# Post-fire Treatment of Noxious Weeds in Mesa Verde National Park, Colorado

M. Lisa Floyd
David D. Hanna

*Prescott College*
*Environmental Studies Program*
*Prescott, AZ 86301*

and
Gary Salamacha

*Arches National Park*
*Moab, UT 84532*

**Abstract**. Re-introduction of fire as a management strategy can be detrimental to conservation of native ecosystems by promoting "noxious weeds" within invasion-susceptible plant communities. This idea was central to treatments following fire in the piñon-juniper (*Pinus edulis, Juniperus osteosperma*) woodlands and mountain shrublands (*Amelanchier utahensis, Quercus gambelii, Fendlera rupicola*) of Mesa Verde National Park, southwestern Colorado.

Fire is an integral ecological process in piñon- juniper woodlands and adjacent petran chaparral shrublands. However, wildfires in 1989 and 1996 created opportunities for the proliferation of noxious weeds, especially *Carduus nutans*, *Cirsium arvense*, and to a lesser extent, *Bromus tectorum*. Old-growth piñon-juniper woodlands were especially susceptible to non-native invasion and required aggressive management actions. In this study, we evaluated the effectiveness of three treatment strategies (mechanical, herbicide, and native grass seeding) in these high risk habitats. Introducing native perennial grasses, within three years of the fire, proved the most effective treatment in reducing non-native plant proliferation

**Key words**: noxious weeds, aerial seeding, Mesa Verde, species of concern

Email: Lisa Floyd, lfloyd-hanna@prescott.edu

## Introduction

In contrast to the early twentieth century, disturbed habitats today are increasingly targeted by non-native species (Heywood 1989, Mooney and Drake 1989, Soule 1990, Westman 1990, Floyd-Hanna and Romme 1993, Burke and Grime 1996). Fire has been an important natural disturbance agent on the Colorado Plateau, but fire frequencies have increased in the past century (Covington et al. 1997, Grissino-Mayer and Swetnam 1997,Turner et al. 1998), thus changing fire-related ecological patterns. Native seed reserves and declines in native forb diversity are two such changes (Crawley 1987, Hobbs and Huenneke 1992). Possibly as a result of these changes, post fire succession commonly includes non-native plant species. In Mesa Verde National Park (MVNP) in southwestern Colorado, large wildfires that occurred earlier in the twentieth century (1934, 1959, 1972) were not associated with weed invasion. However, following extensive fires in 1989 and 1996, recovery was characterized by significant non-native plant invasion. Based on this information, a series of mitigative treatments were tailored specifically for each burned community considered at risk for noxious weeds after the 1996 Chapin 5 fire in Mesa Verde National Park.

Vegetation recovery and treatment of noxious weeds were funded under the Burned Area Emergency Rehabilitation (BAER) program, 1996-1999. Mitigation treatments outlined in this paper involved mechanical and chemical controls and seeding treatments. Biological controls were also introduced as part of the BAER program and will be discussed elsewhere (Kendall, pers. comm.). In this paper, we focus specifically on the effectiveness of weed treatment strategies on high weed-risk areas following the 1996 fire.

## Study Area

Mesa Verde National Park (MVNP) is located in the extreme southwestern corner of Colorado (Fig. 1). The Park encompasses over one-half of a prominent cuesta, the top of which gently slopes from 2050 m in the south to approximately 2485 m in the north. The southern end of the cuesta drops into the canyons of the Mancos River, while the northern end terminates in a steep, highly eroded escarpment. The cuesta is composed of Cretaceous sandstone and shale substrates: Mancos Shale, Point Lookout Sandstone, Menefee Shale, and Cliffhouse Sandstone (Griffits 1990). The top of the cuesta consists of numerous north-south trending, relatively flat ridges or "mesas," separated by rugged canyons.

Annual precipitation at MVNP averaged 45.8 cm between 1923 and 1994. Most precipitation falls in winter months as snow, or during the summer monsoons as thundershowers. July (avg. 4.52 cm) and August (avg. 5.2 cm) are the highest precipitation months. Lightning from mid-July through mid-August is the cause of 94% of the fires at MVNP.

Mesa Verde exhibits an elevation gradient in pre-fire vegetation communities. In the northern portions are several types of mountain shrublands, collectively called Petran chaparral (Fig. 1, light gray). These shrublands are of variable composition, often dominated by *Quercus gambelii* (gambel oak), *Amelanchier utahensis* (Utah serviceberry ), *Cercocarpus montanus* (mountain-mahogany), *Fendlera rupicola* (fendlerbush)

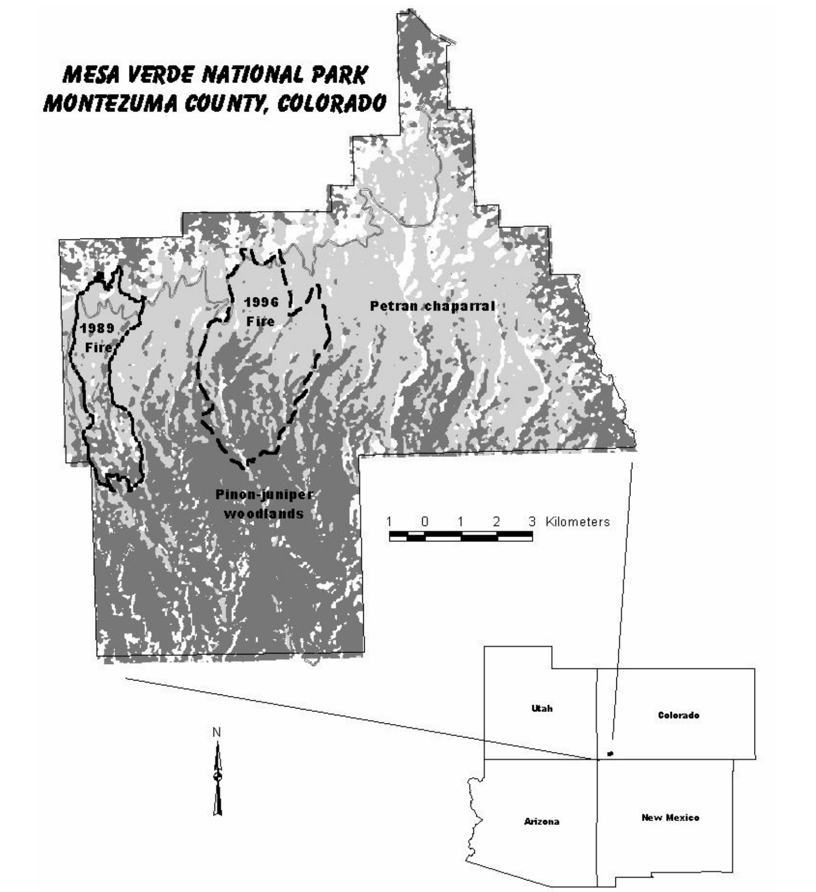


**Figure 1**. Locations of Long Mesa (1989) and Chapin 5 (1996), Mesa Verde National Park, Colorado.

and other perennial shrubs (Spence et al. 1995). Piñon-juniper woodlands (Fig. 1, dark gray) commonly interdigitate with these chaparral communities that share many of the same species, but have distinctly different structure. The woodlands are dominated by *Pinus edulis* (Colorado piñon pine) and *Juniperus osteosperma* (Utah juniper ), and may have shrub understory dominated by gambel oak or *Purshia tridentata* (bitterbrush).

## *Disturbance History*

Small, lightning-caused fires are frequent in MVNP; the annual average for fire starts between 1926-1969 was 5 per year, and between 1970-1997 was 18 per year. Most fires started in the piñon-juniper woodlands and burned less than 1 hectare. Large fires occurred in 1934, 1959, 1972, 1989, and 1996. The southern half of Mesa Verde is covered with dense, old-growth piñon-juniper woodlands that had not burned for several centuries. However, the 20th century has seen several spectacular wildfires that burned extensive portions of the pinon-juniper woodlands. The Chapin 5 fire began with a lightning strike in the dense piñon-juniper/bitterbrush woodland on the archeologically-rich Chapin Mesa, and burned through Soda Canyon, Little Soda Canyon, and large portions of the research area Park Mesa, before it stopped at the Visitors Center and hotel complex in dense oak and serviceberry shrublands. The fire covered 1934 ha, including seven pre-fire vegetation communities (Fig. 1).

Fire is the major disturbance factor in MVNP, but numerous smaller gaps also occur throughout the woodland canopy. Small gaps are often caused by pathogens, such as the Black stain root rot, *Ophiostoma wagnerii* Goheen and Cobb (=*Verticicladiella wagnerii*=*Ceratocycsis wagnerii*) which kills patches of up to 50 piñon trees, and has been present in southwestern Colorado since the 1930's (Harrington and Cobb 1998). Also, roads and park facilities provide continual disturbances. The woodlands are also disturbed in narrow belts, surrounding housing and park buildings, by annual fuel reduction activities. Thus, small patches of noxious weeds have been present in MVNP in the last 3 decades (M. Colyer, pers. comm.).

## *Weed Species of Special Concern in MVNP*

Following the last two large fires, *Cirsium arvense* (Canada thistle) and *Carduus nutans* (musk thistle) aggressively invaded bare mineral soils. Musk thistle has an extensive native range from North Africa, Europe, Siberia, to Asia Minor. It has spread to New Zealand, Australia, and North America, where it is still expanding its range (Shea and Kelly 1998). In 1976, populations of musk thistle were located in eastern Colorado (Dunn 1976), and since that time, it has spread at an alarming rate through the state. Musk thistle is usually a biennial, but it can also be annual or perennial, reproducing exclusively from seed. Treatments of herbicide (Colorado State University Extension Service), biocontrol agents, and limitations on grazing (Rees 1982, Shea and Kelly 1998) are used to control its local distribution.

Canada thistle is more difficult to control because of horizontal adventitious roots that may extend 2 m deep (Hodgson 1968, Rees 1990), from which it rapidly resprouts after fires. Canada thistle is an aggressive weed which can reproduce from seed or vegetative buds, expands 2-4 m in one year, and significantly reduces forage in pastures throughout the western United States. The expansion of Canada thistle is controlled locally by herbicides, mowing, and biological controls (Colorado State University Extension Service). *Urophora cardui* and *Ceutrohynus litura* are commonly used biological control agents in Colorado (McCarty and Lamp 1982).

Other invasive species, which have become persistent in disturbed sites within MVNP and the surrounding region, include *Cirsium vulgare* (Bull thistle), *Salsola iberica* (Russian thistle), *Centaurea dehisa* (knapweed), *Centaurea repens* (knapweed), *Lactuca serriola* (wild lettuce), *Ranunculus testiculatus, Tamarix ramosissima (T. pentandra)* (tamarix), *Alyssum minor*, *Linaria vulgare* (butter and eggs), *Lepidium latifolia* (pepperweed), and the grasses *Festuca pratense, Agropyron intermedium* (intermediate wheatgrass), *Bromus tectorum* (cheatgrass), and *Bromus inermis* (smooth brome).

# METHODS

## *Rehabilitation Treatments*

### Aerial Seeding Treatments

Although seeding treatments typically occur in a narrow window of opportunity within months of a fire, our treatments involved aerial seeding with assemblages of native grass seeds during three time periods: (1) immediately after the Chapin 5 fire, (2) on bare soils that remained one year after the fire, and (3) on bare soils two years after the fire. Perennial grass mixes simulated, as much as possible, the native grass community for the elevation, substrate, and pre-fire vegetation of each area (Appendix A). Seeds were primarily obtained from the Park itself or from local vendors who grow local seed varieties. In 1996, the extent of severely burned areas in the Chapin 5 burn exceeded the availability of native grass seeds (the demand for seeds was high because of numerous fires in the western United States). Therefore, we aerially seeded only 278 acres of the high-risk portion of the burn (Fig. 2).

In 1997, additional areas of the fire were seeded. Again, seeds were obtained locally with every attempt made to ensure that local seed sources were used. The selected areas either encompassed a very high density of archeological sites, were particularly susceptible to erosion, or had very little regrowth and were, therefore, at high risk of weed invasion (Fig. 2).

The 1996 and 1997 seeding treatments were quite successful in reducing weed invasion (see below). However, in the southern portion of the burn, up to 50 % of the soils remained exposed in some areas that had not been treated. These soils could be targets for the incoming noxious weeds, native forb and grass species, or seeded grasses, if introduced. In 1998, we took the bold step of applying additional seeding treatments to six small areas that were deemed particularly vulnerable to weed invasion.

During each year, seeds were applied with mechanical seeders from a Bell Jet Ranger helicopter (Mark Santee, pilot and Bob Greeno, seeder engineer). Seeding treatments took place in early October.

Success of seeding was measured in a series of 80 $m^2$ circular plots, placed at approximately 500 m intervals within treated areas (20 plots), and adjacent burned controls (20 plots), in the spring following each seeding treatment. In addition, a series of 20 plots were established within unburned portions of Park Mesa. Since the seeded species were bunch grasses, it was possible to identify individuals in the early stages of growth; therefore, the density, rather than the cover, of each species was recorded. The density of each weed species was also recorded.

### Herbicide Treatments

Twenty-three Canada thistle patches were located (with GPS), photographed, and sprayed in June and again in August, 1998, with back-pack sprayer application of Curtail (3,6-dichloro-2-pyridinecarboxylic acid, monothanolamine salt 7.5 %, 2,4-dichlorophenoxy acetic acid, tris-propanolmaine salt 38.4 %), mixed with Improved JLB oil plus and IFA- S-90 Surfactant. Each stand was revisited within two months of spraying treatment, post-application photographs taken, and the percent mortality was estimated visually.

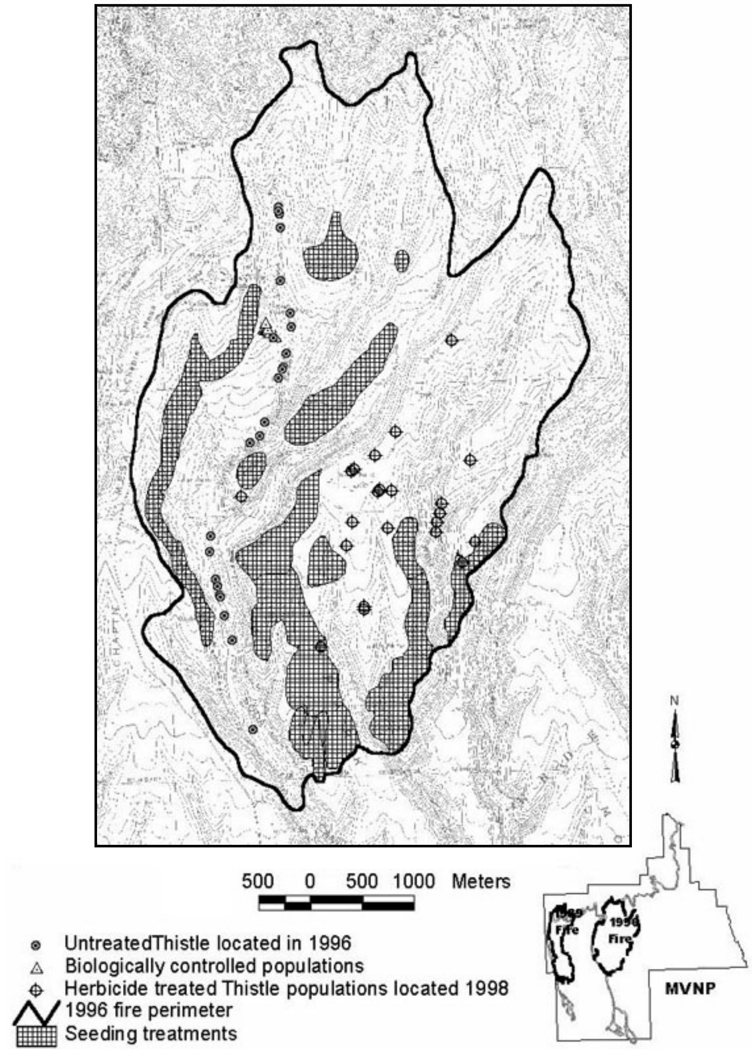


**Figure 2**. Weed treatments at Chapin 5 Fire site, Mesa Verde National Park.

In 1999, each stand was revisited, and if the noxious weeds were still alive, an additional application of Curtail was used. Photographs were taken of each plot, and an ordinal variable was created whose values approximated the percent of Canada thistle mortality.

### Mechanical Treatments

Particularly dense stands of musk thistle were removed by digging up the rosettes (hand-grubbing) in June-August 1977 and June 1998. Treatment areas included canyon bottomlands, where native grasses were likely to resprout, and rocky canyon walls and mesa tops, where residual vegetation was lacking. A year after treatment, the number of musk thistle was counted in belt transects, each 33 m long and 4 m (132 $m^2$) wide, in each mechanical treatment stand. Fifteen transects were established in treatment areas, paired with an adjacent, non-treated "control" stand, and the density of musk thistle was statistically compared with a paired T-test.

Data were analyzed using one-way analysis of variance or T-tests to compare means of each dependent variable across treatments (seeded or control). All data were analyzed with SPSS, Statistical Package for the Social Sciences, version 10.

## RESULTS

### Aerial Seeding Treatments

One year after seeding treatment, grass density was significantly higher in the seeded areas than in nearby control plots (Table 1). This trend was also apparent in nearby plots the following two years (Floyd et al. unpub.). All species flowered and produced seeds in 1997 and 1998. *Agropyron trachycaulum* (slender wheatgrass), *Sitanion hystrix* (squirreltail grass), and *Oryzopsis hymenoides* (Indian ricegrass) were especially conspicuous.

The potential effect of the seeding treatment on the expansion of noxious weeds was analyzed in 1998 and 1999. We monitored the density of all non-native species; however, during the first 2 years, only musk thistle and Canada thistle had spread appreciably. Scattered patches of cheatgrass arrived later (in 1999). In the 1996 treatments, there was a 7.5-times reduction in musk thistle in the seeded areas, compared with the control; there was a 4-times reduction in weed density following the 1997 seeding (Table 2). Weed invasion was absent from all unburned control plots; therefore, unburned controls were not shown in Table 2. During summer, 1999, we monitored the germination of grass seed applied in fall, 1998. Germination was successful, resulting in significantly greater grass density than in control areas; however, the effect of the 1998 seeding on reduction of musk thistle cannot be evaluated until next year.

In related studies (Floyd-Hanna et al. 1999) recovery by native species was tracked for over three years following the fire. Abundant native forbs included *Polygonum sawachensis* (knotweed), *Lupinus caudatus* (lupine), *Lupinus ammophila* (lupine), and *Penstemon linearoides* (low penstemon). There has been no evidence to date that native forb diversity has declined due to seeding treatments compared with adjacent burned control plots.

### Herbicide Treatments

Upland patches of Canada thistle were treated with herbicide applications. It should be noted that herbicide was not used in drainage systems near water. Herbicide treatments with Curtail varied in their effectiveness. In 75% of the herbicide applications, Curtail was locally effective, killing between 70-100% of the ramets of Canada thistle within two months of spraying, and maintaining an average of 80% kill the next year. In 25 % of the application, live plants persisted on the periphery of

**Table 1**. The density of native perennial grasses one year after aerial treatment, Chapin 5 fire, Mesa Verde National Park. Each value is mean ± standard deviation. Sample sizes were n=20 per treatment. T-tests indicate significant differences between seeded and control (not seeded) burned treatments. (*denotes P<0.05).

| Grass Species | Control Density | Seeded Density | Significance |
|---|---|---|---|
| *Poa fendleriana* | 1.0 ±2.1 | 12.0 ±17.4 | T= 2.2* |
| *Sitanion hystrix* | 0.0 | 5.9 ±6.0 | T= 3.5* |
| *Oryzopsis hymenoides* | 1.0 ±2.3 | 0.6 ±.9 | T= 0.6 |
| *Agropyron trachycaulum* | 0 | 5.6 ±6.3 | T= 3.2* |

the patch. In Soda Canyon, Canada thistle had been well-established before the fire, and re-sprouting was visible within a few weeks. These areas are strictly treated with biological controls, reported elsewhere (Kendall, pers. comm.).

### Mechanical Treatments

Only extremely dense patches of musk thistle were chosen for mechanical treatments. Results varied considerably among the mechanically treated (hand-grubbed) areas. No significant difference in musk thistle density was detected one year after treatment in areas where grasses were lacking (pre-treatment average 32,400/ha, post-treatment average 37,600/ha). However, there was a three-fold (pre-treatment average 28,400, post-treatment 9,300/ha) and five-fold (pre-treatment average 33,900, post-treatment average 6650 ha) decrease in density in two treated areas where mechanical treatment was followed by "natural" grass invasion. While it appeared that mechanical reduction was an effective local treatment if followed by natural or artificial grass seeding, further long-term evaluation is needed.

**Table 2**. The density of musk thistle, *Carduus nutans*, in seeded and control (not seeded) treatments, one year after treatment, Chapin 5 fire, Mesa Verde National Park. Each value is the mean ± standard deviation. Sample sizes were n=20 per treatment. Analysis of variance tests indicate significant differences between seeded and control (not seeded) treatments in 1996 treatments (F=10.9, P<0.05) and 1997 treatments (F=8.1, P<0.05).

| Treatment | Density of musk thistle (#/80m$^2$) |
|---|---|
| **1996** | |
| Mesa top seeding | 10.4 ±8.3 |
| Control, unseeded mesa top | 83.1 ±66.6 |
| **1997** | |
| Canyon site seeding | 28.0 ±53.4 |
| Control, unseeded canyon | 96.5 ±47.2 |

## DISCUSSION

In the three years following the 1996 Chapin 5 wildfire in Mesa Verde National Park, burned old-growth piñon-juniper woodlands supported the greatest diversity and density of non-native plant species relative to the six other vegetation types burned. In many of the other vegetation communities, residual vegetation, in the form of resprouting perennial shrubs and grasses, allowed rapid recovery and prevented noxious weed invasions (Floyd-Hanna et al. 1999). Post-fire mitigation activities conducted under the Burned Area Emergency Rehabilitation (BAER) program, were designed to prevent noxious weed invasion and severe erosion, and to encourage native plant species. These were carried out most intensively in the old-growth piñon-juniper community.

In all three treatments, we documented a significant reduction in weed densities. Of the treatments applied, seeding with native grass species has shown the most pronounced effects in reducing weed density. Furthermore, there has been no evidence that the diversity of native forbs has declined by introducing native perennial grasses. Herbicide and mechanical treatments were effective in the short-term, but whether they reduce population expansion, decreasing subsequent seedling germination and establishment, is not yet known. Mechanical treatment was only effective if followed by native grass invasion. Both mechanical and herbicide treatments can only be applied, realistically, in small patches; aerial seeding of native grasses can be applied over large areas. The effect of biological controls will not be evident for at least several more years (Kendall, pers. comm.).

While it cannot be known to what extent the noxious weeds would have spread had we not performed the treatments, it is reasonable to assume that the spatial extent has been reduced by at least the areas treated. BAER funding is available only to treat emergencies; therefore, we could only apply treatments to the most severely burned or threatened habitats (primarily old-growth piñon-juniper communities). Over one-half of untreated piñon-juniper communities were invaded by musk thistle within three years of the fire, as detected by helicopter survey (Floyd-Hanna et al. 1999). Musk thistle is now the dominant species in these areas. Thus, we recommend that future fires be seeded with native species extensively in burned communities that lack residual vegetation, such as dense, old-growth piñon-juniper woodlands. Such treatments promote native, perennial grass growth and reduce the proliferation of non-native species.

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**Appendix A**. Community-specific native grass seed mixes used for rehabilitation of the Chapin 5 fire, Mesa Verde National Park. Locations of seeded areas are shown in Figure 2; approximate acreage which were seeded are shown in parentheses.

Seeding Area A: (77 acres)
- *Kohleria cristata,* June Grass, 2 lb/acre
- *Oryzopsis hymenoides*, Indian Rice Grass, 6 lb/acre
- *Agropyron trachycaulum* , Slender Wheat Grass, 5 lb/acre
- *Sitanion hystrix,* Squirrel-tail Grass, 6 lb/acre

Seeding Area B: (201 acres)
- *Poa fendleriana*, Mutton Grass, 2 lb/acre
- *Oryzopsis hymenoides*, Indian Rice Grass, 6 lb/acre
- *Agropyron trachycaulum* , Slender Wheat Grass, 5 lb/acre
- *Sitanion hystrix,* Squirrel-tail Grass, 6 lb/acre

Seeding Area C.: (250 acres)
- *Agropyron smithii,* Western Wheat grass, 8lbs/acre
- *Poa fendleriana*, Mutton Grass, 1.5 lb/acre
- *Oryzopsis hymenoides*, Indian Rice Grass, 6 lb/acre
- *Agropyron trachycaulum* , Slender Wheat Grass, 5.5 lb/acre

Seeding Area D: (110 acres):
- *Kohleria cristata,* June Grass, 1.0 lb/acre
- *Sitanion hystrix*, Squirrel-tail Grass, 2.4lb/acre
- *Agropyron trachycaulum* , Slender Wheat Grass, 5.5 lb/acre
- *Stipa comata*, Needle and thread grass, 3.5 lb/acre

Seeding Area E: (125 acres)
- *Oryzopsis hymenoides*, Indian Rice Grass, 6 lb/acre
- *Agropyron trachycaulum* , Slender Wheat Grass, 5.5 lb/acre
- *Sitanion hystrix*, Squirrel-tail Grass, 2.4lb/acre
- *Poa fendleriana*, Mutton Grass, 1.5 lb/acre

Seeding Area F: (50 acres)
- *Kohleria cristata,* June Grass, 2 lb/acre,
- *Oryzopsis hymenoides*, Indian Rice Grass, 5 lb/acre
- *Agropyron trachycaulum* , Slender Wheat Grass, 5 lb/acre
- *Sitanion hystrix*, Squirrel-tail Grass, 2.5 lb/acre

Seeding Area G: (125 acres)
- *Poa fendleriana*, Mutton Grass, 2 lb/acre
- *Oryzopsis hymenoides*, Indian Rice Grass, 6 lb/acre
- *Agropyron trachycaulum* , Slender Wheat Grass, 5 lb/acre
- *Sitanion hystrix*, Squirrel-tail Grass, 6 lb/acre
- *Agropyron smithii,* Western Wheat Grass, 5 lb/acre

Seeding Area H: ( 35 acres)
- *Poa fendleriana*, Mutton Grass, 2 lb/acre
- *Oryzopsis hymenoides*, Indian Rice Grass, 6 lb/acre
- *Agropyron trachycaulum* , Slender Wheat Grass, 5 lb/acre
- *Sitanion hystrix*, Squirrel-tail Grass, 6 lb/acre

Seeding Area I: (60 acres)
- *Kohleria cristata,* June Grass, 2 lb/acre,
- *Oryzopsis hymenoides*, Indian Rice Grass, 6 lb/acre
- *Agropyron trachycaulum* , Slender Wheat Grass, 5 lb/acre
- *Stanion hystrix*, Squirrel-tail Grass, 6 lb/acre
- *Agropyron smithii,* Western Wheat Grass, 5 lb/acre
- *Stipa comata*, Needle and thread grass, 2 lb/acre