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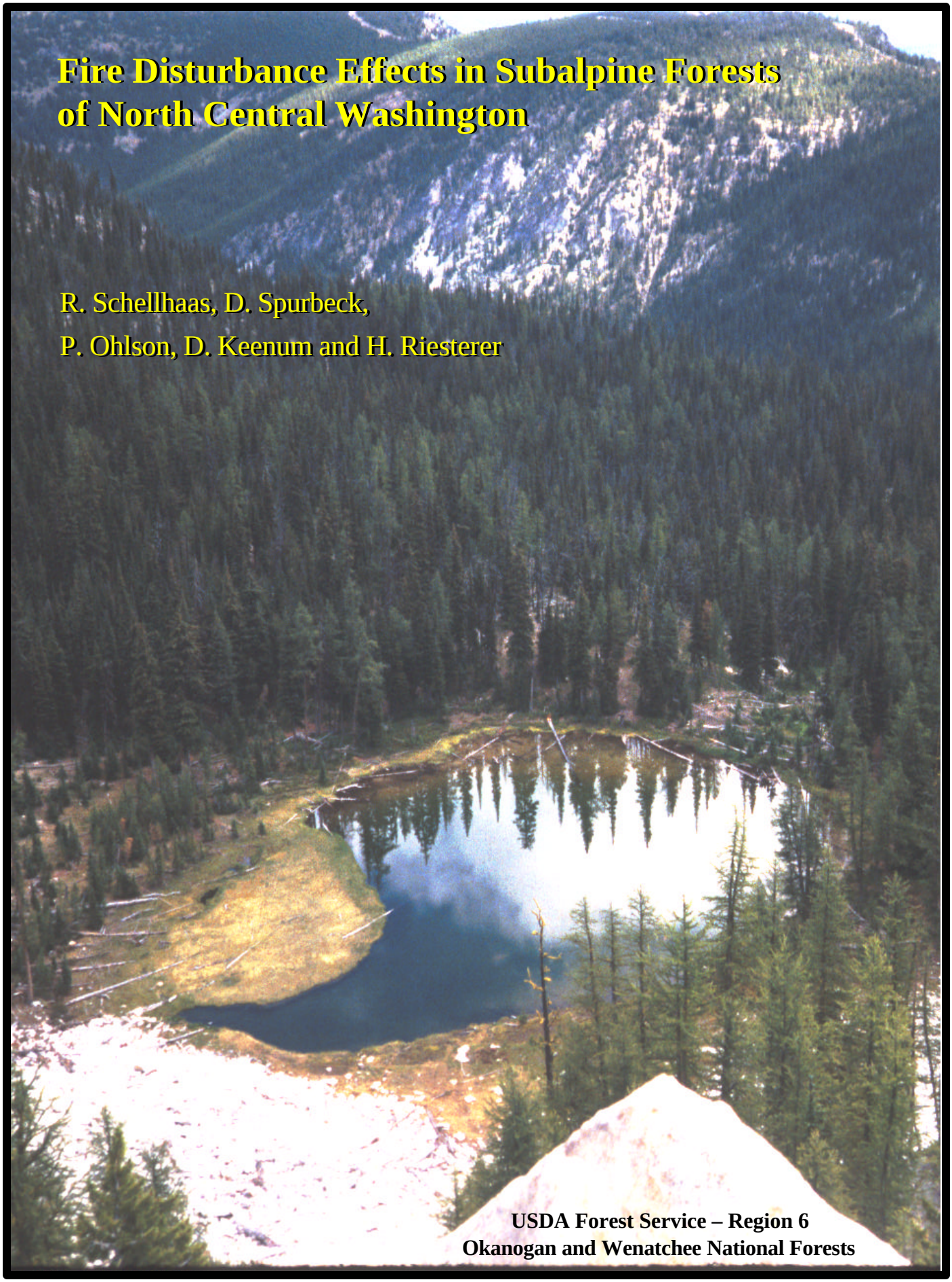

USDA Forest Service – Region 6
Okanogan and Wenatchee National Forests

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INTRODUCTION

Assessment of the historical disturbance effects across landscapes can provide an important foundation for land management decisions aimed at ecosystem restoration and maintenance. There have been numerous investigations regarding the historic disturbance patterns and resulting stand characteristics in low-elevation, dry forests of the inland west (Arno 1995, Everett et al 1999), yet little research has been concluded locally in subalpine forest communities. Subalpine forests include subalpine fir (*Abies lasiocarpa*), mountain hemlock (*Tsuga mertensiana*), whitebark pine (*Pinus albicaulis*), subalpine larch (*Larix lyallii*), and some colder silver fir (*Abies amabilis*) plant associations with high and persistent snowpacks (Lillybridge et al 1995). Based on the widespread presence of charcoal, fire is one of the major elements of disturbance although other factors such as insects, disease and large areas of windfall have influenced the historic and current forest conditions. Historic fire-free intervals (FFI) for these subalpine forests are long, generally over 100 years (Agee 1994). Fire severity is most often very high, resulting in stand replacement (Gorman 1899, Agee 1994, Smith and Fischer 1997).

The goal of this research is to describe the historical fire regimes and the effects of fire and fire exclusion across the landscape in selected subalpine communities of the Okanogan and Wenatchee National Forests. The frequency, severity and extent of historic fire events and the passage of time since the last fire have impacted species composition and stand structure found in subalpine landscapes. Examination of tree cores, fire scars and cross-sections removed from live trees, snags, logs and stumps provide evidence of past fires. Information about the frequency, severity and extent of these past fires can be used to identify the historic natural range of variability (HNRV) across the landscape. This will allow assessment of current conditions in reference to what was found historically.

Past fire events are often difficult to precisely date in these forests due to the long fire return intervals and high severity fires that occurred here. Most of the tree species found in subalpine forests are very intolerant of fire, with mortality being the usual result (Agee 1994). Unlike the lower elevation forests of ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*), fire-scarred trees are not commonly found in subalpine forests. Fire disturbance years were determined from a combination of available documentation, fire scars (when found), and age class distributions of live trees (Hawkes 1980).

AREA OF STUDY

The areas sampled were the upper Entiat River watershed on the Wenatchee National Forest and the area from Loup Loup Summit, north to the Toats Coulee drainage on the Okanogan National Forest. Both areas are situated along the east slopes of the Cascade mountains of north central Washington State. Elevation generally ranges from 4500 to 6800 feet. The climate during

the growing season can be described as cool and moist with occasional summer drought periods of up to a month in duration. Lingering snowmelt provides moisture through the spring and early summer with periodic thunderstorms providing moisture later during the summer. Most of the annual precipitation falls as snow from late October through early April.

These subalpine landscapes exhibit a variety of vegetative cover types. This diversity is at least partially a consequence of topography and climate. The cover types range from clumped patches of trees or no vegetation along the higher ridges, to densely forested valley bottoms. The lower elevation forests tend to include conifers associated with somewhat warmer, wetter climates including Engelmann spruce (*Picea engelmannii*), western hemlock (*Tsuga heterophylla*), and silver fir. The upper elevation forests include subalpine fir and mountain hemlock in colder sites, while lodgepole pine (*Pinus contorta*) and Douglas-fir are found in drier areas. Whitebark pine and subalpine larch are located near timberline (approximately 6500 feet).

The upper Entiat drainage is glacier formed with a typical broad valley floor. Much of the study area here consists of the upper slopes with extremely incised topography between high, rocky, alpine ridges and deep V-shaped valleys. Avalanche paths are found on steep slopes where regular snow slides in winter months prevent progression of tree development beyond that of sapling size (1-5 inches dbh). Meadows are present but incidental in this area.

The study area on the Okanogan NF has much more gentle and rolling topography than was found in the upper Entiat. In general, slopes are not deeply incised and alpine ridgelines that would provide a barrier to many fires are not common here. Species composition is also somewhat different than was found up the Entiat. Western hemlock, mountain hemlock and silver fir are not found in this portion of the Okanogan NF, but lodgepole pine is widespread.

Several distinct types of meadow cover a substantial amount of this area and they may act as barriers to some fires. Meadows on broad, open ridges are dominated by sparse grass/forb vegetation and rock. Fuel loads here are generally light and not conducive to sustain a spreading fire. Meadows found along wide draw bottoms (such as Tiffany Meadows) are shrub-dominated and often very wet throughout the growing season. Only during prolonged drought periods will these meadows dry sufficiently enough to burn.

The early seral inclination of the lodgepole pine cohort is formed in a relatively short time period thus when lodgepole is the dominant species of a stand, disturbance can be dated with greater accuracy. Assessment of stands with shade tolerant species in the upper and lower canopy layers is not as precise due to longer cohort development.

SAMPLING DESIGN

To ensure a diverse mix of subalpine forest stands, aerial photography and topographic maps were used to stratify the two sample areas into similar aspect and slope class landform polygons (Everett et al 1999). Aspect classes were sorted as either north or south facing. Slope

classes were: 0-30%, 30-50% and >50%. A total of 33 landform polygons were randomly selected for sampling. In addition to these selected polygons, some adjacent landform polygons were partially sampled to confirm fire extents, where necessary. A minimum of four replications of each landform polygon type (i.e. north aspect/30-50% slope) were sampled, with the exception of south aspect/>50% slope where 3 replications were sampled. Selected landform polygons were stratified internally into stand types based on forest cover and structure. Cover classes used were: 0-10% (non-forest, not sampled), 10-40%, 40-70% and >70%. Forest structure was classified as either single or multiple-layered. Within selected landform polygons, a minimum of 2 stands of each type were sampled. A total of 223 stands were sampled with 327 fixed radius plots.

Plots were 1/20th acre in size except for 20 smaller plots that were used where tree density was so great as to make the larger plot impractical. In these cases the smaller plots were either 1/50th or 1/100th acre in size. Due to high severity fires in the past and the fire-intolerance of tree species in subalpine forests, fire scarred trees and remnant trees (those that have survived at least 1 fire event) are not as abundant as they are in lower elevation forests of ponderosa pine and Douglas-fir (Heinselman 1983, Covington et al 1994). In addition to the plots installed, remnant trees were searched for and cored to help establish additional age cohorts and historic fire extent. In the absence of fire scarred trees, cores from remnant trees may provide the best information about historic fire events (Kipfmueller and Baker 1998).

Information recorded on the fixed area plots included live trees, snags, logs, understory vegetation, plant association, basal area, slope position, aspect, % slope and elevation. All trees were grouped into the following diameter classes: 0-1”, 1-5”, 5-9”, 9-16”, 16-25” and >25”. Representative samples of forest trees were cored at ground level (a minimum of two per species and diameter class on each plot).

Fire scar cross sections were collected where available using methods described by Arno and Sneck (1977). Occasionally remnants and or fire scars were collected from areas outside of selected polygon boundaries to help establish fire dates and extents. Evidence of fire (primarily charcoal), disease or insect infestations or any other relevant observations that would help explain the history of the stand were included in stand narratives that were written in the field.

Where boundaries of historic burns were discernible from aerial photography, paired plots were installed opposite one another along the boundary. Many of these fire boundaries burned with a low enough severity to have allowed trees to survive while showing evidence of the fire through fire scars or changes in the growth patterns on tree rings. Research conducted along historic fire boundaries can depict various age cohorts and may reveal two or more events. Verification of fire dates in the form of fire scars or abnormal growth rings are often found near these disturbance borders as well (Kipfmueller and Baker 1997).

ANALYSIS METHODS

Fire disturbance years were determined from a combination of fire scars, age class distributions and available documentation,. In addition to data collected in the field, existing documentation including fire atlases, Forest Service District records, aerial photography and historic lookout photos were useful in determining the year and extent of past disturbance events.

Tree age classes in sampled stands were identified by the construction of frequency histogram plots from tree core data (Figure 1). Because we did not core all trees, regression equations of tree diameter and age were developed. The equations were then applied to plot data to identify the presence and/or abundance of trees in a particular cohort. Classification of similar age cohorts within an even-aged or uneven-aged stands is the principle means for disturbance identification in the absence of fire scars. However, verification of age distributions must be supplemented by other evidence (Lorimer 1985). We examined annual growth ring patterns from tree cores that verified results of age distributions. This information was combined to determine historic fire frequency, extent and severity. Estimated fire extent boundaries in each polygon and/or polygon group were then mapped.

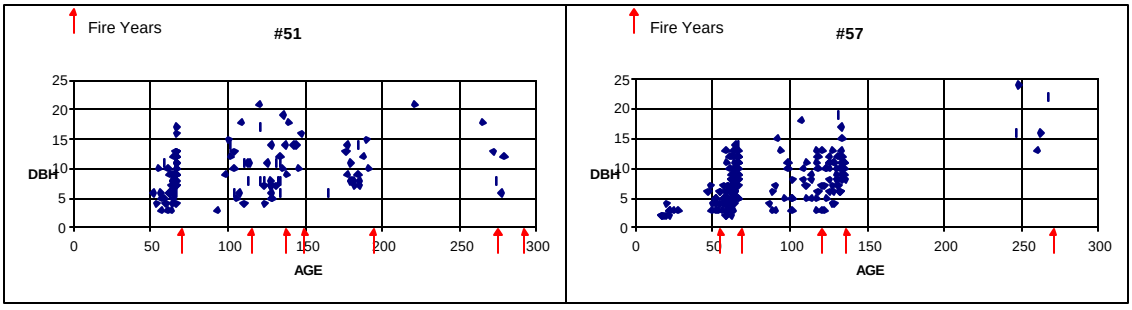

Figure 1. Age and diameter distribution of cored trees in Okanogan polygons 51 and 57.

Historic fire-free intervals (FFI) were calculated for each polygon as: (total length of fire record in years)/(number of fire events minus 1). The fire-free interval for a polygon may be somewhat misleading in reference to the stand level and is only relevant for the entire polygon. Point frequency or even stand level frequency is determined with considerable difficulty in the subalpine plant associations because of the tendency toward stand replacing fires in these communities (Agee 1994, Gorman 1899). These high intensity fires often destroy much of the evidence of previous fires.

RESULTS AND DISCUSSION

Each of the sampled landform polygons are unique in their forest cover and historic fire disturbance history. The following are descriptions of the forest conditions and fire disturbance history for each individual and/or group of sampled landform polygons. Groups of polygons are

geographically close to one another and share some similar disturbance events. Maps of the Entiat and Okanogan sample areas are included in the appendix.

Wenatchee:

Mad Lakes

Polygons: 68, 84, 89, 90, and 101

These landform polygons are located on an elevated bench between the Entiat River and the Entiat/Chiwawa divide. Elevations range from 5400 to 6600 feet. Wide draw bottoms and broad ridges form the relatively gentle topography of the area. A diverse group of forest stand types exist across this landscape; from single layer lodgepole pine stands to multi-layer, multi-aged Pacific silver fir and mountain hemlock forests. Large, 100-200 acre tracts of even-aged lodgepole pine stands are present. Most of these stands have or are developing an understory comprised of shade tolerant subalpine fir, Engelmann spruce, Pacific silver fir and mountain hemlock. Also located on the landscape are stands that include many age classes and multiple canopy layers. These stand types are in a more advanced stage of succession and as a result include an assortment of species in all crown layers.

Located in the vicinity of Mad Lake, Two Little Lakes and Pond Meadow are several subalpine meadows. These meadows have likely been maintained by fire disturbance. The landscape, while still within the natural range of fire occurrence is approaching the extent of the average historic frequency. This would account for the visible expansion of forest edge into the meadows.

A large portion of this area experienced a major fire event 115 years ago in 1885. This fire appears to have covered much of the area, at least between upper Tommy Creek and the Entiat/Lake Wenatchee district boundary along Entiat Ridge. Numerous areas such as riparian zones, cool and moist north slopes and sparsely forested ridgetops escaped the stand replacing runs of this large fire. Stand replacement crown fires and subsequent regeneration are evident in aerial photography as single-layered, even-aged stands. Areas occupied by a variety of ages, sizes and species of trees were not severely burned by this fire if at all. Other disturbance events were detected at 230-250, 300-360, and 430-490 years ago.

Aerial photos expose the diversity of stands created by the 1885 fire. In approximately 35% of the sampled polygon area this fire was a stand replacing event and has resulted in an even-aged, single layer of lodgepole pine. A mix of small stand replacing runs and ground fires of mixed severity occurred on 20% of the area and about 45% of the area was either not burned or experienced only low severity ground fire.

Within the Mad Lake/Two Little Lakes area a total of 20 paired plots were installed. One plot was placed in a dense single layer stand which as described earlier indicates stand replacing crown fires while another plot was installed in an adjacent multiple layer stand. With reference to

the most recent fire, the paired plots indicate a relationship of aspect to stand replacement crown fire. 75% of the north facing slopes or riparian areas have multiple crown layers while 90% of the single layer stands are found on southerly aspects. Land type in this area does display an apparent distinction in fire frequency. The average frequency of 85 years for south slopes is nearly half that of north facing aspect polygons (165 years).

Polygon 84 is located at the lowest limit of the subalpine forest series on a southerly aspect and also has the most frequent fire history of the sample polygons in the Entiat drainage. This polygon is situated on a broad gentle ridge above a dry, south slope and is segregated from the Mad Lake polygons in elevation (4200-5000 feet) as well as by significant ridges and riparian areas. The short fire free interval (42 years) is a product of low elevation and the dry south slope directly adjacent. Much of the area experienced a stand replacement fire in 1890 that appears to have been a reburn of a fire in 1873. Examination of growth increment patterns from surviving remnants indicate that both fires spread through the area. This evidence, in combination with the sparse fuels and in particular the lack of large woody debris, suggest a reburn did in fact occur (Lotan et al 1984). The 1934 panoramic, lookout photo from Cougar Mountain (Figure 2) offers an excellent view of this ridge and the 1890 burn area.

We suspect that subalpine plant communities similar to polygon 84 which are linked to drier plant associations by homogenous topography are often influenced by the fire regimes of those adjacent habitat types. These drier forest areas act as pathways where fires may spread into the subalpine landscape. A greater incidence of fire would be expected compared with those areas separated by natural barriers such as large riparian areas or nonforested, open ridgetops.

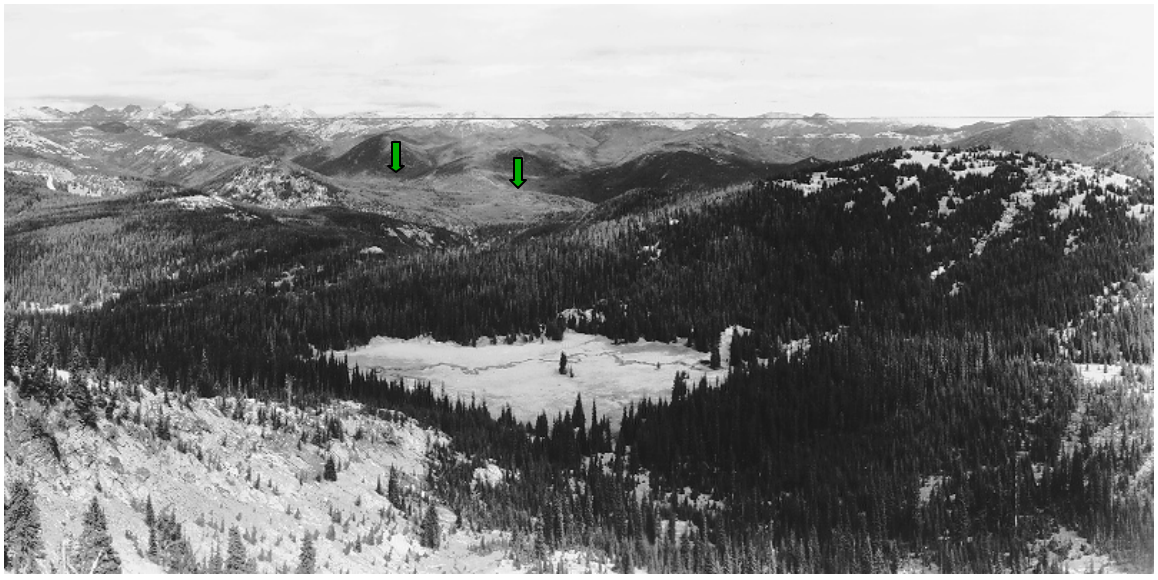

Figure 2. A portion of the 1934 Cougar Mountain lookout photo. The area burned in 1890 is indicated by the arrows. (USDA Forest Service Photo)

Description of polygons and fire history for Mad Lakes area. % burned column refers to percentage of polygon burned by the last fire discovered.

Polygon	Acres	Aspect	Slope	FFI	Fire years	% Burned*
101	1414	north	30-50%	107	1885, 1765, 1665, 1565	50%
68	637	north	<30%	200	1885, 1685	35%
90	529	north	>50%	190	1885, 1695	48%
89	685	south	30-50%	127	1885, 1745, 1635, 1505	50%
84	479	south	<30%	42	1890, 1873, 1853, 1798, 1788, 1735, 1640, 1595	75%

Lake Creek Basin

Polygons: 77, 81, 109 and 110

Lake Creek Basin contains a variety of subalpine fir plant associations and at the upper elevations, grades into colder subalpine larch and whitebark pine plant associations. The most noticeable feature of Lake Creek Basin may be its vast, ubiquitous, single layered lodgepole pine stands. Open, clumpy stands or scattered individual trees are located on the harsh surroundings of the highest ridges. Multiple layers of Engelmann spruce and subalpine fir are encountered as remnants in some riparian areas. On elevated south slopes exposed to extremes of temperature and wind, only a few individuals or clumps of subalpine larch and whitebark pine are found.

Most of the area has experienced stand replacement fires within the last 100-150 years. The most recent, in 1895, burned through at least 60% of the 5540 acres in the basin. This was evidently a severe, crown fire that left remnants only in some riparian areas, along narrow ridgetops or on open south-facing slopes. 75%-80% of the riparian forests here exhibit at least some remnant overstory. Extent of fires prior to 1895 are difficult to estimate due to the large size and severity of the 1895 event which destroyed much of the evidence of older stands. However, there were three single-layered stands of different ages found adjacent to each other in the southern portion of the basin. Apparently there were at least two stand replacement fires in this area and (probably) in much of the rest of the basin prior to 1895. Areas of high elevation and sparse vegetation functioned to slow and stop the spread of crown fires traveling in this direction (upstream), as several stand layers are still visible.

Fire occurrence in Lake Creek Basin is influenced by the close proximity to lower elevation, dry forests. Some of the fire behavior in these polygons is similar to frequent, low-elevation fire regimes. The fire-free interval here is approximately 60 years; more frequent than most subalpine areas. Ponderosa pine and Douglas-fir are more prevalent, and numerous age cohorts of each species can be found. This suggests that stand replacement fires have not created even-aged stands in this area; rather, lower intensity fires have enabled survival of a variety of cohorts.

Ten fire scar samples were collected from Polygon 81 that verified fire dates established in adjacent polygons. Fire scars were more difficult to find in other polygons in the area, so a

comparison of the changes in incremental growth rates on older tree cores with the abundance of trees in different age classes contributed to ascertaining fire dates and extents.

Typically, fires burned through the basin from the lower end, slowed down and even stopped near the top of the ridge, at the south end of the basin. The area near Pawn Lakes in the bottom of the basin was affected little (if at all) by fire over the years. In fact, cores from shade tolerant (fire intolerant) subalpine fir and Engelmann spruce dating back as far as 1534 exhibited no growth-ring variation which could be attributable to fire disturbance.

Throughout the basin, some areas spared from the 1895 fire included riparian zones, narrow ridgetops and open south facing slopes. It was also noted that there were other riparian zones, narrow ridgetops and south slopes that were burned severely by the same fire. At least 50 and as much as 70 percent of the riparian overstory survived the 1895 fire. The north end of the basin is made up of steep (>50%) south facing slopes. Remnant trees can be found scattered and in large groups on some of the open south facing slopes and in some riparian draws but overall most of these south slopes were burned severely in the 1895 fire.

Description of polygons and fire history for Lake Creek Basin area. % burned column refers to percentage of polygon burned by the last fire discovered.

Polygon	Acres	Aspect	Slope	FFI	Fire years	% Burned*
77	931	south	>50%	76	1970, 1891, 1819	95%
81	242	north	30-50%	57	1935, 1895, 1835, 1774, 1739, 1712, 1655, 1595	75%
109	502	north	>50%	100	1895, 1835, 1695, 1595	50%
110	813	north	<30%	75	1895, 1774, 1712, 1670	70%

North Fork Entiat River

Polygons: 43, 46, 49, 51, 52, 53, 54, 73 and 248

The terrain in this area consists of narrow valleys, steep side slopes and high alpine ridges and peaks. Plant associations in the valleys and side slopes range from dry, subalpine fir series to wetter mountain hemlock or silver fir series. Alpine ridges are dotted with whitebark pine and subalpine larch. As with most subalpine areas, a diverse assortment of stand types exist. Also typical of many subalpine landscapes are natural openings in the forest cover associated with alpine meadows, thin rocky soils or avalanche tracks which may act as natural fire barriers.

Many lower elevation sites in this area are dominated by lodgepole pine. South slopes average 138 years between fires and are commonly dominated by lodgepole pine. North slopes and riparian areas have longer fire-free intervals (224 years) which support the advancement of more shade tolerant species. These north slopes also have quantities and arrangements of fuel conducive to intense stand replacing, crown fires. An average of 30% of the area in south-facing polygons burned during the last fire, compared to 85% for north facing polygons. Some historic fires appear to have been relatively large. The 1889 fire was approximately 2200 acres--more than

half was stand replacing. There were also numerous smaller events such as the 1870 fire in polygon 43 (200-400 acres). Many polygons experienced a fire between 1870 and 1900 however most were comparatively small in size.

Forest stands of some riparian zones have survived the latest fire while others were completely destroyed. Riparian areas along the North Fork Entiat River have had only a few acres burned by recent fires (<100 yr. old). South Pyramid Creek, on the other hand was burned severely in 1898. Much of the riparian area directly adjacent to the creek was also destroyed by this fire. Evidence of fire spreading into the alpine zones of this area is visible in the 1934 Pyramid Mountain panoramic lookout photos (Figure 3). The 1889 fire actually extended to timberline along the Entiat/Chelan divide south of Pyramid Mountain. However, among these high transition zones, areas of total destruction are rare, attributable to the cool moist conditions and the meager fuel supply.

Steep, open ridges provide an obstacle to the expansion of subalpine wildfires. The major ridge of the Entiat/Chelan divide consists of high peaks, cliffs and talus slopes which create a natural fire barrier. Sparse soil, extremes of wind and cold as well as a shortened growing season provide a hostile environment for any tree species. Many of the ridges found in this area are at or above timberline where only a few clumps of hardy trees exist. The restricted growth potential in these settings supply minimal quantities of fuel. While portions of these areas may burn when ideal conditions are met, they usually obstruct the spread of wildfire. Consequently it is rare for a fire to spread across entire landscapes of such heavily dissected topography.

Description of polygons and fire history for North Fork Entiat River area. % burned column refers to percentage of polygon burned by the last fire discovered.

Polygon	Acres	Aspect	Slope	FFI	Fire years	% Burned*
43	400	south	<30%	138	1870, 1750, 1595	25%
46	409	south	30-50%	unknown	1855-1875	40%
49	714	north	30-50%	224	1889, 1665	85%
73	736	south	30-50%	179	1886, 1707	50%
51	3343	south	30-50%	126	1889, 1765	40%
52	478	south	>50%	124	1871, 1765	25%
54	507	south	30-50%	122	1893, 1771	10%
248	235	north	30-50%	unknown	1725	5%

The historic fire regime of the North Fork area may be described as one of infrequent and high-severity fires. Average fire-free intervals range from 120-250 years. Approximately 40% of the landscape experienced intense crown replacement during the most recent fire event. These lethal crown fires raced up steep, forested slopes along a single front or as several separate runs to the ridgetop where the advance was terminated. While the extreme topography of this area contributes to intense crown fires, the moist valley bottoms and rocky ridgelines may also limit their extent.

Figure 3. A portion of the 1934 Pyramid Mountain lookout photo showing some of the 1889 stand-replacement fire area. (USDA Forest Service Photo)

Larch Lakes

Polygon: 23

This polygon is generally north facing with many steep (>50%) slopes. Plot elevations ranged from 4200-5250 feet. A variety of terrain and vegetation exist including steep rocky ridges with avalanche chutes, alpine meadows, lakes, creeks, open south slopes with scattered trees, and the heavily forested north slopes.

Stands at the north edge of the polygon originated as a result of a stand replacement fire in 1926. This fire is on record in fire atlases and was verified by tree ring growth increment analysis and aerial photo observations. The fire extended from 4400-5600 feet elevation on a steep, east-facing slope. This was a severe burn, killing all but a few individual Douglas-fir. Currently, the regenerated fire area is a very early successional stand and has reached the stem exclusion stage (Oliver and Larson 1996) of its development as is currently stocked with an extremely dense 4000-5000 stems per acre. The subsequent regeneration includes Douglas-fir (5-13" dbh), Engelmann spruce, Pacific silver fir and subalpine fir (1-5" dbh), and smaller amounts of western hemlock and mountain hemlock. The larger sized trees range from 20-50 feet in height while the true firs and hemlocks are somewhat smaller. There is an obvious reduction in tree height as one nears the upper portions of the fire area.

The oldest tree found in this polygon was 352 years old and many tree cores collected were between 260-280 years old. Evidence in the form of cohort data suggests there may have been a stand replacement fire approximately 360 years ago. Some trees germinated shortly after this fire while more shade tolerant pacific silver fir and mountain hemlock continued to reclaim the site for another 80-100 years. Agee (1994) reported that establishment of shade- tolerant, understory

species may take more than two centuries which may explain the extended time period for recovery here. We found no other evidence of fire disturbance on our plots. Cross-sections cut from very small, (1-2" dbh) thin-barked, Pacific silver fir were found to be as much as 270 years old. It is highly unlikely that these trees could have survived any significant fires. Due to the limited fire disturbance record in this polygon, it is difficult to make accurate estimates of the fire-free interval.

Anthem Creek
Polygon 32

Polygon 32, Anthem Creek encompasses 461 acres of generally steep (>50%), south facing slopes. Many different stand types can be found throughout this area. Terrain varies from very steep, sharp, rocky ridges with avalanche chutes and few or no trees; to more gently sloped riparian zones with trees that have survived for as long as 300 years. As found in other polygons, fire frequency does not seem to be affected as much by aspect as it is by localized land characteristics such as wet areas and rocky outcrops on open slopes and ridgetops. The average fire-free interval for polygon 32 is 115 years. The last fire was about 90 years ago and entered a small part of the north side of the polygon. Most of this fire was north and west of Anthem Creek. Another fire dated in the 1870's entered the south border of the polygon and burned with irregular severity from the Entiat River north to Anthem Creek. The oldest age cohort discovered was nearly 300 years old, suggesting an even earlier disturbance in the late 1600's.

Garland Creek
Polygon 37

The Garland creek polygon occupies a southeast facing slope that extends from 3500 feet elevation near the Entiat River, up to 6000 feet near the Entiat/Chiwawa divide. Most of the 275 acre polygon has a single layer of Douglas-fir while the upper slopes grade into subalpine fir, silver fir and mountain hemlock. The understory tree species include: western white pine (*Pinus monticola*), Pacific silver fir, mountain hemlock, Engelmann spruce and subalpine fir.

Nearly all of the overstory Douglas-fir originated from a fire about 1870. Wet conditions here are not very conducive to fire but, once ignited this last fire swept through about 200 acres of this steep polygon. Most of this fire burned with high severity fire as there are very few older trees that have survived. Some older remnant trees (up to 320 years) were found on a sparsely forested open south slope. Abundant amounts of forest litter and fuel were noted throughout most of this polygon.

Description of polygons and fire history for Larch Lakes, Anthem Creek and Garland Creek areas. % burned column refers to percentage of polygon burned by the last fire discovered.

Polygon	Acres	Aspect	Slope	FFI	Fire years	% Burned*
23	704	north	>50%	291	1926, 1635	8%
32	461	south	>50%	115	1905, 1873, 1675	5%
37	276	south	>50%	-	1870	72%

Okanogan:

Beaver Creek/Starvation Mountain

Polygons: 129, 141 and 155

The overall terrain in this area is not heavily dissected. Slopes are long and continuous with very few benches or sharp ridgelines. There are few rocky outcrops, talus slopes or other barriers that would limit the spread of wildfire. The upper end of these polygons reach the upper limit of the subalpine fir zone and begin to grade into whitebark pine plant associations near the ridgetops at about 6500 feet. Much of these upper ridgetops are non-forested and provide the only natural fuel breaks in the area. Forest composition at the lower limit of this area is transitional from a subalpine forest into lodgepole pine on the northern aspects and Douglas-fir and ponderosa pine on the southern aspects. The proximity to these drier forest types, as was found in a portion of the Mad Lakes area in the Entiat River drainage, provide links to the more frequent fire events at lower elevations. Fire-free intervals here range from 41 to 65 years.

There are portions of this area where recent timber harvest and prescribed fire have been completed. These fires were noted but were not included in any calculations of historic fire-free intervals. The last significant fire event in this area was in 1917 and this fire burned across most of the area. Fire behavior was apparently severe as most slopes are now dominated by even-aged lodgepole pine overstory and Engelmann spruce and subalpine fir understory that became established following this fire. Information from historic fire atlases indicate this fire reached a total size of about 6000 acres. The majority of polygon 129 (Granite Creek) did not burn in 1917. Only the upper ridgetops were affected by this fire. Granite Creek did experience a large, severe fire in 1890 which may have limited the spread of the 1917 fire in this area.

Many other smaller and older fires burned throughout the area. These fires years were most often detected by the presence of even-aged stands that established following the fire. These even-aged stands and the lack of older, remnant trees would indicate these fires burned with fairly high intensity but their spread was limited. Older, remnant trees were found primarily in the moist valley bottoms along upper Beaver Creek and it's tributaries and on the upper ridgelines. Some scattered, very old (up to 600 years), remnant Douglas-fir and western larch are also present.

Description of polygons and fire history for Beaver Creek/Starvation Mtn. area. % burned column refers to percentage of polygon burned by the last fire discovered.

Polygon	Acres	Aspect	Slope	FFI	Fire years	% Burned*
129	716	south	>50%	41	1917, 1890, 1869, 1803, 1766, 1712	10%
141	2894	south	>50%	59	1917, 1896, 1841, 1776, 1732, 1622	90%
155	480	north	>50%	65	1917, 1851, 1785	90%

SW Side Pearrygin Peak

Polygon: 137

This area lies at the lower elevation limit of the subalpine forest series. Much of the polygon grades into the cool, dry end of the Douglas-fir series. Elevations range from 4700 to 6500 feet near the top of Pearrygin Peak. Slopes are generally moderate (30-40%) with many flat benches. The lower reaches of this polygon have a Douglas-fir and ponderosa pine overstory and a sparse Douglas-fir and lodgepole pine understory. The upper end of the polygon is dominated by Douglas-fir and lodgepole pine overstory with Douglas-fir, subalpine fir and Engelmann spruce understory.

We found evidence of 4 larger fires that burned across most of the polygon in 1896, 1855, 1828 and 1766. These fires burned with low intensity as there are numerous trees that survived them. Two other fires also occurred in only the lower, western end of the polygon in 1917 and 1885. These 2 fires were also low severity, probably due to the frequent fires keeping fuel levels at a minimum. Remnant trees are as old as 350 years, but no age cohorts were detected beyond 230 years (resulting from the 1766 fire).

The fire-free interval for this polygon is calculated at 28 years. This fits more in line with mixed severity fire regimes found in the adjacent, drier, Douglas-fir plant associations compared with what would be expected in the subalpine fir series. Average area burned during each fire is estimated to be about 60% of the polygon.

Clark Creek

Polygon: 120

This polygon is found on the north aspects in the upper end of Clark Creek, to the northeast of Mt. McCay. The south side of this polygon is defined by a distinct ridgeline that also acted as a portion of the perimeter of the McCay fire in 1992. Overall tree cover is very dense with a mostly subalpine fir overstory. Douglas-fir, western larch and lodgepole pine also exist in the overstory but in fewer numbers. Engelmann spruce and subalpine fir are sparsely scattered in the understory. Elevation range is from 5000 to 6600 feet. The subalpine fir/Cascade azalea (abies lasiocarpa/ Rhododendron albiflorum plant association was found throughout the polygon.

Current growth rates found here are very slow. Root rot pockets can be found throughout the area. Evidence in the form of gallery patterns of fir engraver (*Scolytus ventralis*) in the subalpine fir and mountain pine beetle (*Dendroctonus ponderosae*) in the lodgepole pine is also present.

The dominant disturbance to have occurred here was a fire in 1808. We found no evidence of any fires after that time. Only a small handful of trees were found that are older than this fire, suggesting it burned hot and across all of the polygon. The few remnant trees that were found here indicate age cohorts originating about 1747 and earlier about 1661. Portions of the area had a high number of heavily decayed lodgepole pine and Engelmann spruce logs. Many of these logs had char on them, indicating they most likely died from the 1808 fire. The size (8-12 inch diameter) of these logs is also consistent with the likely diameter of trees in 1808 that would have established following the 1747 fire. We observed an age cohort of lodgepole pine originating about 1661, suggesting a fire may have also occurred about that time.

Based on these three fire events (1808, 1747 & 1661) the fire-free interval within this polygon is calculated at 73 years. We believe each of these fires burned nearly the entire polygon each time.

Description of polygons and fire history for SW side of Pearrygin Peak and Clark Creek areas. % burned column refers to percentage of polygon burned by the last fire discovered.

Polygon	Acres	Aspect	Slope	FFI	Fire years	% Burned*
137	771	south	30-50%	28	1917, 1896, 1885, 1855, 1828, 1766	20%
120	698	north	>50%	59	1808, 1747, 1661	95%

Tiffany Meadows

Polygons: 86, 87, 90 and 93

This area includes the upper reaches of the South Fork of Twentymile Creek and the North Fork of Boulder Creek. The overall terrain in this area is very gently rolling. Wet, shrubby meadows occupy many of the valley bottoms. Shrub cover of common juniper *(Juniperus communis*) and bog birch (*Betula glandulosa*) form thick layers that limit the establishment of conifer seedlings. Upper ridgelines are not sharply defined and are generally well forested with the exception of the open meadows near the top of Tiffany Mtn. and Rock Mtn. above 6500-7000 feet.

The dominant overstory tree species here is lodgepole pine with a few Engelmann spruce. The understory (where there is one) is mostly subalpine fir, Engelmann spruce and lodgepole pine. The majority of the polygon is covered by dense, even-aged, uniform stands of lodgepole pine that originating following severe stand-replacement fires.

Several past fires (1917 and 1841) were detected throughout much of this area, indicating these fires probably exceeded several thousand acres in size. Fire severity was mostly very high , but some smaller pockets of low to moderate severity occurred in rocky areas and wet areas where

stand densities and fuels were probably lower or where fuel moisture was higher. In these areas of lower fire intensity, remnant lodgepole pine and Engelmann spruce survived. Older fire events also occurred here but their extent is difficult to estimate due to the high severity of the later fires. The oldest fire recorded here was in 1636 and appears to have been a high severity fire as there is a sharp absence of trees older than this age. Charred remnant logs of lodgepole pine and Engelmann spruce also indicate that the size of trees in the previous stands were similar those found here today.

Downed logs are abundant throughout the entire area. Root rot pockets are common and evidence of mountain pine beetle and spruce beetle (*Dendroctonus rufipennis*) damage and mortality is widespread.

Description of polygons and fire history for the Tiffany Meadows area. % burned column refers to percentage of polygon burned by the last fire discovered.

Polygon	Acres	Aspect	Slope	FFI	Fire years	% Burned*
86	909	north	30-50%	69	1911,1841,1799 1732, 1627	5%
87	1328	south	<30%	75	1917, 1841, 1766	30%
90	751	north	<30%	51	1917, 1885, 1841 1766	60%
93	1109	north	<30%	107	1841, 1732, 1627	80%

Middle Fork Toats Coulee Creek
Polygons: 45, 51 and 57

Much of this area is dominated by dense stands of pure lodgepole pine. Understory of subalpine fir and Engelmann spruce in these dense stands is very sparse. Mixed stands of lodgepole pine, subalpine fir and Engelmann spruce overstory with subalpine fir and Engelmann spruce understory are also common. Slopes are uniform with only broad, gentle draws and ridges dissecting the area. Natural fire breaks are few, with the only non-forested areas being the meadows north of the Middle Fork of Toats Coulee Creek and extending upslope to the vicinity of Hodges Horse Pasture. Elevation ranges from 4700 to 6700 feet. Near the lower, eastern end of these landform polygons (also near the Forest boundary) the forest becomes dominated by Douglas-fir with a small component of ponderosa pine. Wet seeps are common on many of the toe slopes. In those areas, stands of Engelmann spruce and quaking aspen (*Populus tremuloides*) are more abundant. Remnant Douglas-fir can be found scattered on the south slopes of this area. Some of these remnants are very large (up to 72" dbh) and up to 500 years old.

There have been several different logging entries here. About 1974 some lodgepole pine stands were heavily thinned. This thinning covered only a small portion of the area. These thinned stands are currently increasing in radial growth much faster than the unthinned stands and also show no signs of mountain pine beetle infestation as was observed elsewhere in the area. In the

same year several fire breaks were cut along some of the ridgelines and down the slopes on the north side of Long Peak. During the mid 1980's a series of small clearcuts were made in the eastern end of the area where large Douglas-fir is more abundant.

Many of the historical fires here were large and of high severity. Stand replacement was the most common result, with remnants surviving only along the rockier portions of the ridgelines where pre-fire fuels and stand density were probably less. The most notable fire event in the area occurred in 1930 and resulted in the most abundant age cohort in the area (Figure 3). Evidence of this fire was widespread and it's size is estimated to have been at least 7000 acres. Cross-sections from remnant logs and snags killed by the 1930 fire indicate an earlier, even-aged cohort that had become established following another large fire in 1860. Evidence of this fire was also widespread and it's size is estimated to be at least 6000 acres. Another large fire in 1730 burned across much of this area, but it's size is difficult to estimate due to the loss of evidence in the subsequent fires.

Not all historical fires in this area were large. Fire scars and age cohorts also indicate many smaller fire events took place. The most recent of which burned approximately 30 acres northeast of Long Peak in 1942. In 1885 a small fire burned along the top of the ridge south of Hickey Hump. The area around Four Point Corral burned in 1877, and in 1760 a small fire created a uniform cohort of lodgepole pine in the upper end of Daisy Creek. Other fires also burned in 1850, 1805, 1760, 1710 and 1695.

Description of polygons and fire history for the Middle Fork of Toats Coulee Creek. % burned column refers to percentage of polygon burned by the last fire discovered.

Polygon	Acres	Aspect	Slope	FFI	Fire years	% Burned*
45	3331	south	30-50%	47	1930, 1885, 1877, 1860, 1760, 1730, 1695	90%
51	2054	south	<30%	37	1930, 1885, 1860, 1850, 1805, 1730, 1710	60%
57	3129	north	30-50%	49	1942, 1930, 1877, 1860, 1730, 1695	1%

CONCLUSIONS

Our investigation affirms the conclusion that fire behavior in subalpine forests is notably different from low elevation fire patterns. Historic fires in the subalpine zone were infrequent; 28-291 years mean FFI overall, 42-291 years for the Wenatchee and 28-107 years for the Okanogan (Figure 4). The notably shorter fire-free intervals observed on the Okanogan are expected given the somewhat drier vegetative conditions and lack of barriers to fire spread. Since fire is a relatively rare occurrence in subalpine forests, fuels are allowed to accumulate. When fires did occur they were often more severe than typical frequent underburns of the lower valley. The average fire-free interval

for all polygons was 93 years compared to the 6-9 year average found in the drier forests of the lower Entiat Valley (Everett et al 1999).

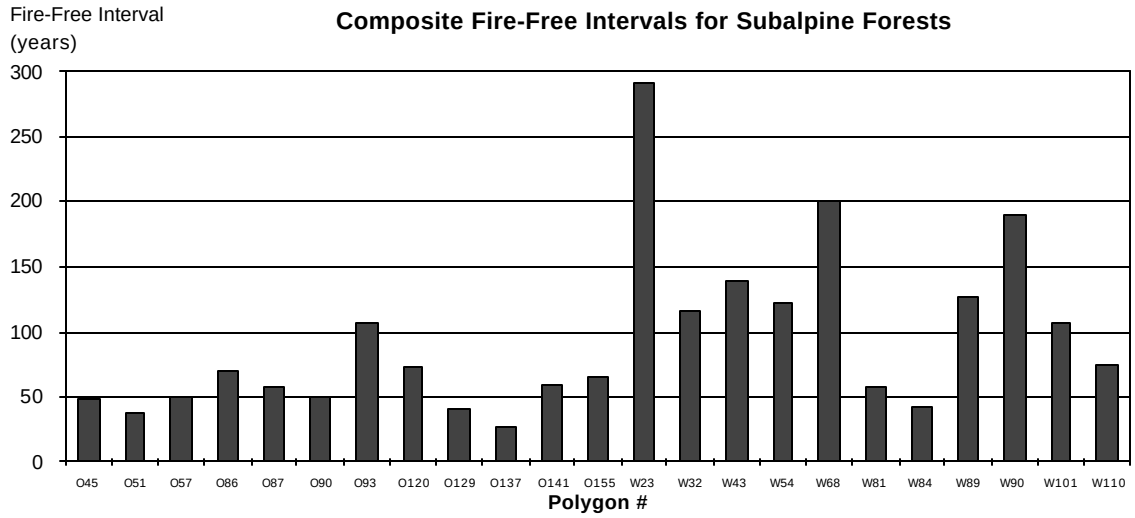

Figure 4. Composite fire-free interval by polygon.

Of all incidents of fire detected in the subalpine community, the majority were stand destroying fires. Even within the perimeters of small fires located on the upper slopes where flames evidently didn't reach into the tree crowns, most trees were killed directly from heat or indirectly by insect and pathogens. This mortality is probably attributable to characteristics of tree species adapted to subalpine communities that are thin barked and therefore extremely fire intolerant. Those individuals not killed immediately were weakened to the point where they became susceptible to other agents. In the Pasayten Wilderness of northern Washington State, Fahenstock (1976) reported that 75% of the lightning fires between 1910 and 1969 were less than 1/4 acre in size. Most of the fires found in the Entiat subalpine area were also small in size but we discovered some that exceeded 1,000 acres. These larger fires occurred in areas occupied by the warm, dry end of the subalpine forest series. Larger fires (1000+ acres) were also common in the Okanogan subalpine area where fewer topographic barriers are present that can limit the spread of fire. Wet forest types did experience severe fires but they were relatively small in size. These fires were confined to spots near upper slopes and ridges or narrow runs upwards from lower areas.

Topography seems to have a greater effect on fire size in subalpine zones than in warmer and drier habitats. Some of the largest fires we discovered occurred in areas with low and moderate topographic deviation. The 1895 fires in Lake Creek Basin and the Mad Lakes area of the Entiat drainage and the 1930 fire in the Toats Coulee drainage on the Okanogan NF are examples of a large contiguous fires occurring in areas with gentle terrain. Everett et al (work in progress) found little resistance to fire expansion in and across riparian zones of dry Douglas-fir/ponderosa pine plant associations in the Entiat watershed. We however found that these riparian areas often

provided significant barriers to fire spread in the subalpine community. When fires did manage to burn into riparian forests the rate of spread and intensity was often either stopped or reduced, allowing much of the overstory to survive. 70% of all riparian areas were either unburned or had significant remnant overstory survive the latest fires, characteristic of lower fire intensity.

Our results agree with Agee (1994) that the wettest subalpine plant associations tend to have the longest fire-free intervals. It was observed that some forest stands had experienced two fires within a period of several decades. These reburns were found only within the drier subalpine plant associations where lodgepole pine was the primary component. Fuel levels of these stands are low with relatively little debris present on the forest floor. The lack of larger fuels including logs is especially evident and indicative of the reburn effect. The even-aged and uniform structure of these stands and the sparse crowns characteristic of lodgepole pine, serve as a deterrent to the spread of crown fires (Lotan et al. 1984). These stands with lower fire risk could be used in a matrix of managed stands to break up fuel continuity across large landscapes.

Agee (1994) reported that spruce and true fir become dominant only after 100-250 years following stand replacing wildfire. We found stands of 100-110 year old lodgepole pine that originated following stand replacing wildfires where the establishment of shade tolerant Pacific silver fir, mountain hemlock and subalpine fir had reached only 1-6 feet in height. Barring any additional fire disturbance these understory species will not grow to sufficient height to become ladder fuels in these stands for many decades.

Successful fire suppression over long periods of time in subalpine forests has increased the proportion of area in late successional structural stages of stand development and led to increased homogeneity in forest cover (Smith and Fischer 1997). Prior to fire suppression, we suspect that a mosaic of stand types were maintained on the subalpine landscape by the smaller fires inherent to these areas. Historic lookout photos from the 1920's and 1930's document greater stand variability across this terrain than is visible today. One possible consequence of nearly 100 years of fire suppression is a potential increase in wildfire extent. As subalpine forests become increasingly homogenous due to a cessation of small stand replacement fires, risk of larger fire occurrence may be heightened.

Some land managers and agencies favor a "let burn" policy toward fire management. However, if some protection of designated reserves and wildlife habitat is desired, a light handed approach may be to reduce stem density and crown cover in combination with prescribed fire in warmer, drier areas of connectivity adjacent to subalpine forests. This treatment may decrease the number of incidents entering subalpine zones by allowing more effective suppression techniques within these disturbance conduits and lessen the risk of destructive fire events.

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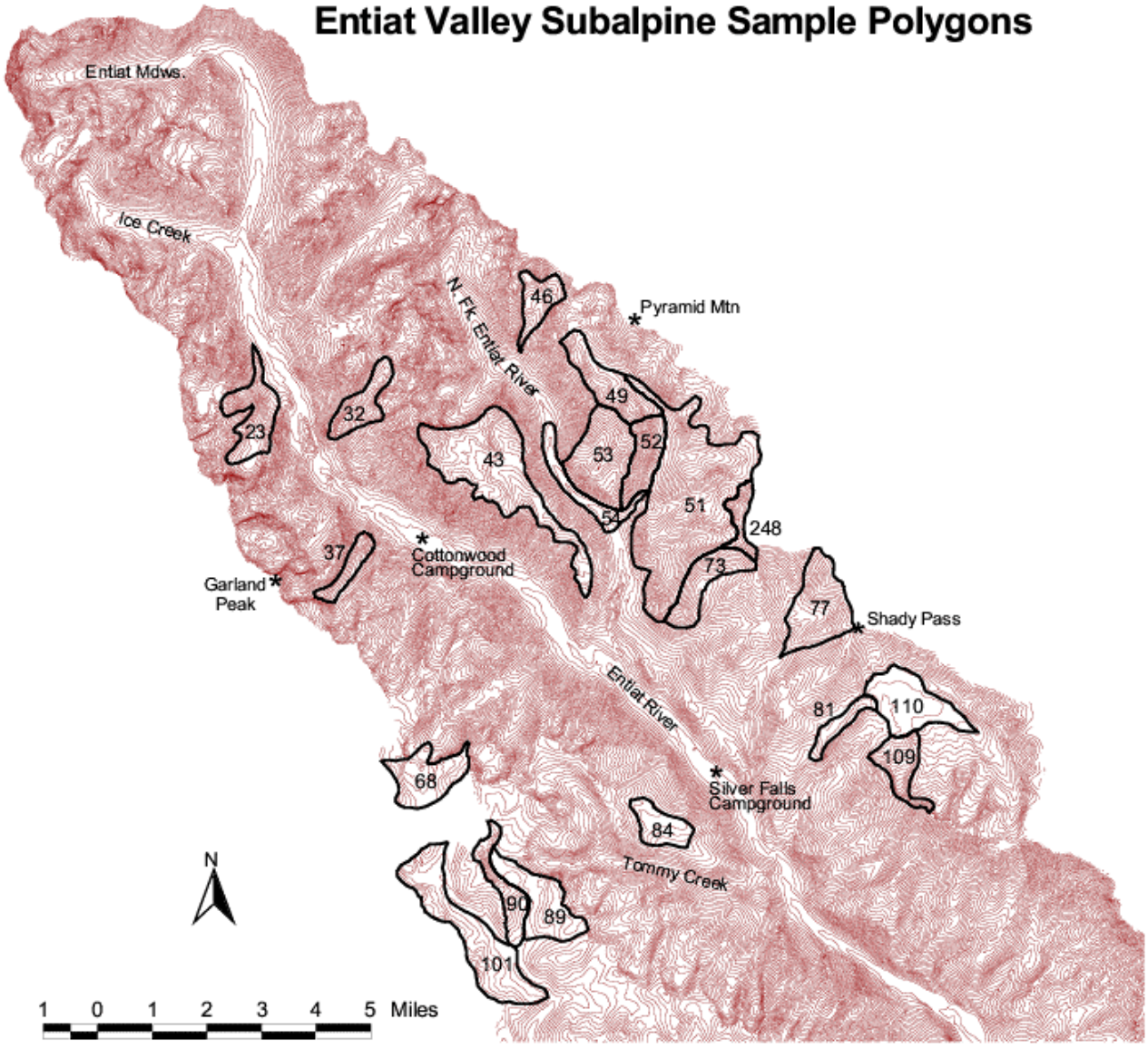
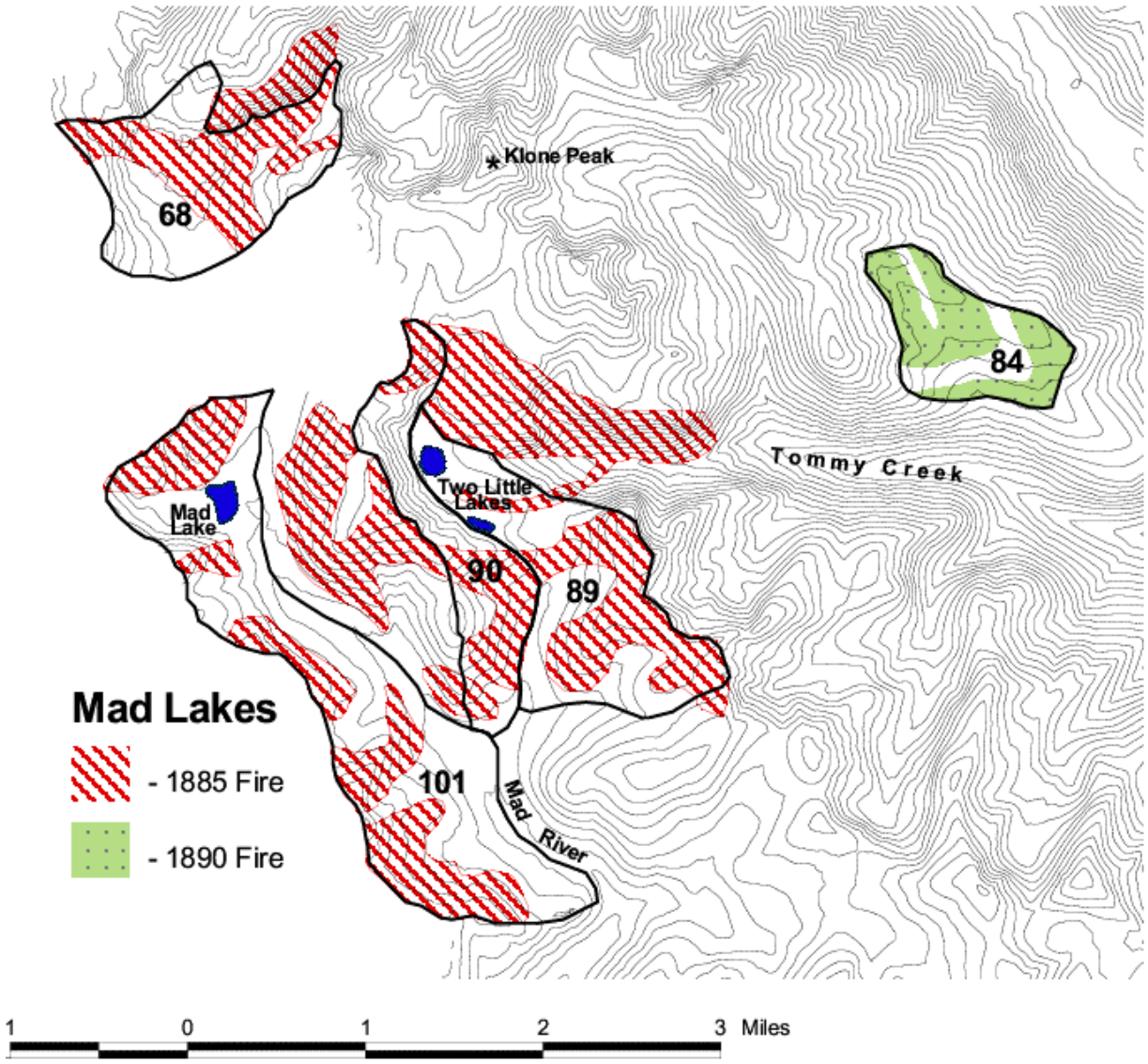
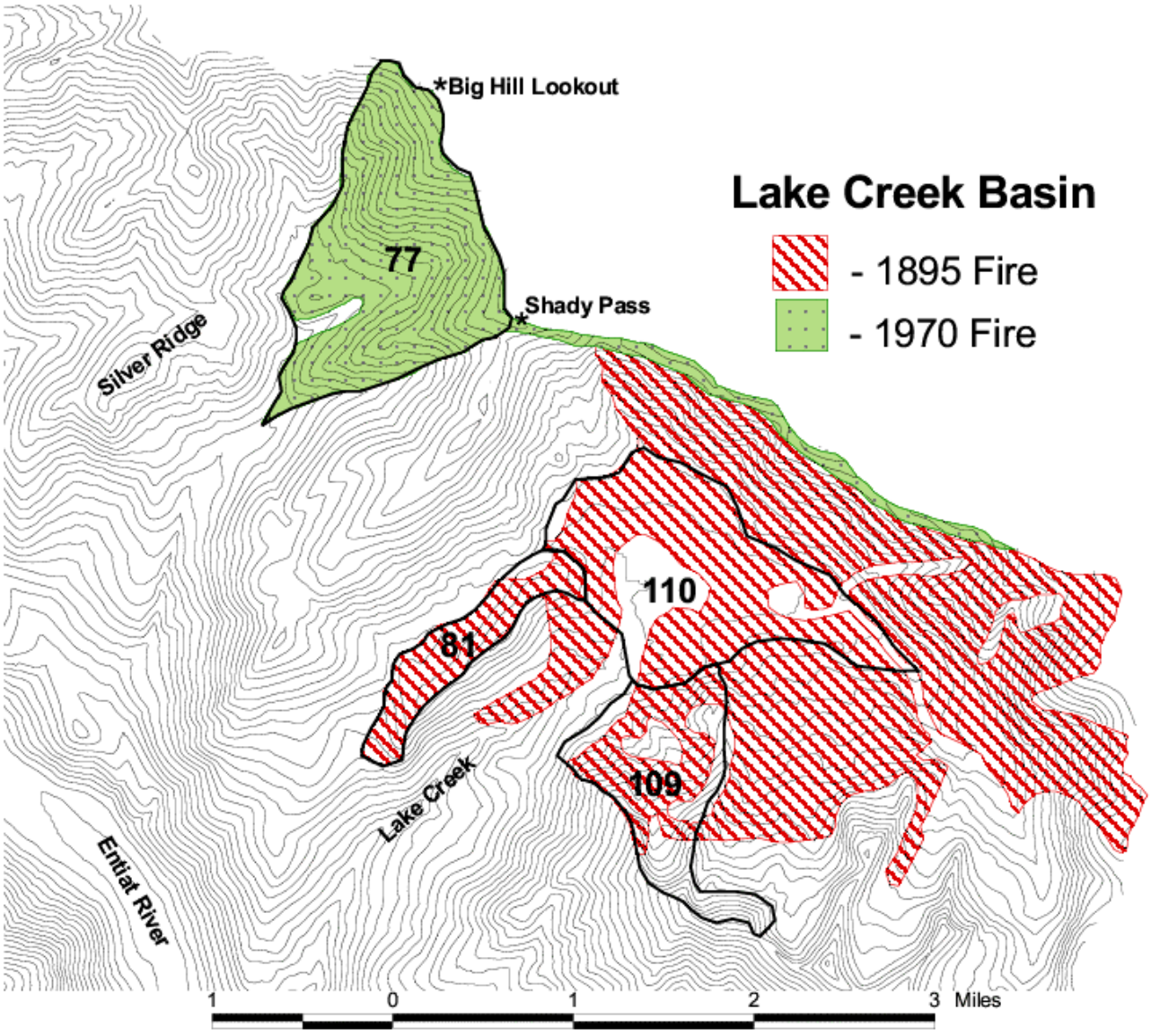
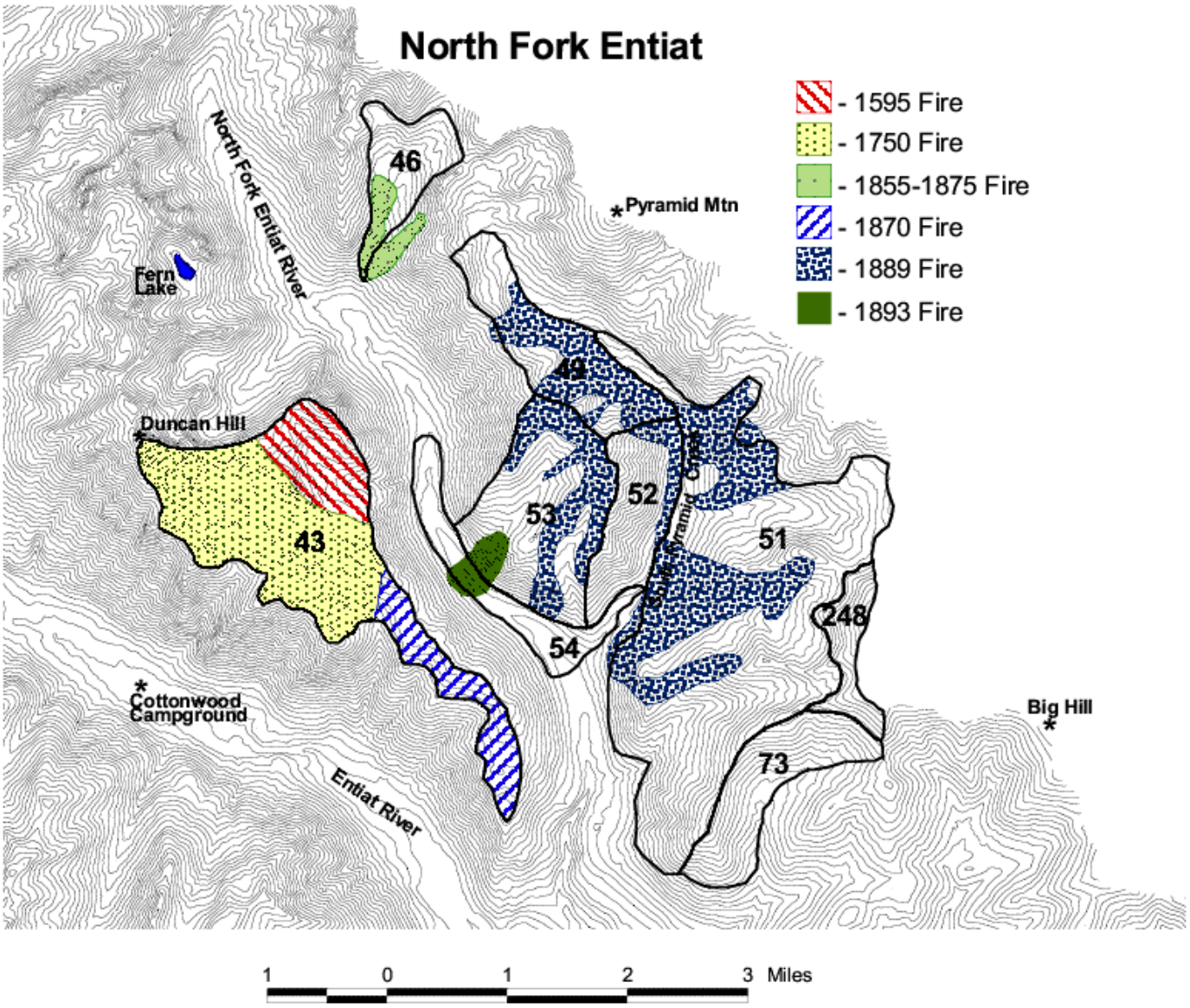
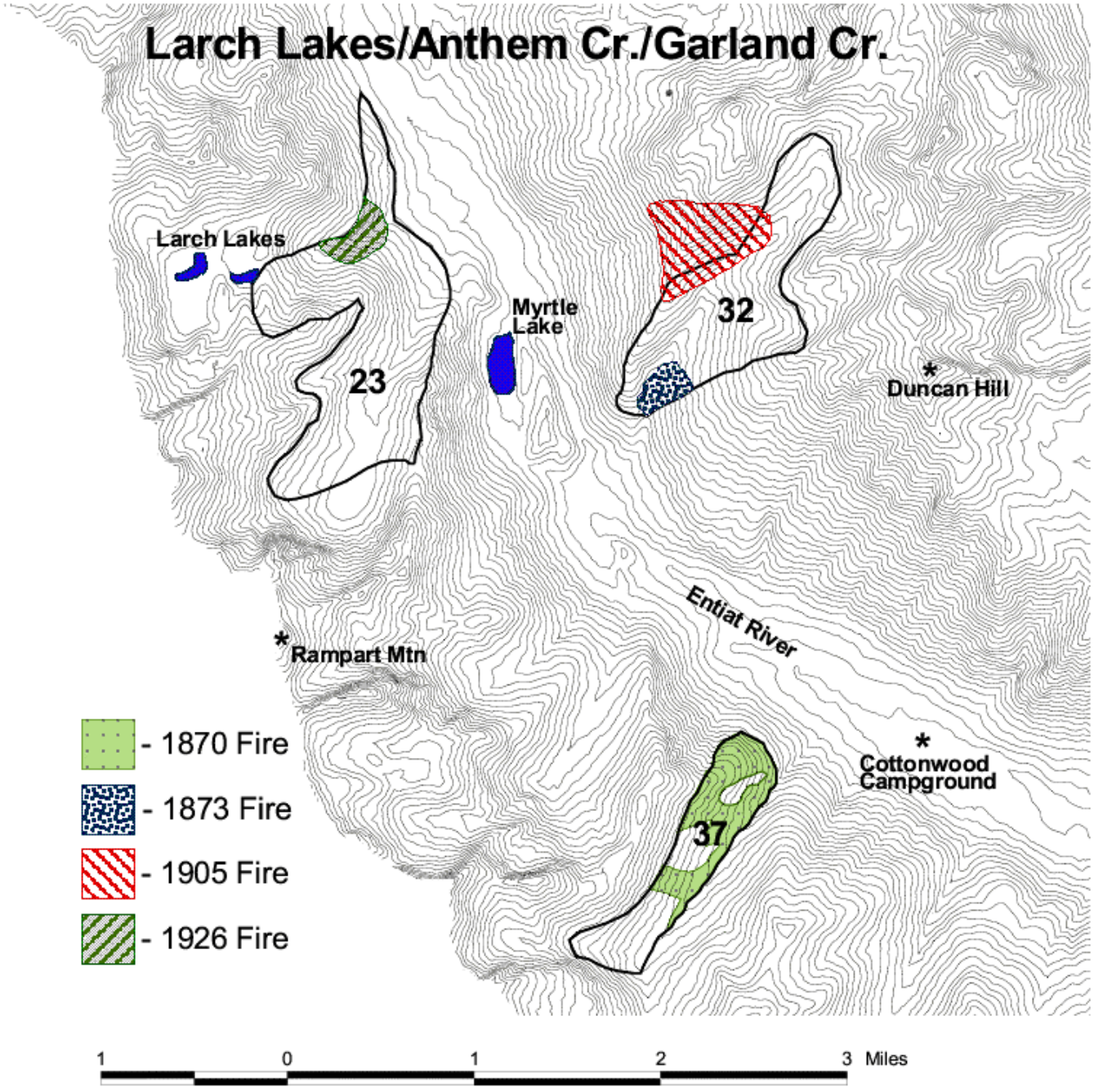
Entiat Valley Subalpine Sample Polygons

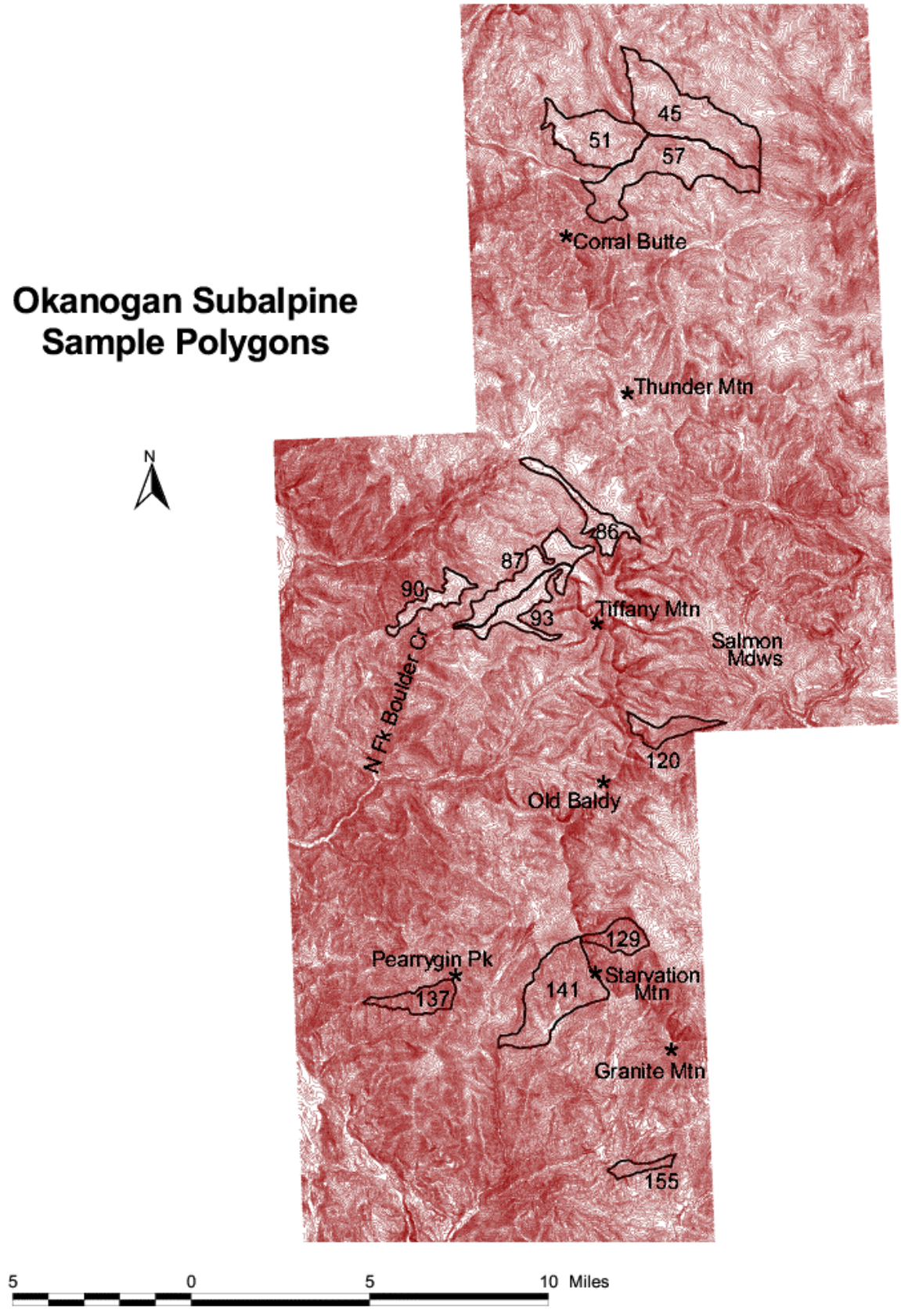


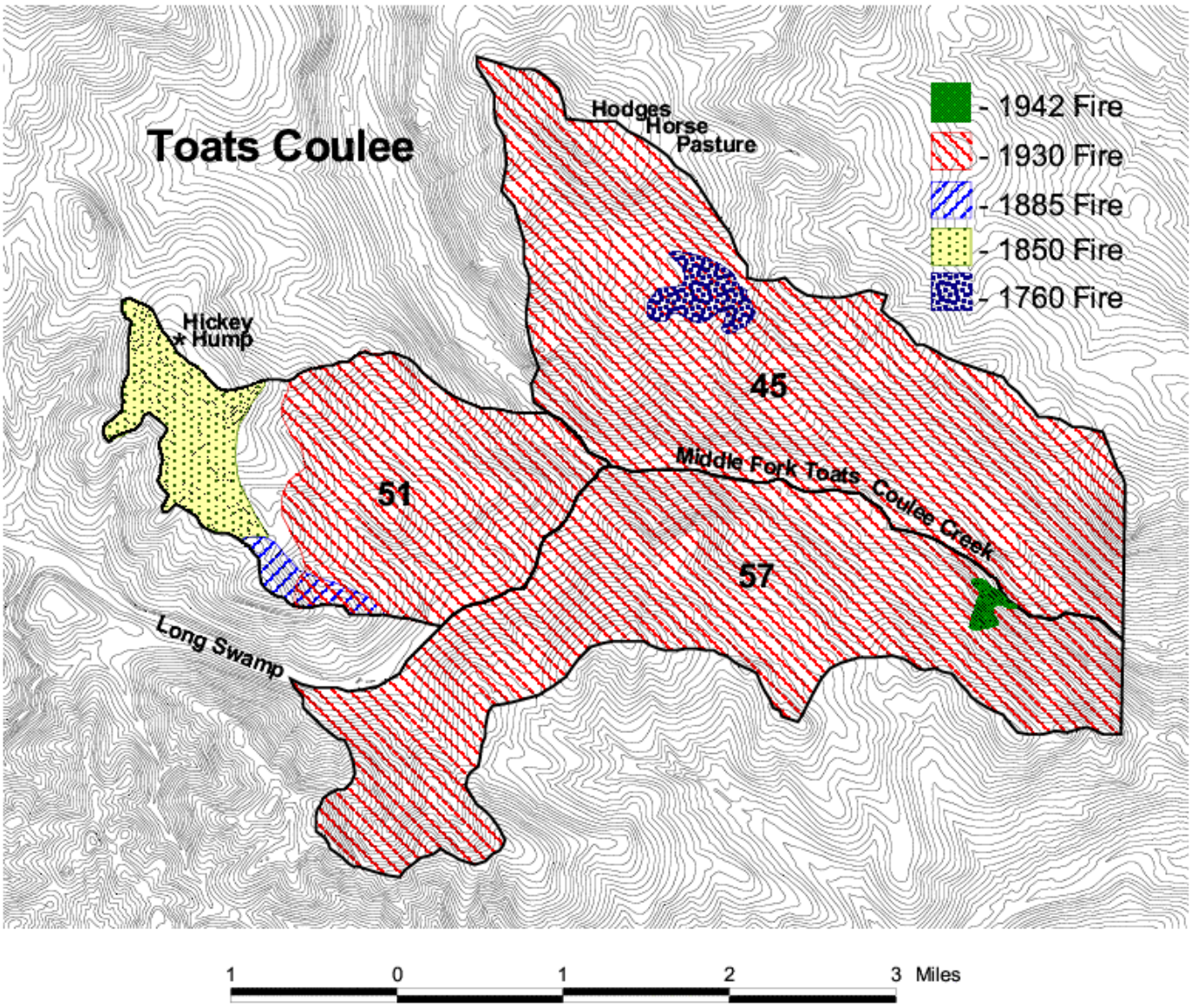

Klone Peak
68
84
Tommy Creek
Two Little Lakes
Mad Lake
90
89
101
Mad River
Mad Lakes
- 1885 Fire
- 1890 Fire
1 0 1 2 3 Miles

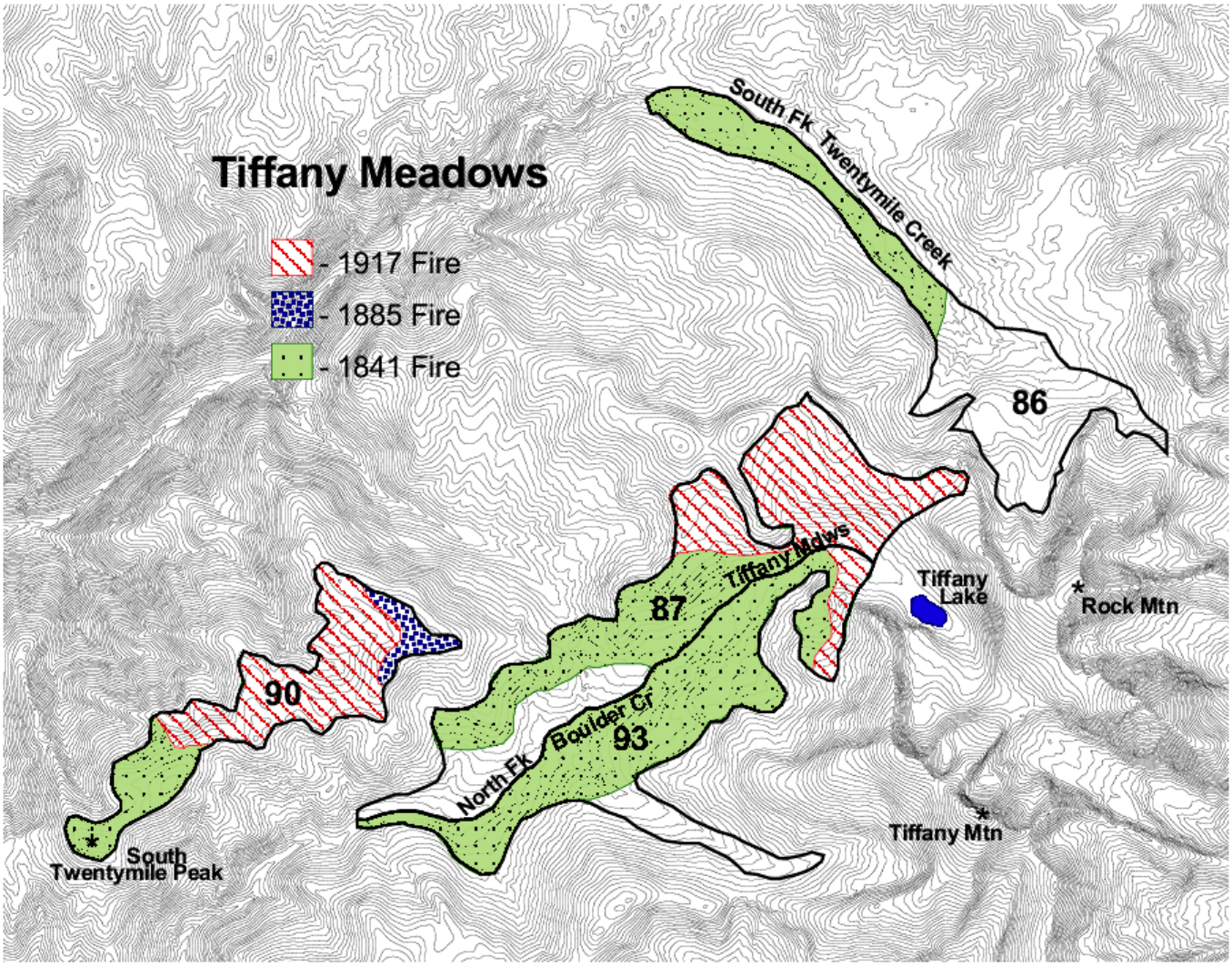

Lake Creek Basin
- 1895 Fire
- 1970 Fire
*Big Hill Lookout
Shady Pass
Silver Ridge
77
110
81
109
Lake Creek
Entiat River
1 0 1 2 3 Miles

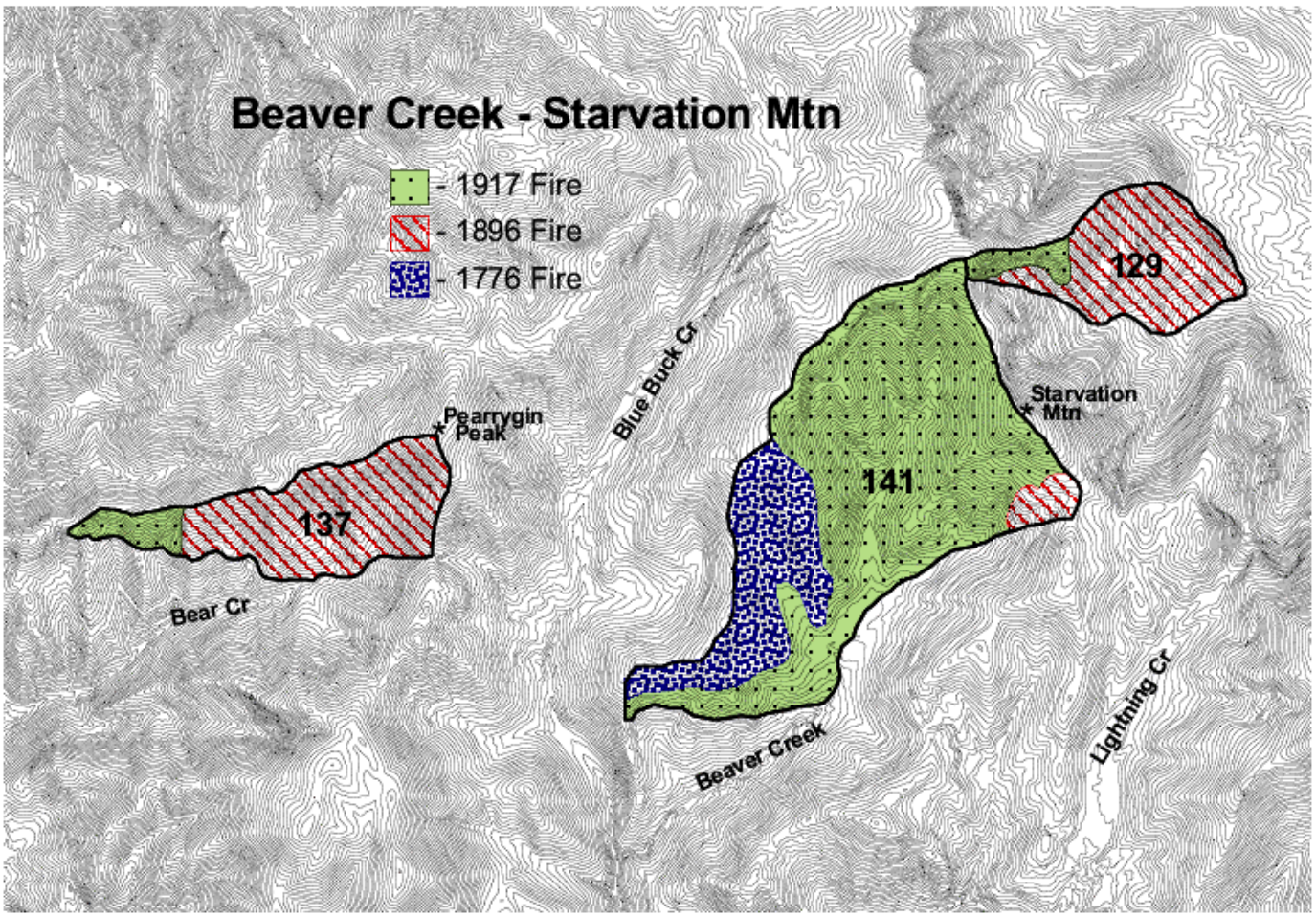

North Fork Entiat
- 1595 Fire
- 1750 Fire
- 1855-1875 Fire
- 1870 Fire
- 1889 Fire
- 1893 Fire
North Fork Entiat River
Fern Lake
Duncan Hill
Pyramid Mtn
Pyramid Creek
Cottonwood Campground
Entiat River
Big Hill
46
49
52
53
43
51
248
54
73
1 0 1 2 3 Miles

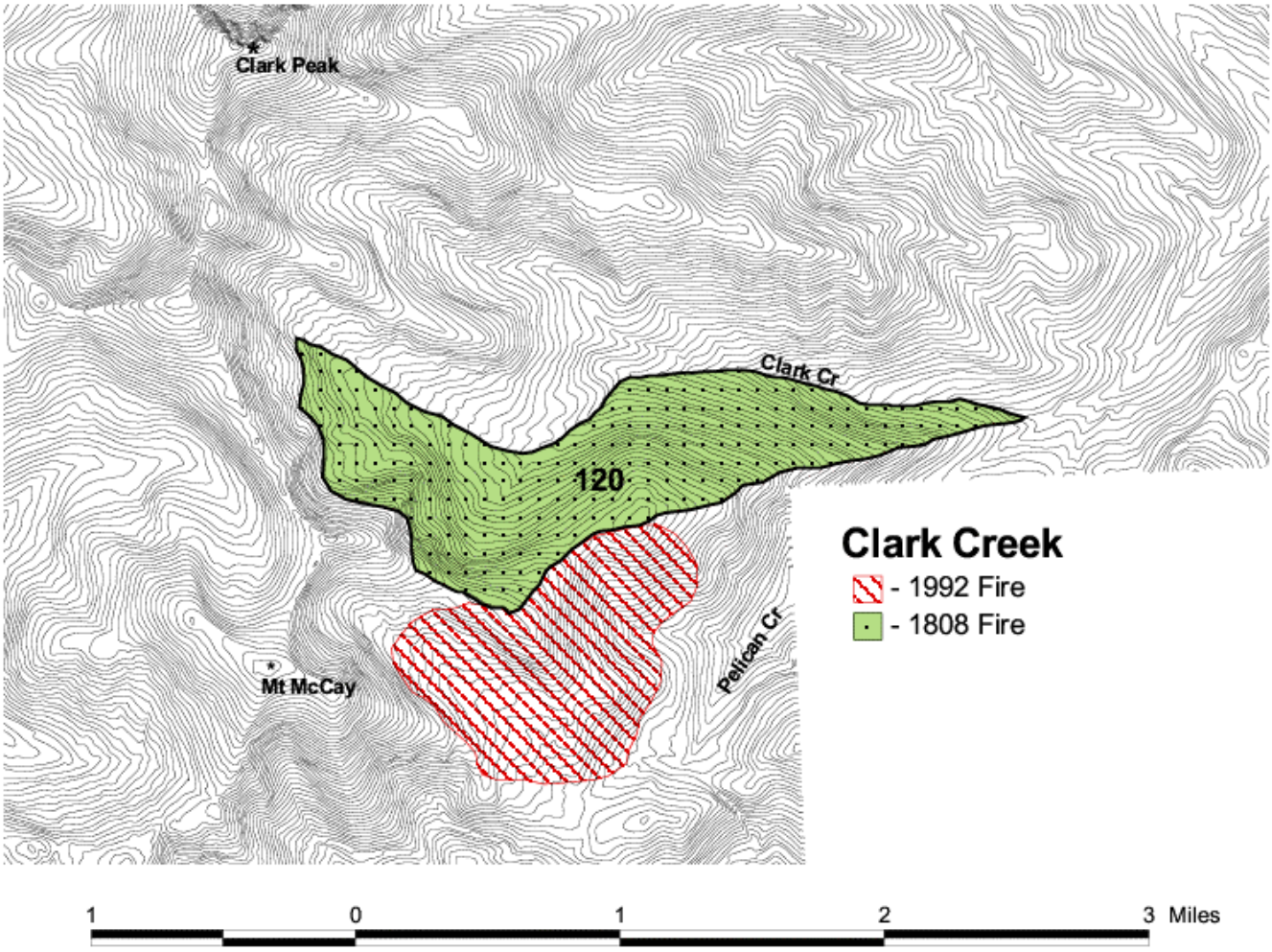

Larch Lakes/Anthem Cr./Garland Cr.
Larch Lakes
Myrtle Lake
23
32
37
Duncan Hill
Entiat River
Rampart Mtn
Cottonwood Campground
- 1870 Fire
- 1873 Fire
- 1905 Fire
- 1926 Fire
1 0 1 2 3 Miles


Okanogan Subalpine
Sample Polygons
N
45
51
57
*Corral Butte
*Thunder Mtn
86
87
90
93
Tiffany Mtn
Salmon
Mdws
N Fk Boulder Cr
120
Old Baldy
129
Pearrygin Pk
137
141
*Starvation
Mtn
Granite Mtn
155
5
0
5
10 Miles


Toats Coulee
Hodges Horse Pasture
Hickey Hump
45
51
57
Middle Fork Toats Coulee Creek
Long Swamp
- 1942 Fire
- 1930 Fire
- 1885 Fire
- 1850 Fire
- 1760 Fire
1 0 1 2 3 Miles


Tiffany Meadows
- 1917 Fire
- 1885 Fire
- 1841 Fire
South Fk Twentymile Creek
86
Tiffany Mdws
87
Tiffany Lake
Rock Mtn
90
Boulder Cr
93
North Fk
Tiffany Mtn
South Twentymile Peak
1 0 1 2 3 Miles


Beaver Creek - Starvation Mtn
- 1917 Fire
- 1896 Fire
- 1776 Fire
129
Blue Buck Cr
Starvation Mtn
Pearrygin Peak
141
137
Bear Cr
Beaver Creek
Lightning Cr
1 0 1 2 3 Miles


Clark Peak
Clark Cr
120
Mt McCay
Pelican Cr
Clark Creek
- 1992 Fire
- 1808 Fire
1 0 1 2 3 Miles