditions would have led to forest patches burning by active crown fire (fire spreading both on the surface and tree-to-tree). We now suspect that low stand densities (crown closure under 35 percent) were the general condition in the historical landscape, and we hypothesize that the mixed severity fire regime included passive crown fire (ignition from a surface fire and not from adjacent crowns) as a major component, because trees were generally too far apart to spread fire in the crowns.

More open forests would likely have had a grassy understory, perhaps with a strong but patchy shrub component including primarily mountain mahogany and currant. Local fire behavior specialists suggest that the transition between grassy understory vegetation and a litter surface fuel condition occurs between 30 and 40 percent crown closure (Henry Goehle and Doug Steven, personal communication). While coarse-textured granitic soils and low precipitation result in low overstory and understory productivity in the study area, particularly when the climate is in dry cycles, more open stand conditions would favor better (though patchy) understory production. Furthermore, fires are most common during the decade-long pulses of tree recruitment, when climatic conditions probably favor both tree recruitment and understory production favorable for surface fire (Kaufmann and others 2000b). If shrubs, low limbs, or coarse woody debris accumulate beneath individual tree crowns, large numbers of trees may be killed by passive crown fire. In addition, we suspect that small patches of young trees may have occurred in some areas, and these patches may have been burned by localized active crown fires. Thus passive crown fire and very localized active crown fires in young trees were probably major causes of openings and low density forest in the South Platte ponderosa pine/Douglas-fir system.

Implications for Landscape Restoration

Research at Cheesman Lake on characteristics of historical ponderosa pine/Douglas-fir landscapes provides a sound basis for landscape restoration in surrounding areas (Culver and others, this proceedings). Clearly the current forest density and amount of Douglas-fir in these areas are too high. The 11,900 acre Buffalo Creek fire in 1996 near the Cheesman Lake landscape illustrated the huge risks of wildfire and postfire erosion in these dense forests.

An ecologically sustainable landscape would have a forest structure similar to that found historically, presuming that climatic conditions have not changed substantially. The lower portion of figure 7 suggests how changes in the four primary components of the South Platte basin might be returned to the landscape structure conditions found historically. The amount of persistent old growth, reduced sharply by logging of old trees, requires considerable time for restoration. However, many trees over 200 years exist in logged areas examined in the Turkey Creek landscape adjacent to Cheesman Lake and in logged forests northeast of Deckers in potential restoration areas, placing the age structure well on the trajectory for reestablishing the persistent old-growth condition (Kaufmann 2000b). Restoration activities should protect all old trees.

Openings existed historically but were lost since settlement. They can be recreated by removing trees, perhaps through a combination of mechanical treatment and prescribed burning. The ponderosa pine component can be restored by selective removal of Douglas-fir, and thinning would reduce densities to levels found historically. Similar treatments would reduce the spatial extent of the ponderosa pine/Douglas-fir component.

A landscape assessment for the South Platte watershed identified several large subwatersheds at high risk of wildfire and postfire erosion (Culver and others, this proceedings). These areas are close to the Cheesman Lake landscape, and they have similar topography, soils, and climate. Restoring historical conditions is likely to address the two major issues of the Upper South Platte Watershed Protection and Restoration Project (Culver and others, this proceedings): (1) restoration of the landscape to an ecologically sustainable condition, and (2) mitigation of the risk of large-scale crown fires and postfire erosion. The changes in landscape components in the lower portion of figure 7 address both of these issues.

It is unrealistic to expect the entire South Platte watershed to be restored to historical conditions in a short amount of time. Furthermore, in some places the historical condition may not be the desirable outcome. However, with priorities established by the landscape assessment for the South Platte watershed, restoration of portions of the overall watershed can be staged to create fuel breaks that reduce the risk of large-scale crown fires such as that in Buffalo Creek in 1996.

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