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Where have all the suckers gone?: A comparison of Aspen treatments on the Deerlodge National Forest

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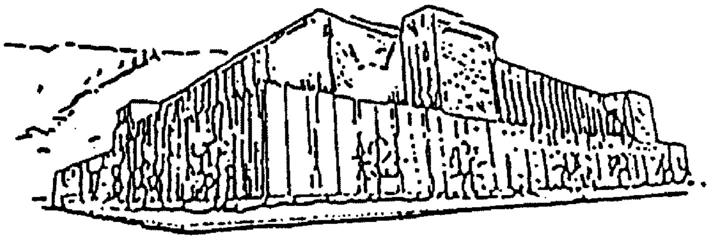

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Where Have All the Suckers Gone?

A Comparison of Aspen Treatments on the Deerlodge National Forest

by

Robert Hodge

B.S. Montana Tech 1995

presented in partial fulfillment of the requirements

for the degree of

Masters of Science

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1997

Approved by:

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Date

Abstract

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Where Have All the Suckers Gone: A Comparison of Aspen Treatments on the Deerlodge National Forest

Director: Dr. Tom DeLuca TLD

Quaking aspen (*Populus tremloides*) clones in the Deerlodge National Forest in Southwestern Montana have been declining in both density and patch size. Regeneration efforts have achieved varying degrees of success. The purpose of this study was to examine the effects of existing silvicultural treatments on aspen regeneration success in the Deerlodge National Forest. Over the past ten years, quaking aspen clones were treated in four areas in the Deerlodge National Forest using fire and mechanical scarification on upland sites and cutting on riparian sites. This study compared treatments as an attempt to identify factors which affect the success of aspen regeneration on these sites. Representative control sites were selected for each of the four areas and treatments were compared to the controls using paired t-tests. Aspen treatments were not consistently successful. Regeneration failure was caused by poor response to treatment and by large scale aspen sucker mortality due to *Cytospora* canker infections encountered in the years following treatment. Fencing proved to be effective when applied to a treated site. Leaving high slash concentrations on treated sites did not reduce browse intensities when compared to untreated sites. Mechanical scarification was probably the most successful treatment observed in upland sites.

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To all, many thanks,
BH

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Chapter 1

INTRODUCTION

Quaking aspen (*Populus tremuloides*) grows in a wide variety of climates and soil conditions and is the most widely distributed tree species in North America (Jones 1985). Aspen has been reported growing at sea level in western Washington and at over 11,000' in elevation in Colorado (Jones 1985). In the interior West, aspen is often associated with sites that are relatively moist (16-40 inches of annual precipitation), experience cold winters and yet have a reasonably long growing season (Jones 1985). Aspen is generally found on south slopes in Alaska, slopes with all aspects in the Northern Rockies and on north slopes and mountain tops in the Southwest (Jones 1985). Aspen also tends to grow at progressively higher elevations the farther south it is found in the western United States (Jones 1985).

Occurrences of aspen regeneration from seed have been noted (Kay 1993), but aspen primarily reproduces vegetatively in the intermountain West (Schier et al. 1985). Aspen has exacting temperature and moisture requirements in order for seeds to germinate and for seedlings to grow (McDonough 1985). In the intermountain West, sporadic rainfall is often followed by periods of dry weather which usually kills recently germinated seedlings (Kay 1993).

Aspen throughout the intermountain West tends to be in decline (Jones and DeByle 1985b). Stable aspen communities, although fewer in number than seral types do exist (Jones and DeByle 1985d) but the majority of the aspen stands encountered in the West tend to be seral communities which will eventually be replaced by conifer or shrubs and grasses in the absence of disturbance (Jones and DeByle 1985b). These seral aspen stands are relatively even aged and have originated as a result of stand replacement fire (Jones and DeByle 1985b). Aspen trees are easily killed by fire although aspen stands don't readily burn (Jones and DeByle 1985b). Aspen stands tend to have light fuels in the understory making it more difficult for fire to burn. The even aged and declining condition of aspen encountered in the West has been aggravated by livestock overgrazing in the early development of the West and by more recent fire suppression (Jones and DeByle 1985b).

Quaking aspen is a relatively small but important component of tree cover on the Deerlodge National Forest. Aspen occurs in both riparian and upland settings throughout the forest stabilizing riparian soils and providing important wildlife habitat. The upland component often consists of a single clone or a group of clones occurring as patches in open areas or adjacent to a stand of conifer. Additionally, over a large portion of the forest, upland aspen may occur as suppressed individual trees scattered through the understory of a stand of dominant conifers. Upland stands are less than 5-10 acres and are distributed throughout the forest with some exceptions in the Deerlodge Valley. On the west side of the valley, contiguous aspen stands occupy an area of over 100 acres near

Willow Creek and on the east side of the valley are some larger stands. Aspen that occurs in riparian settings exists primarily as one or a few clones scattered along draw bottoms of the forest. Aspen occurs in drainages with standing and running water and also in ephemeral drainages.

Beginning in the late 1980's as an effort to regenerate upland and riparian aspen stands, managers on the forest employed various treatments to aspen stands in conjunction with some other activity such as a riparian improvement project or a timber sale. Most of the aspen treatments occurred in riparian areas. In many cases there was an initial prolific suckering response followed by a rapid decline in the number of live aspen suckers following treatment. Managers on the Deerlodge National Forest need to determine the cause or causes of success and failure of aspen regeneration on the forest in order to prescribe treatments which will not lead to the eventual reduction or elimination of aspen.

A volume of literature is available concerning factors affecting aspen regeneration, but the investigations are usually conducted on sites where aspen exhibits a greater presence on the landscape than it does on the Deerlodge National Forest. Regeneration efforts in the productive stands where aspen is considered a commercial species often result in significantly higher numbers of aspen sprouts, however it is not clear whether conventional aspen regeneration practices apply to often poorly stocked aspen stands growing on the granitic soils of the Deerlodge National Forest. The purpose of this study is to provide land managers on the Deerlodge National Forest with an assessment of the effectiveness of past aspen stand management efforts and ultimately aid in future aspen management.

Objectives

The primary objective of this study was to assess the effect of cutting burning and mechanical scarification treatments on the numbers of surviving aspen suckers on the Deerlodge National Forest. These comparisons should aid in explaining why sprouting and survival rates of aspen regeneration have been significantly lower than expected following treatment and also in developing recommendations concerning future treatment. A secondary objective is to discuss the effect of site factors on aspen regeneration in both upland and riparian settings.

Hypothesis

In order to judge the degree of success of the treatments the study deals with these hypotheses:

1. For a treatment to be successful, aspen suckering should be significantly greater than before treatment. Therefore:

H_0: The number of aspen suckers on a site is not significantly greater following any treatment.

H_1: The number of aspen suckers on a site is significantly greater following any treatment.

2. Are some treatment types more successful than others? If some treatment types are more successful than others, when site conditions are similar, one type of treatment should produce more aspen suckers than another. The second hypothesis then deals with different treatments on similar sites:

H_0: The numbers of aspen suckers on similar sites following different treatments are not significantly different.

H_1 The numbers of aspen suckers on similar sites following different treatments are significantly different.

3. The study examines the relationship of site conditions to the number of surviving suckers. Do different types of sites respond differently to treatment?

H_0: There is no difference in the number of aspen suckers produced by riparian and upland sites following treatment.

H_1: There is a difference in the number of aspen suckers produced by riparian and upland sites following treatment.

Literature Review

There has been a substantial amount of research performed concerning aspen regeneration. The bulk of this research has taken place in areas where aspen is considered a commercial species - the Great Lakes states, Canada, Colorado, Utah and Arizona (DeByle and Winkour 1985, Perala 1991, Weber 1991, Shepperd 1996,). Some research is also available for Yellowstone National Park (Despain 1990, Renkin and

Despain 1994) and in northwestern Wyoming (Bartos et al. 1994) in areas that are more similar to the Deerlodge National Forest. These studies identify several factors influencing the success and survival of aspen regeneration including stocking of the parent clone, condition of the parent root system, genetic variability, apical dominance, climate, soils, browse, insects and disease and light availability. Since aspen in the intermountain west reproduces primarily by vegetative propagation only factors that apply to sprouting are examined in this study. These factors are roughly divided into three categories:

- Factors associated with the parent clone
- Factors associated with the reduction of apical dominance
- Factors associated with site conditions

Factors Associated With the Parent Clone

Stocking of the Parent Clone

Basal area of aspen stands is commonly correlated with below ground biomass (Perala 1991, Renkin and Despain 1994). The amount of below ground biomass can be used to predict the degree of suckering following a stand replacement treatment such as cutting or burning. In a study in Yellowstone National Park, Renkin and Despain (1994) concluded that above ground biomass and height of suckers both positively correlate with preburn basal area and root biomass. Perala (1991), who mainly worked with aspen in the Great Lakes region contended that stands should have at least 4-5 square meters/hectare of basal area in order to successfully regenerate. This figure is speculative since successful regeneration is defined by the purpose of the treatment. Successful regeneration for a well stocked stand where the production of pulpwood is the primary goal may be different than successful regeneration where the goal is merely to retain aspen as a continuous component of the landscape.

Condition of the Parent Root System

Recently sprouted aspen suckers depend on the parent root for water and nutrients (Jones and DeByle 1985d). As the suckers grow the distal parent root enlarges and branch roots form in this thickened portion. Eventually the sucker 'adopts' this portion of the root as its own. As the suckers continue to grow and compete for available nutrients and growing space the clone begins to self thin. This thinning results in the death of some of the sprouts. When the sprouts die the portion of the parent root may or may not also die resulting in a clonal root system where many but not all of the trees are connected through the root system (Jones and DeByle 1985d).

While it is known that the parent root system affects the regeneration, the degree of influence and all the ways the parent root system influences regeneration remains clouded. Shepperd (1993) studied the dynamics of lateral root systems in aspen and concluded that the role played by the parent root system was much greater than the immediate establishment of regeneration. Root functions between the parent root and the sucker continued for at least 14 years in some of the populations studied. There is a relationship between mortality in the root system of the parent clone and mortality in the aspen regeneration. Because suckers tend to be aggregated at root nodes, the death of the root node results in the death of all the suckers at that node (Shepperd 1993). The age of the parent root apparently has no significant effect upon the sprouts. Schier (1979) studied aspen root cuttings and concluded that the age of the parent roots had no effect upon the production of suckers. Schier (1979) also concluded that aspen suckers arising from parent roots derived from deteriorating clones performed no better than suckers arising from parent roots derived from healthy clones when grown in uniform conditions. Root systems in sparsely stocked clones tend to have less suckers produced at a root node (Shepperd 1993). Research is lacking in this area but Shepperd (1993) speculated that poor stocking of clones may be related to the condition of the parent root system when the disturbance that caused regeneration occurred. What all this seems to be saying is that basically well stocked parent clones produce well stocked regeneration and poorly stocked parent clones produce poorly stocked regeneration.

Genetic Variability

Aspen may be one of the most genetically variable plant species (Mitton and Grant 1996). Genetic variation of a species will increase with size of its geographic range, different environmental conditions experienced by the species and the size of its total population (Mitton and Grant 1996). Electrophoric surveys of aspen proteins revealed that over 90% of the enzymes that were analyzed were genetically variable compared to an average of 50% for all plant species that have been analyzed to date (Mitton and Grant

1996). Arid environments seem to be associated with the highest levels of genetic variation and moist environments are associated with the least (Mitton and Grant 1996).

Schier (1980) found variation among clones in their ability to sucker and produce roots. Schier, Jones, and Winkour (1985) contend that although genetic factors influence suckering capacity, environmental factors probably exert a stronger influence.

Factors Associated With the Reduction of Apical Dominance

In order for aspen to reproduce vegetatively, apical dominance must be reduced or eliminated. Suckering is stimulated when a high ratio of cytokinins to auxins exists in the root (Schier et al. 1985). Severing the stem or root, mechanically or with an intense fire stops auxins from entering the root and also prevents cytokinins from exiting the root via the xylem. The resulting higher than normal ratio of cytokinins to auxins stimulates suckering. If the auxin flow is interrupted but the cytokinin flow is not (as is the case with girdling and often with incomplete burns) the ratio of cytokinins to auxins will not increase and suckering will generally not be stimulated (Schier et al. 1985). The degree of suckering therefore is influenced by the type and possibly to some extent the timing of treatment (Weber 1991).

Stand replacement treatments usually result in prolific sucker production. In studies by Schier (1979) and Walters et al. (1982), partial cutting stimulated sprouting but damage by logging increased susceptibility to disease in the residual stand due to wounds. In a

Canadian study, Weber (1991) noticed that timing of treatment may play a significant role in the success of aspen regeneration. Cutting before leaf flush propagated the most suckers. Conversely, a low intensity burn before leaf flush significantly reduced the number of suckers produced. Cutting produced more suckers than burning in post leaf flush treatments (Weber 1991).

Another treatment type that is often not specified but is implied is mechanical scarification. Studies cite prolific suckering following clearcutting on commercial aspen sites (Schier 1979, Shepperd 1993,1996). Not only is apical dominance reduced by cutting the trees but root damage as a result of skidding and slash treatment also reduces apical dominance. Schier (1979) found scarification alone did not significantly increase sucker production, but went on to suggest (Schier et al. 1985) that mature stands of aspen may be regenerated by shearing or severing the roots. In this work, Schier et al. quoted unpublished work by another researcher (Trujillo) as a basis for their conclusion.

Shepperd (1996) studied bulldozing as a method of regenerating aspen clones. Bulldozed sites consistently supported more aspen suckers after five years than sites that were cut. Shepperd (1996) suggested that cutting may not totally suppress apical dominance. Some auxin may be produced in the stumps by previously dormant buds and possibly by stump sprouts. In the case of bulldozed aspen clones, it may be possible that suckering is stimulated by damage to the roots caused by root movement as the stems are pushed over (Shepperd 1996).

Factors Associated With Site Conditions

Climate

Slope, aspect, and elevation all affect aspen growth (Jones and DeByle 1985c). Aspen is the most widely distributed tree species on the North American continent growing over a wide range of sites and climatic conditions (Jones and DeByle 1985c). Aspen grows from alpine areas to the Great Plains (Jones and DeByle 1985c).

As with many other species, favorable soil moisture conditions is often one of the primary influences governing the occurrence of aspen at a site (Jones and DeByle 1985c). Aspen growth has been shown to be related to elevation, slope position, steepness of slope, temperature regime, age of the individual tree and degree of exposure to wind (Mitton and Grant 1996, Jones and DeByle 1985c). Cooler daytime and nighttime temperatures (68°F-day and 50°F-night) produce less aspen growth than do warmer temperatures (Jones and DeByle 1985c). Tree growth usually decreases with elevation (Mitton 1996). Frost pockets also have been shown to cause serious injury to aspen suckers (Jones and DeByle 1985c).

Soil Factors

Aspen grows on a variety of landforms and on soils derived from a variety of parent materials. Soil horizonation may provide insight as to whether aspen can be considered stable or seral on a site (Jones and DeByle 1985a). A site that has been occupied by aspen over several generations will develop a mollic horizon typical to aspen sites. A site that is occupied by aspen and then alternately conifer species may show zones of elluviation (Jones and DeByle 1985a).

In a Colorado study Cryer and Murray (1992) observed that stable aspen clones are associated with mollic horizons and seral clones are associated with soils that have developed an albic horizon with an ochric A horizon. This study suggested that the longer conifer species persist on a site, the more well developed the albic horizon becomes. It is thought that at some point the soil will become too acidic to support even a seral aspen community and that the site will then revert to permanent conifer occupation. Cryer and Murray (1992) noted the lack of threshold values for soil characteristics for successful aspen regeneration.

In an as yet unpublished study done in Colorado from 1990-1992 by William Jacobi (Colorado State University), aspen regeneration failures were thought to relate to stress brought on by both excess and insufficient soil moisture. Both poorly drained soils and soil with better water holding capacity increased the likelihood of canker infections. These infections were caused by species of canker (primarily *Cytospora*) that are normally present but are not usually lethal to the clone.

Browse

Browse by livestock and wildlife is a well documented factor affecting aspen regeneration (Bartos et al. 1994, Mueggler and Bartos 1977, Krebill 1972). In a study of aspen burns in Wyoming, Bartos et al. (1994) found that after 12 years of heavy elk browsing, the numbers of suckers and their growth had been significantly reduced. Although the number of suckers produced in the period immediately following the burn was considered sufficient for restocking, repeated browsing in subsequent years eliminated or severely suppressed the aspen suckers on one study site. Bartos concluded: "In this situation, fire treatment may have hastened the demise of decadent aspen." (Bartos 1994).

Wounds from browse activity provide infection sites for pathogens including sooty bark canker (*Cenangium singulare*) and *Cytospora* (Krebill 1972). Sparsely stocked aspen clones seem to experience a higher degree of browse than do dense clones. Shepperd (1993) found that sparsely stocked clones seem to experience less height growth than dense stands allowing browse to continue for a longer time.

In a Utah study, Mueggler and Bartos (1977) suggested that patch size is a factor influencing the degree of browse. As part of a 41 year study of small aspen clearcuts, aspen suckering was compared on sites that were unfenced, fenced to exclude livestock only and fenced to exclude both livestock and wildlife. Suckers were present for only a few years after treatment in both the unfenced areas and the areas fenced to only exclude livestock suggesting that both livestock grazing and wildlife use had led to the decline of aspen on the sites (Mueggler and Bartos 1977). Uncut, unfenced control areas were still producing aspen suckers 41 years later but the suckers were totally suppressed (Mueggler and Bartos 1977). Adjacent to the study site were large areas of successful aspen regeneration resulting from a burn "several hundred hectares in size" (Mueggler and Bartos 1977). Mueggler and Bartos (1977) concluded that the small treatment areas concentrated browse activity and that clearcutting or burning aspen patches of less than about 10 acres without some sort of protection from browse "might be futile."

Insects and Disease

Over three hundred species of insects have been observed in association with aspen (Batzer 1972). The species most frequently encountered in the West are:

- Tent caterpillars (*Malacosoma californicum*)
- Large aspen tortix (*Chorestoneura conflictana*)
- Aspen leftier (*Sciaphila duplex*)
- Several gemetrid moths
- Sawflies (Tenthredinidae)
- Leafminers

- Leaf rollers
- Leafhoppers (Cicadellidae)
- Aphids
- Several species of borers

(Jones et al. 1985).

Insect damage in aspen stands ranges from epidemic to incidental (Jones et al. 1985), but tent caterpillars, poplar borers and leafhoppers are most associated with damage in otherwise healthy stands of aspen (Jones et al. 1985, Batzer 1972).

Aspen is also a host to a variety of diseases. Foliar diseases are capable of killing aspen trees but more often only result in reduced tree growth in severely infected trees (Hinds 1985). Some of the more prominent foliar diseases that can damage aspen are black leaf spot (*Marisonina populi*), ink spot (*Ciborinia*), shepherd's crook (*Venturia macularis*), leaf rust (*Melampsora medusae*) and powdery mildew (*Erysiphe cichoracearum*) (Hinds 1985).

Several species of fungus also infect live aspen causing trunk, root and butt rots, but the most prevalent disease problem in western aspen is canker (Hinds 1985). Sooty bark canker (*Cenangium singulare*) is the most lethal (Hinds 1985). It is normally found on trees over sixty years old in the mid elevational ranges occupied by aspen. Wind breakage at the canker site is common (Hinds 1985). Black canker (*Ceratoeystis fimbriata*) mainly only results in trunk deformity on larger trees (Hinds 1985).

Cryptosphaeria canker (*Chryptosphaeria populina*) may be lethal to young trees but usually occurs as a branch canker on larger trees (Hinds 1985). *Hypoxylon* canker (*Hypoxylon mamatum*) is widespread in the Great Lakes area and in localized sections of the Southwest, but is not uniformly distributed throughout the West (Hinds 1985).

Cytospora canker (*Cytospora chrysosperma*) is the most common canker found throughout the range occupied by aspen (Hinds 1985). In 1942, *Cytospora* infection was thought to be the main cause of aspen "dieback" in the Rocky Mountain National Park (Packard 1942). The fungus is considered a normal inhabitant of aspen bark (Anderson 1972). Fire, frost, drought and leaf diseases cause aspen trees to become susceptible to *Cytospora* canker, with young trees becoming the most seriously affected (Anderson 1972). *Cytospora* is associated with wounds to trees caused by elk feeding, logging activity, frost cankers, sunscald and slash fires and it may also be associated as a secondary parasite with other cankers (Hinds 1985). Large vigorous aspen trees are least susceptible to the disease and when infected may effectively limit canker growth or form calluses to contain the infection (Hinds 1985, Anderson 1972).

In Colorado, *Cytospora chrysosperma* has been associated with aspen regeneration failure in which over 90% of the aspen sprouts died (Jacobi and Shepperd 1991). Stressed sprouts may be more affected by *Cytospora* than healthy sprouts (Guyon 1990). Guyon (1990) found that when aspen sprouts which had been inoculated with *Cytospora* were subjected to stress by excess moisture, insufficient moisture and defoliation, the stressed plants showed increased canker size (Guyon 1990).

Light Availability

Aspen has long been recognized as a shade intolerant species (Jones and DeByle 1985e, Mitton and Grant 1996). Maximum photosynthetic rates in aspen occur when the equivalent of 10,000 foot candles of light are present but when light availability is reduced to 2,000 foot candles, photosynthesis drops to about 50% of maximum (Jones and DeByle 1985e). Photoperiod differences also account for differences in growth rates (Jones and DeByle 1985e). Light availability has been demonstrated to limit stocking in shaded areas of aspen stands in Colorado (Jones 1975), and Shepperd (1993) suggested that suckering could be inhibited by heavy logging slash left on a site.

Chapter 2

METHODS AND MATERIALS

Study Site Selection

A formal inventory for aspen sites is not available for the Deerlodge National Forest. In the past aspen sites were labeled as aspen/wet meadow in the timber stand data base. Stands had to be approximately 5 acres or more to be classified as a separate entity and then they were grouped with wet meadows. Aspen mixed with conifer was given a conifer classification unless aspen was the dominant cover type. When stands were inventoried aspen trees were usually not measured and often not mentioned in stand descriptions unless the species was a significant component of the stand. Aspen community types are mentioned in ECODATA plots but this inventory is not complete for the forest at this time. Study site selection therefore, concentrated on sites that had been treated since the late 1980's as part of riparian improvement projects, range improvement projects and timber sales.

Aspen treatments occurred in small areas across the forest. For logistical reasons the study focused on the east 1/2 of the Deerlodge National Forest. The majority of aspen treatments since the late 1980's occurred on this half of the forest and soils on the eastern portion of the forest were derived from similar parent materials.

The following criteria were used when selecting the study sites:

- The sites show evidence of previous occupancy by aspen or proximity to an existing aspen clone. In many treatment areas, aspen was not the only target of the treatment so just the sites that were occupied by aspen were selected.
- The soils at the treatment sites were all derived from granitic parent material. Confining the study sites to a single parent material may reduce some variability.
- Treatments were at least two years old and older in order to obtain a more realistic estimate of sucker survival over time.
- Treatment types were isolated so that no two treatments overlapped. Occasionally in an area, burning was the primary treatment but the aspen sites did not carry the fire. The trees were then cut at a later time. In these cases, if cutting was identified as the treatment places that showed evidence of burning were excluded. Conversely, if burning was identified as the treatment areas where trees had been cut were also excluded. If fencing occurred in any of the areas, study sites were either completely fenced or not fenced.

Since pre treatment data was not available for most sites, a non treated control was selected for each area. The control was located in close proximity to each treatment and was located on the same soil map unit as the treatment.

Study Design and Data Collection

In order to best describe the trends of aspen treatment, as many sites as possible were sampled rather than an intense sampling of just one or a few sites. The intent of this sampling design was to minimize isolated incidences and attempt to focus on trends.

A 1/100 acre circular plot was chosen for the sample point. A circular shape was chosen because one person can easily lay out the plot. The 1/100 ac. size was chosen because larger plots would have been much harder for one person to accurately count the number of suckers. Most of the treatment sites were relatively small (0.5-1.0 acres in size) making it difficult to place larger plots randomly. Smaller plots (1/300 ac.) were also considered, but because of the clumpy nature of aspen suckers, theoretically less incidences of counts of zero would be obtained using the larger plot size.

Each control and treatment site was traversed using a GPS unit. Maps were made of each traverse were made and a scaled 20’ by 20’ grid was overlain. Sample locations were selected by picking five intersects using a random number list. In order to eliminate the overlap of plots, sample points at adjacent grid locations were avoided.

Sucker counts were taken in June and early July 1996. In order to get the most accurate sucker counts possible, sites were counted after the aspen had leafed out but before competing vegetation made counting too difficult. Sites were counted before any livestock were allowed on the allotment.

Plot centers at each sample location were identified with a survey stake. Plot perimeters were identified using surveyor's pin flags. The following observations were made at each plot:

- Total number of suckers
- Diameter at breast height of aspen trees if present (to measure relative basal areas of the controls)
- Height of tallest sucker (measures both vigor and success of the sprouts, for instance if six year old treatment areas have only 6" tall sprouts it may indicate heavy browsing or only the presence of one year old sprouts)
- Percent browse based on three classes (ocular estimate, 0-33%, 33-66%, and 66+%). In order for a stem to be classified as browsed the terminal leader had to have been browsed within the last two years. Two years was stipulated as a criteria because the observations were made before livestock had been on the treatment sites and the new growth of 1996 had only recently emerged.
- Percent ground disturbance (ocular estimate, measures the intensity of scarification and the amount of charring due to burn treatments)
- Brush height (an indication of shading and competition)
- Fuel transect -an indication of shading on the site (two fuel transects were run at each plot). Transect direction and length were determined using methods described by Brown (1974). Because different amounts of time had elapsed

since treatment on many of the sites and many of the fine fuels had decayed or dropped to the ground only the 3" and larger diameter material was measured.

- Soil sample (At the first three plots established a sample of the A horizon to a depth of 4 " was obtained. Samples were air dried in bags and sieved to 2mm. Soil pH was obtained and water holding capacity was calculated using pressure plate analysis.)

Site Data

Elevation was obtained from a topographical map for each treatment site. Slope was calculated for each site as a whole rather than for each individual plot. Slopes were rounded to the nearest 10% for the entire site. Aspect was also assigned to the site as a whole.

Treatment types and the dates the treatments occurred were obtained from records in the Forest Service data base and sale administrator's inspection reports. When possible or where any discrepancies occurred, verification was obtained from the people who performed the treatments.

Soil descriptions for each treatment area were obtained by digging soil pits on the sites. The location for each pit was determined by the forest soil scientist and was deemed as representative of the soils found at each treatment site. Soil characteristics were similar for treatment sites and their paired controls. Soil descriptions from each pit include soil classification, horizon depth and designation, texture, color, presence of ground water or gleying, drainage class, and root distribution. Habitat types were also obtained for each treatment site.(according to Hansen 1995 or Pfister 1977)

Data Analysis

The data for this study has two components. One group consists of sites that had no pre treatment information available. The other group consists of two areas that were originally measured before and immediately after treatment in 1993 (West Cr. and Hartman Cr.). In the 1993 study plot size and shape were the same but different sampling intensities were used. Because different sampling methods were used in the 1993 study, the data from the remeasurement of the 1993 sites is used for descriptive purposes only and not for comparisons between the two groups.

Descriptive statistics such as population total, mean and standard deviation were calculated for all response variables on the treatment sites and the controls. The diameter (at breast height) of the aspen trees 5' tall and taller was used to calculate the basal area (in square feet per acre) for the control sites. Paired t-tests were used to compare the individual treatment sites with the control selected for that site to determine if treatment had significantly increased the number of aspen suckers on the site.

Sites were classified as riparian or upland based upon their soil characteristics and habitat types. Comparisons between riparian and upland sites were made using t tests.

Chapter 3

DESCRIPTION OF THE STUDY SITES

The Condition of Aspen on The Deerlodge National Forest

While a formal inventory is lacking, most of the aspen stands on the Deerlodge are perceived as even aged. There is a lack of sapling sized clones and many of the more mature clones are thought to be declining. Several factors may be responsible for the late successional appearance of many of the aspen clones on the Deerlodge. The various mining booms of the late 1800's resulted in widespread logging to supply timber for the mines and accompanying settlements and also to supply fuel for smelters. It is unclear how many of these clones regenerated as even aged stands. Some may have been harvested or burned as a result of slash disposal, creating an even aged stand, but others may not have been harvested or completely burned. Whatever the origin, most of the aspen on the Deerlodge has developed a single storied stand structure giving the appearance of an even aged stand. Whether this is actually the case is not known because very little work has been done regarding the age composition of aspen clones on the forest.

In many areas of the Deerlodge National Forest the composition of the aspen component seems to be changing. The Berkin Flat winter range illustrates this change. Aerial photos taken in 1947 show increases in conifers within aspen clones when compared with photos taken in 1990. Mixed stands of aspen and conifer tended to increase their conifer component during this time. Conifers growing within or adjacent to aspen clones are out-competing the aspen and in many cases the aspen has become suppressed. Grazing and browsing pressures limit sprouting and because many of the clones are approaching the end of their natural life span, mortality is occurring.

Aspen is not considered a commercial species on the Deerlodge National Forest. Most of the aspen stands on the forest are small (usually less than 5 acres) and fairly wide spread with the exceptions previously mentioned near the Deerlodge Valley. Aspen may occasionally be harvested for firewood but large sales of aspen for commercial products is not feasible.

The following provides a description of each of the sites studied in this research project. Some of the important site characteristics are summarized in Table 1.

Table 1. Summary of site characteristics for aspen treatment sites on the Deerlodge National Forest.

Site ‡	Treatment	Date *	Slope	Aspect	elev.	Soil **	Hab. type †
BM1c	none	n/a	<10	E	6100'	AC	Pop/Poa
BM2	fencing	4/94	<10	NE	6100'	AC	Pop/Poa
BM3	burn	9/93	<10	N	6100'	AC	Pop/Poa
BM4	burn/ fence	9/93	<10	N	6100'	AC	Pop/Poa
CA1	cutting	5/94	<10	W	6300'	AC	Pop/Cor
CA2	cutting	5/94	<10	W	6300'	AqC	Pop/Cor
CA3c	none	n/a	<10	W	6300'	AC	Pop/Cor
DC1	scarify	8/90	<10	N	6400'	TC	Pse/Lib
DC2	scarify	8/90	<10	N	6400'	TC	Pse/Lib
DC3c	none	n/a	<10	N	6400'	TCa	Pse/Lib
DC4	scarify	8/90	<10	N	6400'	TCa	Pse/Lib
HB1	cutting	9/91	12	W	6800'	PC	Pop/Cal
HB2	cutting	9/91	<10	W	6800'	PC	Pop/Cal
HB5c	none	n/a	12	W	6800'	PC	Pop/Cal
BG3	scarify	9/91	<10	NW	6800'	PC	Abl/Cal
BG4c	none	n/a	22	NW	6800'	PC	Abl/Cal

‡ c denotes control site

*date of treatment

** soil classifications: AC-Argic Cryoborolls, AqC-Aquic Cryoborolls, PC-Pachic Cryoborolls, TC-Typic Cryochrepts, TCa-Typic Cryoboralfs.

† habitat types according to Pfister et al. (1977) or Hansen et al. (1995): Pop/Poa-*Populus tremuloides Poa pretenses*, Pop/Cor-*Populus tremuloides Cornus stolonifera*, Pop/Cal-*Populus tremuloides Calamagrostis canadensis*, Pse/Lib-*Pseudotsuga menziesii/Linnea borealis*, Abl/Cal-*Abies lasiocarpa Calamagrostis canadensis*.

Bald Mountain Treatment Area

The Bald Mountain treatment area is located approximately 19 miles southeast of Butte on the Jefferson Ranger District. The area consists of a series of aspen clones located along a drainage that runs in a northeasterly direction. There is no running water in the drainage but a small spring is located at the upper end of the treatment area. Water from this spring is piped off the forest and used for stock watering on adjacent BLM ground. A stock watering tank is located in this drainage on the forest and cattle graze in the area. The elevation is approximately 6100 ft. and slopes are less than 10%.

Conifer, primarily Douglas fir was logged in the area in January 1993. The logging slash and portions of the aspen clones were burned in September 1993. Aspen clones that would not burn in September 1993 were cut in June of 1994.

The habitat type at this location is difficult to establish. The area does have more available moisture than the sideslopes and ridges surrounding it, but it is not wet enough to be considered riparian. Although Douglas fir is present on the site, the soil description indicates that aspen has probably been the dominant species on the site. The upland site version of the *Populus tremuloides Poa pretenses* community type described by Hansen et al. (1995) was chosen as the best description of the site. Soils were classified as Argic Cryoborolls.

For the Bald Mountain treatment area a non treated, unfenced control was selected and five treatment sites were identified.

Bald Mountain 1 (BM1)

Bald Mountain 1 is the control selected as a representative for the pretreatment condition of the aspen in this area. It is situated in the bottom of a broad drainage with no live stream. The slope is less than 10% and the aspect is east.

Bald Mountain 2 (BM2)

Bald Mountain 2 is adjacent to BM1 but is located slightly farther up a side slope to the south. This area is largely untreated. A few (less than 10) sapling sized conifer were cut and left in place. The aspect is northeast and the slope is less than 10%. The site was fenced with an electric fence in April 1994. This site was selected to compare fenced versus unfenced non treated areas.

Bald Mountain 3 (BM3)

Bald Mountain 3 is located approximately 600 feet east of the control. This site is on a small bench slightly above the main drainage. The aspect is primarily north and slopes are less than 10%. The site was logged in January 1993. Logging slash was left, unmerchantable trees were felled and the aspen was left standing. The site was burned in September 1993. From the degree of charring it appears that the fire was fairly intense killing most of the standing aspen. This area was not fenced.

Bald Mountain 4 (BM4)

Bald Mountain 4 is across a small logging road adjacent to BM3. The site is located on the south side of the main drainage and closer to the bottom than BM3. This site is also on a small bench (stream terrace) just above the drainage bottom. The slope is less than 10% and the aspect is primarily north. The treatment is similar to BM3 except the site was fenced in April 1994.

Champion Aspen Treatment Area

The Champion Aspen treatment area lies approximately 15 miles southeast of Deer Lodge. The treatment area consists of aspen clones growing along a small stream that flows west. At the time of treatment these clones were mature and most of the stems were located in the riparian area associated with the creek. The treatment area is about 6300 feet in elevation and slopes are less than 10 %. The conifer (primarily lodgepole pine) adjacent to the aspen clones was logged in February and March of 1992 to allow more light to reach the clones and to reduce competition. Only an area of 75 to 100 feet wide by 600 feet long on the north side of the creek was logged. No conifer was removed from the south side of the creek because at the time it was decided that no machinery would be allowed to cross the stream. In May of 1993 the slash from the logging and some of the riparian area was burned. Few aspen trees were killed so in May of 1994 the aspen trees in the lower half of the treatment area were cut and left in place.

Soil descriptions at the Champion Aspen treatment area indicate long term occupancy of the site by a aspen community type. Soils were classified as Argic Cryoborolls or Aquic Cryoborolls. The treatment sites are all within the riparian area associated with the stream that bisects the draw. The *Populus tremuloides Cornus stolonifera* habitat type described by Hansen et al. (1995) best describes the site. Throughout the treatment sites, areas of standing water are located adjacent to the stream indicating places of poor drainage.

Champion Aspen 1 (CA1)

Champion Aspen 1 is a treatment site located up the drainage and adjacent to CA3. The site was left unburned in May 1993 and consequently the aspen were cut and left in place in May 1994. Slopes are less than 10% and the aspect is primarily west.

Champion Aspen 2 (CA2)

Champion Aspen 2 is located farther up the drainage approximately 300 feet from CA1. Like CA1 the site was left unburned in May 1993 and the aspen was cut in May 1994. The aspect is primarily west and slopes are less than 10%.

Champion Aspen 3 (CA3)

Champion Aspen 3 is the control site selected for the Champion Aspen treatment area. The site is located in a drainage with a small stream that runs water most of the year.

The aspen is primarily located in the wet riparian area associated with the stream. On both sides of the stream areas of standing water occurs most years. Slopes are gentle, less than 10% and the aspect is primarily west.

Dry Corners Treatment Area

The Dry Corners treatment area is located near the Champion Aspen treatment area. The Dry Corners sites are on the north slope of the ridge between the drainage where the Champion Aspen sites are located and the next drainage to the north. The elevation is slightly higher than Champion Aspen at 6400 feet but slopes are similar at less than 10%. The aspect is primarily north. The aspen in this area occurred as clones scattered along a fairly dry ridge that were overtopped by conifer (mostly lodgepole pine).

Aspen was not the focus of logging in this area. The lodgepole pine was clearcut and a few Douglas fir seed trees were left. Some scattered aspen trees were left in the clearcut. The area was logged in February 1990, and brush piling and scarification occurred in August of 1990. Much of the aspen was knocked over in the skidding, brush piling and scarifying operations associated with logging. None of the treatment sites selected had been burned.

The soils in the area do not indicate long term aspen occupancy. Soils were classified as Typic Cryochrepts or Typic Cryoboralfs. The aspen clones at the Dry Corners treatment area are probably seral in nature and the site has most likely been occupied alternately by conifer and aspen following a disturbance. This is an upland area with a *Pseudotsuga mensezeii Linnea borealis* habitat type.

Dry Corners 1 (DC1)

Dry Corners 1 is located approximately 500 feet east of DC3 on the same ridge but not at the top of the ridge. The aspect is primarily north and the slope is less than 10%. Several live aspen trees that escaped damage from logging operations are located within this treatment site. Logging and skidding occurred in February of 1990 and brush piling and scarification occurred in August of the same year.

Dry Corners 2 (DC2)

Dry Corners 2 is located approximately 800 feet east of the control on the same ridge and is adjacent to DC1. This treatment sites is situated in a small bowl on the north slope of the ridge. Most of the aspen was knocked over in the activities associated with the brush piling and scarification that occurred in August 1990. The aspect is primarily north and like the other Dry Corners sites the slopes are less than 10%.

Dry Corners 3 (DC3)

Dry Corners 3 is the control site selected for the Dry Corners treatment area. The aspen is an overtopped clone that is dominated by Douglas Fir. The control site is located on the top of a broad ridge. The topography is level and rolling.

Dry Corners 4 (DC4)

Dry Corners 4 is located approximately 200 feet east of the control site. This site is occupied by a few scattered trees that escaped damage from the logging operations. Like the other Dry Corners sites, logging occurred in February of 1990 and brush piling and scarification occurred in August of the same year.

Hidden Bear and Bear Gulch Treatment Areas

The Hidden Bear and Bear Gulch treatment areas are located approximately 16 miles northwest of Butte. This area is higher than the rest of the areas in the study. The elevation is approximately 6800 feet. Slopes are also steeper than the other areas ranging from 10 to 22%. The aspen occurs both as clones growing in the riparian areas associated with the wet drainages and as overtopped clones growing in the drier mid slope regions. The aspen was treated in conjunction with a timber sale. The dominant conifer in the area is lodgepole pine. The area was logged in September 1991. Brush piling and scarification were completed at the time of logging. Additionally, along one stream the aspen was cut and left in place. This cutting also took place in September of 1991.

At the first control site (HB5), soils suggest the long term occupancy of an aspen community type. The *Populus tremuloides Calamagrostis canadensis* habitat type described by Hansen et al. (1995) best fits this site and the treatment sites HB1 and HB2.

These treatment sites have standing water most of the year. Additionally a small stream flows through the treatment sites.

Soils were classified as Pachic Cryoborolls. The mollic epipedon encountered at the second site, Bear Gulch 4, does suggest at least some long term occupancy by an aspen community type, but the understory is occupied by *Abies lasiocarpa* which may indicate that the site is currently in a late seral stage. It is difficult to classify the aspen in the Bear Gulch treatment area as stable or seral. The abundance of *Abies lasiocarpa* in the understory seems to suggest that aspen is probably seral. The *Abies lasiocarpa/ Calamagrostis canadensis* described by Pfister et al. (1977) best describes the site. Classification of this site as riparian or upland is difficult. It seems to have characteristics of both landforms and is an ecotone between the two.

Hidden Bear 1 (HB1)

Hidden Bear 1 is located higher in the same drainage adjacent to HB5. This site is fairly wet with standing water occurring in the areas next to the stream. The aspen was cut and left in place in September 1991. The aspect is northwest and the slopes are from 10 to 15%. The elevation is approximately 6800 feet.

Hidden Bear 2 (HB2)

Hidden Bear 2 is adjacent to HB1 higher in the same drainage. Site conditions are similar to HB1 except the site is flatter with slopes at less than 10%. The aspen at this site was also cut and left in place in September 1991.

Hidden Bear 5 (HB5)

Hidden Bear 5 is the control that was selected as being representative of the treatment sites HB1 and HB2. This site is located in a fairly broad drainage. Water from a spring higher on the slope flows through the site. The aspen clone at this site grows in the wet area associated with the stream. The aspect is primarily north and the slopes range from 10 to 15%.

Bear Gulch 3 (BG3)

Bear Gulch 3 is located approximately 400 feet across the slope from the control. No live stream flows through this treatment site but it is located in a bowl on the slope that shows increased water availability. The slope is flatter than the control at 10% or less and the aspect is northwest. Primarily the site consists of a clone of aspen (25 trees) that was avoided when the conifer in the area was logged. Several live aspen trees remain on this site that existed before treatment. Logs were skidded around the clone on two sides but little damage was done within the clone itself. Like the Hidden Bear sites, logging occurred in September 1991.

Bear Gulch 4 (BG4)

Bear Gulch 4 is the control selected to represent the treatment site BG3. This site is located along a live stream about 500 feet up the slope from HB1, 2 and 5. The stream flows yearlong and has less wet areas with standing water adjacent to it than the stream associated with HB1, 2, and 5. Slopes are steeper at 20%. The aspen occurs as an overtopped clone that is dominated mostly by spruce, and lodgepole. Elevation is approximately 6800 feet and the aspect is primarily northwest.

Remeasurement Areas

While the majority of aspen treatments on the Deerlodge have no pre treatment data, two areas were part of a previous riparian study. At these sites, pretreatment aspen tree and sucker density was measured. No control was selected for either of these sites. Previously established plots were remeasured.

Hartman Creek

The Hartman Creek treatment area is located approximately 18 miles east of Butte. The elevation is approximately 5500 feet and the aspect is primarily southwest. Slopes are less than 10%. The aspen along Hartman Creek consists mainly as clones scattered along a drainage that experiences only seasonal water flow. Douglas fir and juniper grow in conjunction with the aspen and occasionally the Douglas fir has overtopped the aspen clones. The Douglas fir was removed from the site in 1991. In January and February of 1992, the unmerchantable fir was slashed and left in place to facilitate burning the aspen.

In May 1992 the site was burned. Drought conditions before the burn and the naturally dry site led to a fairly intense fire. Most of the aspen trees were killed at this time. This site would probably be best described as the upland version of the *Populus tremuloides Poa pretenses* community type described by Hansen et al. (1995). Although the site is quite dry, some soil moisture was encountered at 24" and deeper in the soil profile. Soils were classified as Typic Haploborolls.

West Creek

The West Creek treatment area is located approximately 6 miles south of Boulder. The elevation is 5200 feet and the aspect is mostly north. Slopes are less than 10%. The aspen along West Creek occurs as scattered clones along a broad drainage that also only experiences seasonal water flow. The treatment area was not logged but juniper and Douglas Fir were cut and left in place along the riparian areas. The site was burned in June 1992. The fire didn't carry well and resulted in only a partial kill on the aspen trees. Many places didn't burn at all, and in the spots that did partially burn, not all the aspen was killed.

The West Creek treatment area is realistically a riparian area. The *Populus tremuloides Calamagrostis canadensis* habitat type described by Hansen et al, (1995) best fits this site. Although only seasonal water flow occurs in the drainage, the resulting soils and vegetation clearly have more available moisture than the surrounding slopes.

Soils are well drained and standing water does not occur in the area. Soils were classified as Oxyaquic Ustivents and Cumulic Haploborolls.

Chapter 4

RESULTS

Aspen sucker counts and the other vegetative measurements were made during June and July of 1996. By this time, aspen suckers had emerged and were readily visible. None of the study sites had been grazed by livestock since the fall of 1995. The two remeasurement sites, Hartman Creek and West Creek were seperately analyzed because in the 1993 study a different study design was incorporated. Different sampling methods and intensities were used. A discussion of the results obtained at both West Creek and Hartman Creek can be found at the end of the chapter.

Correlations between sucker numbers and response variables were confounded by large differences in sucker counts associated with different treatments. Therefore, only t-tests were used to compare treatment responses to control site and to determine significant differences between populations.

Section 1, Effects of Treatment, deals with the responses encountered as a result of treatment. In the latter part of the chapter, Section 2, the effects of site are analyzed, primarily focusing upon the differences between sites that were classified as riparian or upland. To facilitate comparisons, the data has been organized in the following tables. A more complete description of the results obtained for each site can be found in Appendix B.

Table 2. Summary of aspen responses to treatments at four sites on the Deerlodge National Forest.

Site †	Treatment	Sckrs /ac	Sckr ht(ft.)	Browse	% grnd dist	Ht.comp veg (ft)	pH	WHC	Fuels t/ac.
BM1c	none	260	0.5	low	0	0.5	5.33	40.67	8.3
BM2	fence	300	0.5	low	0	0.5	5.31	37.67	4.5
BM3	burn	400	0.5	mod.	70	1.0*	4.99	68.0	18.0
BM4	burn fence	960	1.0	high*	80	1.5*	4.97	53.67	14.3
CA1	cut	1680	1.5	low	4	2.0	5.39	115.0	36.7
CA2	cut	840*	1.5	low	0	2.5	5.89	63.33	21.9
CA3c	none	600	1.0	low	0	2.0	5.77	80.66	7.0
DC1	scar.	2920*	4.5	low	30	1.0	3.91	23.67*	3.3
DC2	scar.	6900*	7.5	mod.	30	0.5	4.04	31.0*	4.9
DC3c	none	500	3.0	mod.	0	0.5	4.72	41.33	2.2
DC4	scar.	1340	4.0	high	30	1.0	4.01	22.0*	3.2
HB1	cut	40*	1.5	low	0	1.0	5.06	43.33	30.3
HB2	cut	280	1.0	low	0	1.0	4.57	59.67	25.6
HB5c	none	280	0.5	low	0	1.0	4.48	47.33	2.1
BG3	scar.	1300	0.5	mod.	30	0.5	3.66	29.33	8.3
BG4c	none	1040	0.5	low	0	1.0	4.16	25.0	4.3

† c denotes control site

* significantly different from the control ($p < 0.1$)

Table 2 is a summary of the treatment responses in relation to the control site for each area. In most cases five samples were taken. The exceptions are pH, water holding capacity, and fuels. Three samples for soil pH and water holding capacity and ten fuel transects were taken at each site. Comparisons were made between the controls and treated areas using paired t-tests.

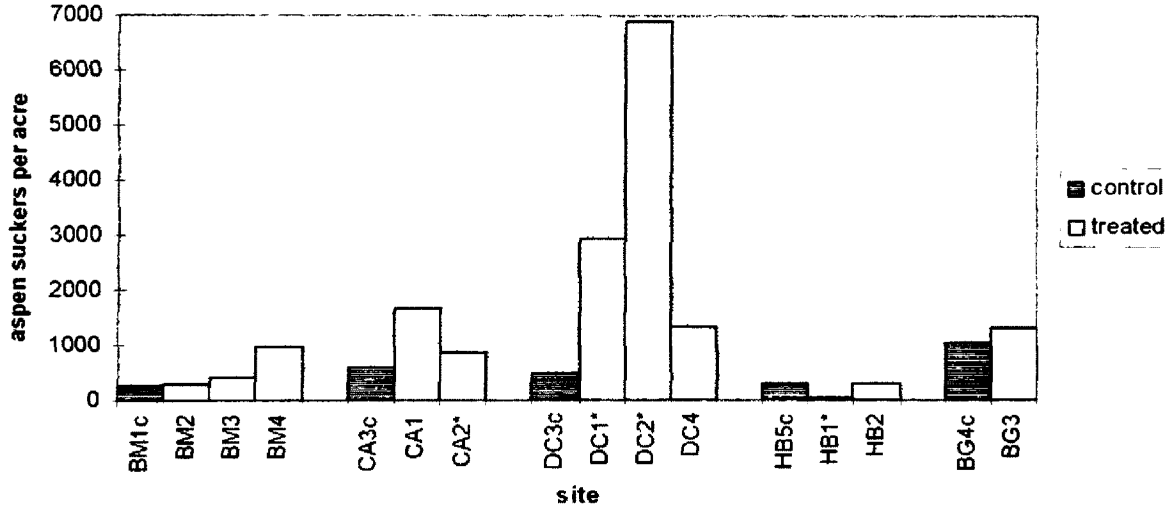
Section 1

Effects of Treatment

Aspen Sprouting

Of the eleven treatment sites only three sites, DC1, DC2 and CA2 showed a significant ($p < 0.1$) increase in sprouting over the control site selected for each treatment site. In one case, HB1, sprouting was significantly lower than the control. Figure 1 compares aspen suckering between the treated sites and their paired controls.

Figure 1. Aspen suckers per acre observed at control sites and treated sites



* significantly different from control ($p < 0.1$)

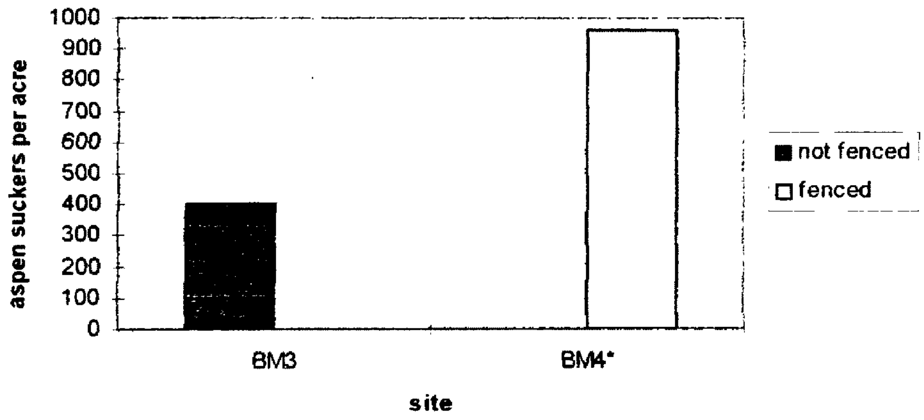
Treatment Comparisons

The following comparisons were made between similar sites with different treatments:

- Fenced versus not fenced on a burned site (BM3 vs. BM4).
- Fencing with no other treatment versus no treatment (BM2 vs. BM control).

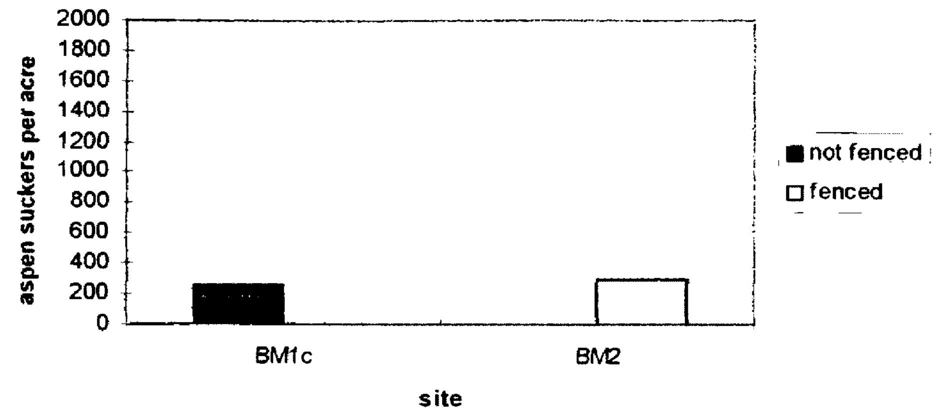
BM4 which was burned and fenced produced significantly more suckers than BM3 which was burned and not fenced ($p < 0.1$). In a comparison of areas where fencing was the only treatment, there was no significant difference in the number of aspen suckers on the site. BM2 which was fenced and BM1 which was the control site produced approximately the same level of suckering.

Figure 2. Comparison of aspen suckering between fenced and unfenced sites which were burned



* significantly greater ($p < 0.1$)

Figure 3. Comparison of fenced and unfenced sites with no other treatment



Figures 4 and 5 compare sucker counts between control sites and treated sites for each type of treatment.

Figure 4. Aspen differences between control sites and sites that were **burned** (BM4 was burned and fenced).

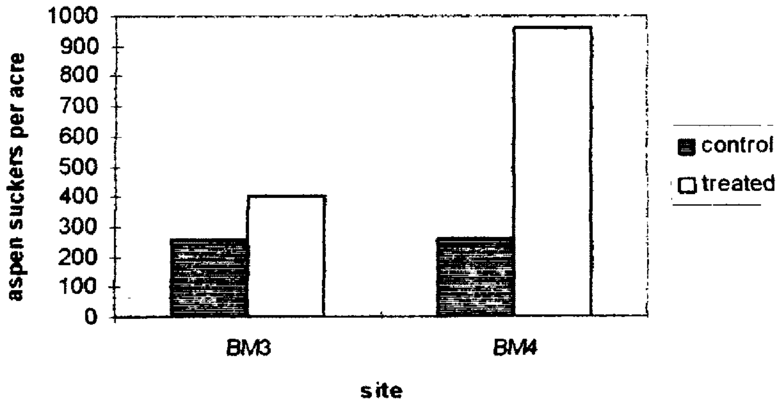
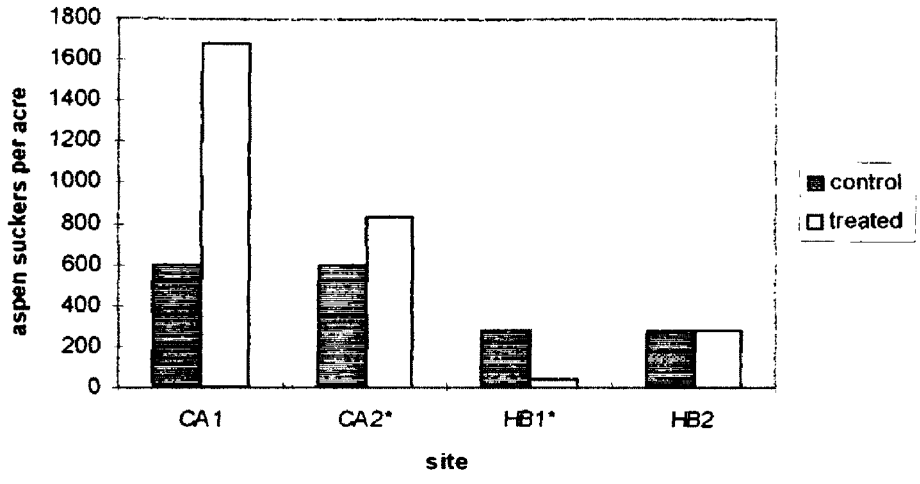
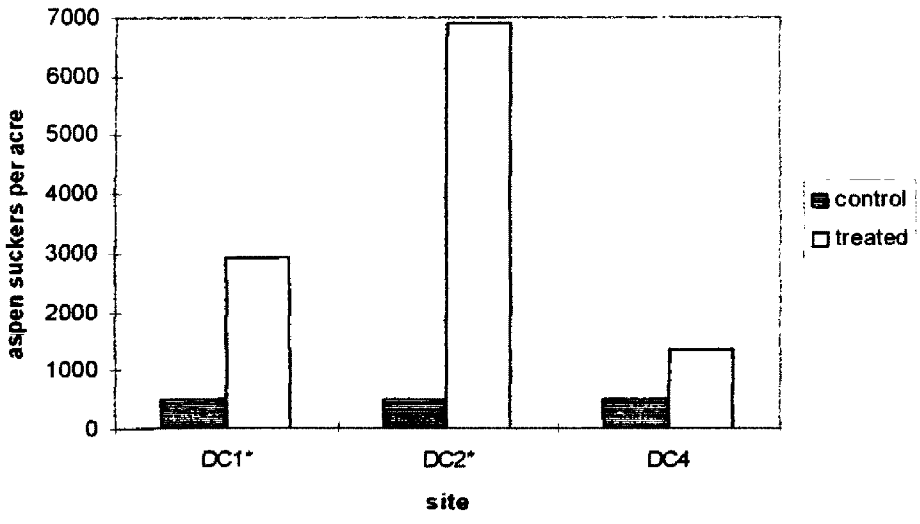


Figure 5. Aspen suckering differences between control sites and sites that were **cut**.



*significantly different from control ($p < 0.1$)

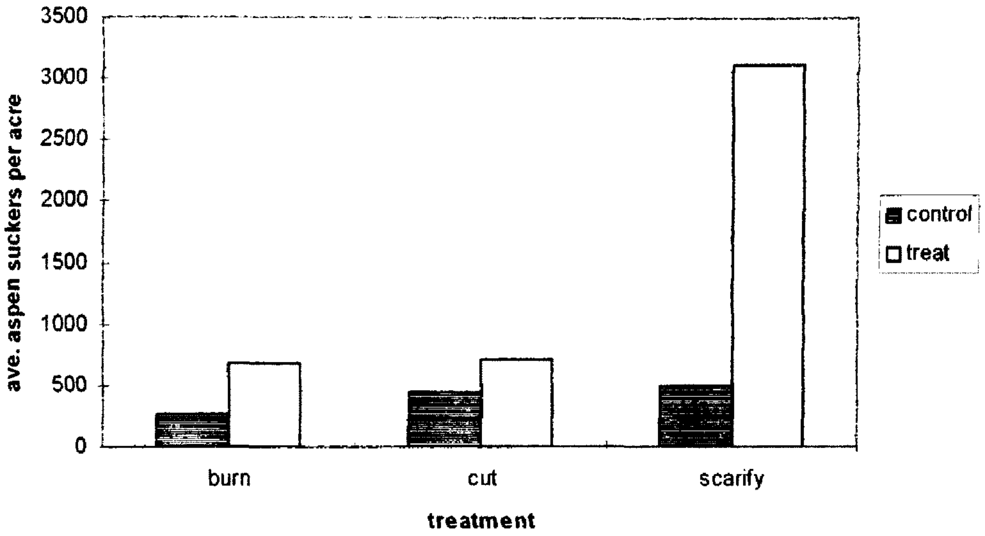
Figure 6. Aspen suckering differences between control sites and sites that were **mechanically scarified**.



*significantly different from the control ($p < 0.1$)

Direct comparisons of treatments across different sites were not valid because of site variability, however the highest degree of suckering following treatment was associated with mechanical scarification.

Figure 7. Aspen suckers associated with various treatments. Values are averages of aspen suckers of all the sites associated with each treatment versus the control sites.



Browse Influence and Fuel Loading

Browse levels and their relationship to fuel loading were examined. Although fencing reduces browse by livestock, fencing does little to discourage deer and elk. High concentrations of slash were purposely left on several of the treated sites in order to discourage browse by wildlife. Following treatment, fuel loading increased on all sites except one, BM2 where the only treatment was fencing. Fencing in this case had no effect upon fuel loading because only the 3"+ fuels were recorded. At the other sites, in cases where relatively high fuel loadings (over 20 tons per acre) were left, browse levels appeared to be low, but no lower than the paired control sites ($p < 0.1$).

Bald Mtn. 4, which was fenced showed a significant increase in browse activity over its paired control, BM1. Sucker counts were made before cattle had grazed any of the areas, but after new sprouts of the year had emerged. Sucker counts for the control consisted mostly of new sprouts which had not yet been subjected to livestock browse. Sucker counts for BM4 included both recent sprouts and ones surviving from previous years, some of which had been browsed. The presence of only new sprouts at the control site suggested that few, if any sprouts survive from one year to the next whether due to browse activity or to apical dominance exerted by the canopy.

Table 3. Fuel loadings and the associated browse intensities of treated and control sites in the Deerlodge National Forest

site	fuel loading tons/ac.	browse level
BM1c	8.3	low
BM2[f]	4.5	low
BM3	18.0	moderate[1]
BM4[f]	14.3	high[1]
CA1	37.6	low
CA2	21.9	low
CA3c	7.0	low
DC1	3.3	low
DC2	4.9	moderate
DC3c	2.2	moderate[2]
DC4	3.2	high[2]
HB1	30.3	low
HB2	25.6	low
HB5c	2.1	low
BG3	8.3	moderate
BG4c	4.3	low

c denotes control

[f] fenced

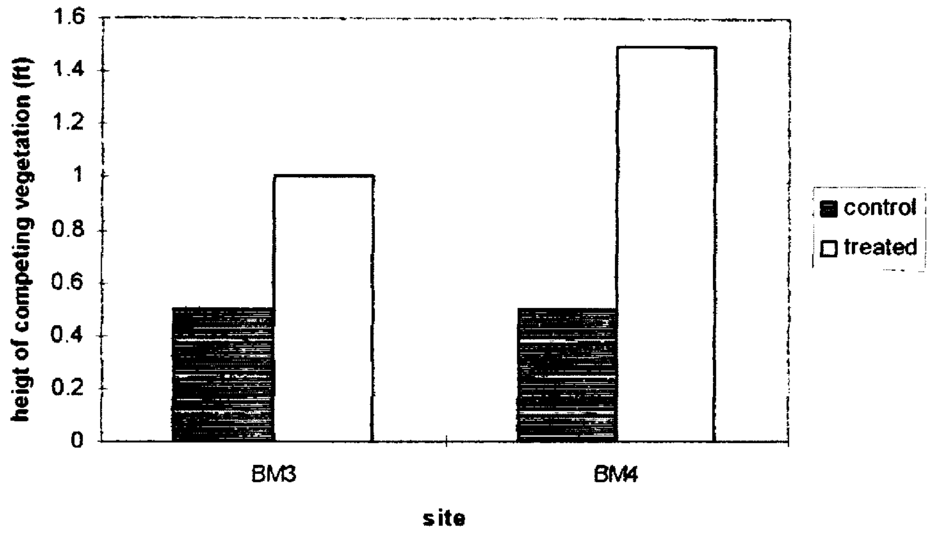
[1] browse intensity was not significantly higher in BM4 which was fenced than BM3 which was not fenced ($p < 0.10$).

[2] browse intensity was not significantly higher ($p < 0.10$).

Competing Vegetation

The height of competing vegetation increased significantly ($p < 0.1$) on two sites, BM3 and BM4. Grass composed the bulk of the competing vegetation at both of these sites. Grass height was expected to be greater at BM4 because this site had been fenced to exclude livestock two years prior to this study. Increased vegetation height at BM3 is probably a result of the previous season's grazing. The control was shaded by the aspen canopy whereas BM3 was not. Cattle used the shaded area more and the result was that more grass from the previous season was left at BM3.

Figure 8. Sites with significant increases in competing vegetation heights



Sucker Heights, Treatment Timing

Sucker height increased significantly on only three sites; BM4 increased 0.5' ($p < 0.005$), DC2 increased 4.5' ($p < 0.001$), and DC4 increased 1.0' ($p < 0.1$). The increase at BM4 is probably a result of both the treatment and the fencing. At the control site, aspen sprouts are suppressed by canopy influences and browse. Few if any sprouts are retained from previous years. The time since treatment figures heavily into the increases in sucker height at DC2 and DC4. Six years had passed between treatment and this study.

The aspen regeneration in this area seemed to be growing well and the significant increases in sucker height support this notion.

Two sites were treated during or just prior to leaf flush, CA1 and CA2. One site, CA2, produced significantly more suckers than the control ($p < 0.1$) and the other site seemed to be producing suckers as well. In this case, treatment timing did not seem to result in regeneration failure. Both of the remeasurement areas, Hartman Creek and West Creek were also treated during leaf flush. In both cases prolific sprouting occurred initially, but the most of the regeneration was damaged or killed by *Cytospora* canker. It is unknown if the timing of treatment may have weakened the root system of if some other factor enhanced infection and caused the die off.

Section 2

Effects of Site Upon Aspen Regeneration

All of the sites used in this study were similar in many respects. The aspect was generally northerly for each site. No sites had a southeast, south or southwest aspect. Slopes were all less than 10% with the exception of three sites which were between 15 and 25%. Soils all were derived from granitic parent material. Elevations were also fairly similar. The highest and lowest sites were separated by only 700 feet. The most obvious difference between all the sites was the presence of surface water. The sites were classified as upland or riparian using habitat type descriptions and soil characteristics such as the presence or absence of gleying. It must be noted that the some of the upland sites in this study are an ecotone between a riparian and upland setting. No sites classified as upland were in proximity to a stream or had standing water anywhere on the site. Upland classification was based upon the general absence of water in the soil profile and habitat or community types which indicate a dry site. The sites classified as riparian had the following characteristics: soils were noticeably moist at a shallow depth, redoximprphic features suggested a fairly shallow water table and soil moisture was evident in the soil profile as a fairly shallow water table, standing water on the site or the presence of a wet site plant indicator species such as *Equisetum arvense*.

Treatments varied in the upland sites. Burning and mechanical scarification were employed but riparian sites experienced only one treatment type. The riparian sites were often too wet to sustain fire, consequently the aspen was slashed and left on the ground. None of the riparian study sites used in these comparisons were fenced. The only instance of a different treatment on a riparian site in this study was BG3. Even though BG3 was classified as riparian, it is the driest of the riparian sites. Mechanical scarification, although possible under certain circumstances (frozen ground) is not a likely treatment on the other riparian sites given the difficulty of obtaining the right amount of scarification without having a D-6 buried up to the drive sprockets in a riparian area.

Riparian Versus Upland

To compare upland and riparian treatments, sucker counts for each plot were grouped as either riparian or upland. A two sample t test was then performed to determine if the two populations were different. Control sites showed no significant difference in the numbers of aspen suckers produced between the upland and riparian sites ($p < 0.1$). Aspen sprouts averaged 380 stems per acre in the upland control sites and 440 stems per acre in the riparian control sites. Treated upland sites produced significantly more suckers than treated riparian sites ($p < 0.02$). Aspen sprouts averaged 710 stems per acre in the treated riparian sites and 2504 stems per acre in the treated upland sites, however, the treatments applied at upland sites (scarification and burning) were different than those of riparian sites (cutting), thus biasing this result.

Figure 9. Aspen sucker means associated with riparian and upland control sites

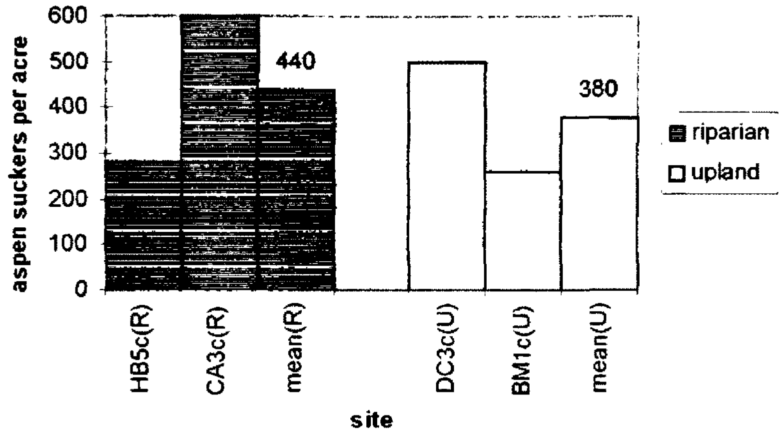
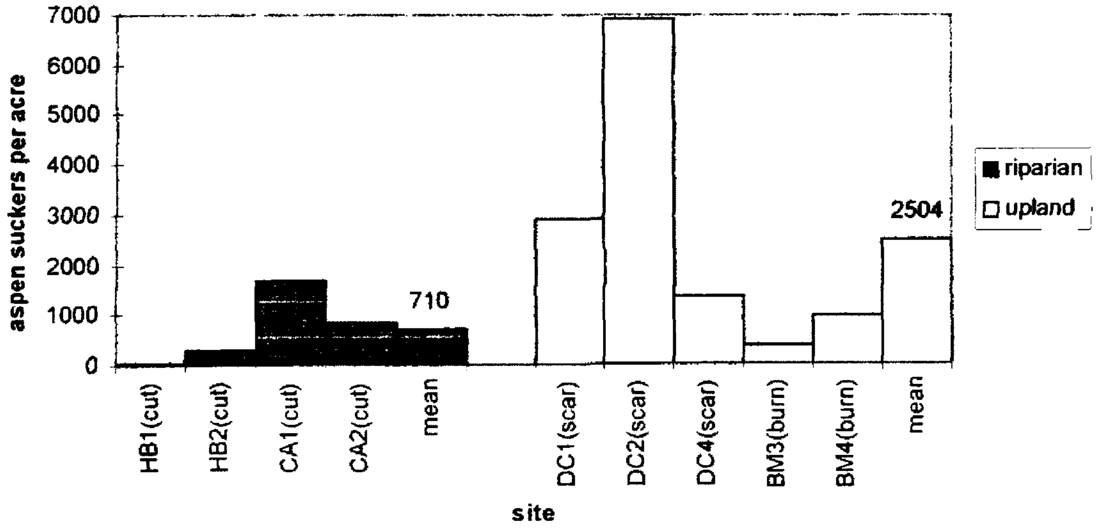


Figure 10. Aspen sucker means associated with treated riparian and upland sites



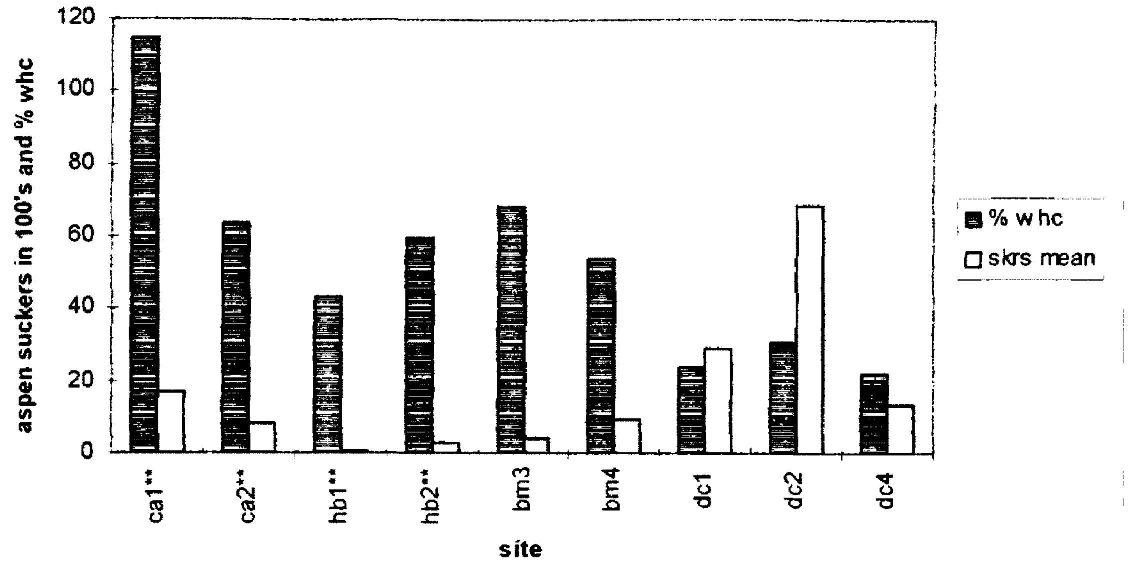
The upland mean is significantly higher than the riparian mean ($p < 0.02$)

Water Holding Capacity

Water holding capacities of the treatment sites differed significantly from their paired control in only one area. The Dry Corners treatments all had significantly lower water holding capacities than their paired control ($p < 0.1$). This difference may have been due to loss of soil following treatment. Since water holding capacity was determined by pressure plate analysis, treatment influence on macro aggregate structure would not have been identified by water holding capacity. Percent organic matter was not determined for the sites, however based on the degree of disturbance associated with scarification, it is possible that total organic matter would have declined following treatment and percent soil organic matter directly influences water holding capacity.

Although, as a group, the control sites showed no significant difference in water holding capacity ($p < 0.1$), the treated riparian sites had significantly higher water holding capacity than the treated upland sites ($p < 0.1$). Figure 12 shows the water holding capacities compared with average aspen suckers per acre for the treated sites. There appeared to be no direct relationship between water holding capacity and aspen sucker populations.

Figure 11. Water holding capacity compared with average aspen suckers per acre of treated riparian and upland sites

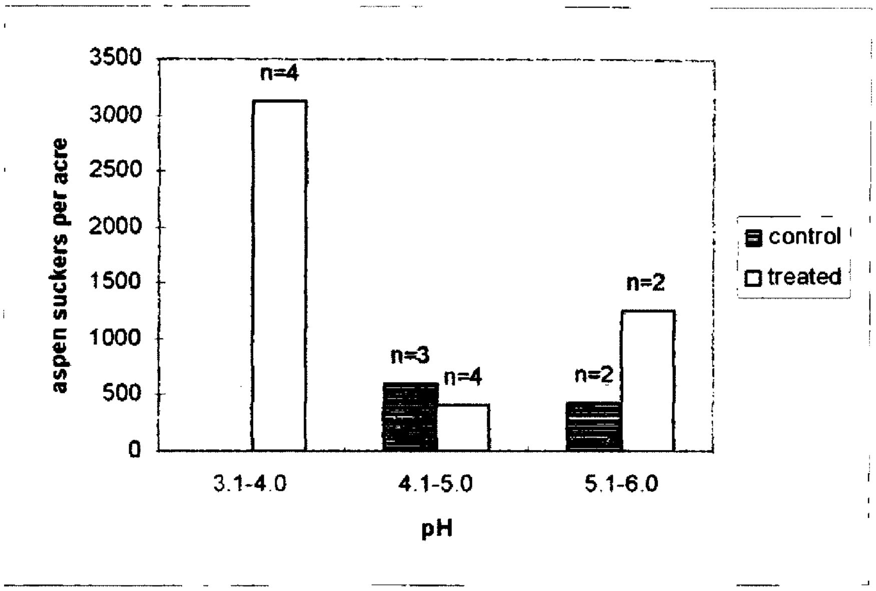


** riparian sites had significantly higher water holding capacity ($p < 0.1$)

Soil pH

There was no significant relationship between soil pH and aspen regeneration (Figure 13). Aspen tolerated some fairly acidic soil in this study, in fact the highest number of suckers were observed on some of the most acidic soil. There appears to be a negative correlation between the number of aspen suckers on the treated sites and soil pH, but this correlation is confounded by other factors. First, the sites with the lowest pH were also those that were mechanically scarified which produced the largest number of sprouts. Secondly, these sites also had the least amount of slash left on them reducing shading on the site. There was no significant difference ($p < 0.1$) in soil pH between the control and the three treatments that might have accounted for the high sucker numbers associated with the more acidic soils. Acidic conditions in the soils within this study area did not inhibit aspen suckering with or without treatment.

Figure 12. Aspen suckers associated with three soil pH groupings (3.1-4.0, 4.1-5.0 and 5.1-6.0)



Basal Area of the Parent Clone

Stocking rates of the parent clone have been shown to directly correlate with underground biomass which in turn correlates with the degree of suckering exhibited after treatment (Renkin and Despain 1994). In this study, basal area was estimated from the control which had been selected because it was representative of the parent clone and may not have always been the actual parent clone. However, reasonable relative estimates were possible. A comparison between average sprouts per acre of the treatment sites and that of the controls showed that the sites with the lowest levels of basal area regenerated well. Table 5 shows basal area per acre of the control sites and the average number of aspen sprouts per acre for all the treatments associated with each control.

Table 4. Basal area of the control sites and average aspen suckers per acre for treated sites

control site	basal area ($ft.^2/ac$)	trees/ac (control)	suckers/ac (treatments)
Bald Mtn.	36.8	300	533
Champion Aspen	11.1	200	1260
Dry Corners	0.9	20	3720
Bear Gulch 4	9.2	140	1300
Hidden Bear 5	17.7	200	160

Remeasurement Sites

Hartman Creek

Hartman Creek, which was burned in May of 1992, showed a dramatic decline in the number of sprouts surviving four years after treatment. Numerous dead aspen stems 3-4' tall still stand on the site. The decline from an average of 13,500 stems per acre in 1992 to only 140 stems per acre in 1996 raises the possibility of aspen being effectively eliminated from the treatment site. The condition of the remaining aspen sprouts is poor. Defoliating insects were present and many of the stems were browsed. Dead aspen stems also indicated a heavy *Cytospora* canker infestation.

The Hartman Creek site was classified as upland. Most of the aspen regeneration is located on a stream terrace with a dry South aspect. Water holding capacity averaged 37% and soil pH averaged 6.66.

West Creek

The regeneration resulting from the June 1992 West Creek burn experienced much the same fate as Hartman Creek. Although the sucker densities at West Creek were initially much less dense than Hartman Creek averaging 3800 stems per acre, the result after four years was only an average of 210 live aspen suckers per acre in 1996. Browsing was relatively light when the site was remeasured but numerous dead aspen suckers 3-4' tall were also present showing signs of *Cytospora* canker infection. The West Creek site was classified as riparian. Water holding capacity averaged 71% and soil pH averaged 6.61.

Chapter 5

DISCUSSION

Effects of Treatment

Aspen Sprouting

The results do not reject the first null hypothesis. The number of aspen suckers following treatment is not always greater. Problems with regeneration ranged from clonal root systems failing to produce sprouts to widespread regeneration failure due to canker infection in clones that originally displayed high sucker density following a disturbance.

Post Treatment Aspen Sprouting

A significant increase in suckering has occurred in only portions of two treatment areas, Champion Aspen and Dry Corners. In the case of the Dry Corners treatment area, aspen densities have increased dramatically over the density of the control having increased from 500 to over 6900 in one instance.

Aspen regeneration densities on the treatment sites in this study are generally less than densities considered "low" by other researchers. In northwest Wyoming, Bartos et. al (1994) reported initial densities of 8000 suckers per acre following burning. Brown and

DeByle (1989) reported densities of 6800 to 15,600 suckers per acre following burns in Idaho and Wyoming. Jones (1975) reported 10,700 suckers per acre 5 years following clearcutting in northern Arizona. Shepperd (1996) reported from 1400 to over 15,000 suckers per acre five years after treatment in a study in Colorado.

In studies of aspen in the intermountain west, aspen sucker numbers are generally expected to decline in the years following a stand replacement event. Shepperd (1996,1993), Bartos (1994) and Brown and DeByle (1989) all reported a decline in aspen sucker density in the first few years following treatment. Bartos and DeByle (1989) observed that initial "low" densities declined little in the first five years, but their "low density" stands contained over 6500 aspen sprouts per acre. Shepperd (1993) also noted a difference in the rate of decline between high and low density stands. High density stands experienced higher rates of decline, but both types did decline.

In order to determine the success of a treatment, the goals of land managers must be examined. In the case of aspen treatments on the Deerlodge, aspen was often treated incidentally in a project where aspen regeneration was not the primary goal. Target stands with specific structure requirements have not been developed. In no case of aspen treatment within the scope of this study was a specific target such as stand density addressed prior to treatment as might be the case in areas where aspen is considered a commercial species. Instead, goals of aspen management on the Deerlodge National Forest are fairly broad but the underlying assumption is that aspen treatments should increase the vigor of the clone and insure the continued presence of aspen at the treated site. This study detected only limited success at the expense of the reduction or elimination of mature aspen clones in the treatment areas studied.

Fencing

The only treatment that occurred on a similar site in this study was fencing to exclude livestock with no other treatment and fencing to exclude livestock following burning. Fencing proved to be worthwhile when employed on the burned site. BM4 which was burned and fenced to exclude livestock produced significantly more aspen suckers than BM3 which was also burned and was located adjacent to BM4. On the unburned site (BM2), fencing did not seem to affect the number of aspen suckers present when compared to the control (BM1). While suckers were produced at both sites, neither site exhibited a developing understory. Suckers usually did not persist at either site from one year to the next. Both sites were located underneath a fairly dense aspen canopy with no large gaps due to mortality and the canopy, not browsing activity accounted for sucker suppression.

The unburned, fenced site (BM2) showed no significant increase in suckering when compared to the unfenced control. The sites that showed no increase in sprouting when fencing was the only treatment were located underneath the canopy in the middle of the clone. Schier (1985) contended that sprouting may be stimulated by warm soil temperatures in the spring before leaf flush. The warm temperatures stimulate root function and cytokinin levels increased before any new auxin is produced in the aspen canopy. Auxin in the root system from the previous growing season breaks down during the winter. When these conditions exist, (warm temperatures before leaf flush) the effect is the temporary reduction of apical dominance. Sprouting is stimulated but after leaf flush, further sprouting is suppressed. Despain (1990) suggests that a spring frost which kills the new leaf growth will reduce the amount of auxin produced and suckering will also be stimulated. In either of these cases, sprouts that are at the perimeter of the clone may continue to grow and expand the area occupied by the clone.

Treatment Type

Direct comparisons between treatment types other than fencing were not possible in this study but the treatment that was associated with the most dense regeneration was mechanical scarification. The sites having the largest number of aspen suckers were DC1 and DC2 which were mechanically scarified. The only area which showed a significant increase in sucker numbers when all sites on the area were considered is the Dry Corners area ($p < 0.01$). Mechanical scarification results in the reduction of apical dominance by completely severing the root from the tree and in some cases removing other physical effects of the tree such as shading by removing the tree itself. Shepperd (1996) found that aspen clones which were bulldozed produced significantly more sprouts than clones which were cut. Shepperd theorized that some auxin is produced in stumps through dormant buds and stump sprouts and that by removing the stumps, less auxin is available to the root system to suppress suckering. In the Dry Corners treatment area where aspen was occasionally pushed over and many of the roots were severed during scarification operations, the most dense aspen regeneration of the study sites resulted. The sprouts at this treatment area are 6 years old and at one site (DC2) have grown above the browse line. This treatment area will probably continue to support aspen. However, Dry Corners is an upland area. Scarification is not a practical treatment in most riparian areas due to the amount of soil damage and sedimentation that would be associated with it.

Fuel Loading and Browse

In the treatment sites where cutting was employed, all the cut aspen trees were left on the site resulting in heavy fuel loadings. It was thought that these heavy concentrations of slash would discourage browse activity on the sprouts. In the four areas of the heaviest slash concentrations, CA1, CA2. HB1 and HB2, browse intensities were the same as the control sites which also were producing young aspen sprouts to attract livestock and wildlife ($p < 0.1$).

In HB1, aspen suckering was actually reduced by treatment. Numerous dead stems were not observed so it is doubtful that the Hidden Bear area aspen regeneration experienced the heavy *Cytospora* infection that led to extremely low aspen sucker numbers in other areas. More likely, the root system just failed to sprout. Heavy fuel loading has been suggested to inhibit aspen suckering (Shepperd 1996) and may have been a contributing factor to the failure in this area.

Competing Vegetation, Sucker Heights and Treatment Timing

The height of competing vegetation did not seem to hinder aspen regeneration in the 1996 study sites. The competing vegetation only increased on two sites as a result of treatment and in both cases the vegetation was grass. A different situation exists at one of the remeasurement sites. West Creek has a dense population of Canadian Thistle throughout. From the height of the dead aspen suckers, it appears that the thistle was not inhibiting the regeneration prior to the *Cytospora* infection. Canadian thistle may however inhibit future aspen sprouting in this area.

Sucker heights increased on three sites in this study. The differences in sucker height are mainly a function of the age of the suckers. Dry Corners, which is the only site to show both a significant increase in sucker numbers and sucker height can probably be considered successful. Some of the sprouts have grown above browse lines and the rest seem to be doing well.

Treatment timing has been shown by Weber (1991) to adversely affect aspen regeneration. Champion Aspen and the two remeasurement sites, Hartman Creek and West Creek, were treated during leaf flush. The timing of treatment did not result in regeneration failure at Champion Aspen. One of the treatment sites produced significantly more suckers than the control and the other seemed to be producing suckers as well. Both Hartman Creek and West Creek suffered widesrpead die off due to the

Cytpospora infection. It unknown if there is a link between the timing of treatment and *Cytospora* in either of these cases, because the time of infection is unknown. Most likely, the *Cytospora* infection occurred as a result of something else. The aspen regeneration in both areas was well stocked immediately after treatment (Rassman 1993) and remained so up until the time of infection judging from the number of dead aspen stems on the site.

Effects of Site Upon Aspen Regeneration

Riparian Versus Upland

The results of this study indicate a difference in number of aspen suckers associated with upland versus riparian sites. Generally, the riparian sites produced less sprouting following treatment. Treatment types were restricted because of the nature of riparian areas. Mechanical scarification, which has been shown to produce more suckers than burning or cutting (Shepperd 1996), was not used in any of the riparian areas which were compared with the upland sites in this study.

Water Holding Capacity

Water holding capacity influenced aspen regeneration in the riparian sites. Although there was no significant difference among the controls, the water holding capacity was significantly higher in the treated riparian sites than the upland sites. Also, the mean suckers/acre were significantly lower in the treated riparian sites. Increased soil moisture has been shown to inhibit aspen growth and sucker production (Fralish 1972, Jacobi 1996). In his aspen work in Colorado, Jacobi noticed that aspen sprouting is generally low in wet areas (personal communication). The same conditions were encountered in this study although they were not measured. On plots where there was standing water or sometimes the presence of a wet site indicator such as *Equisetum arvense* aspen suckering seemed light.

Soil pH

No adverse relationship between the degree of aspen suckers and acidic soil was detected in this study. Cryer and Murray (1992) suggested that at some point soils that have been occupied by conifer will become too acidic to support aspen. In this study, some of the most dense stands of aspen regeneration existed on soils with a pH of 4.0. Other factors such as treatment and moisture content of the soil at key periods in the development of young stands probably influence success more than soil pH.

Basal Area of the Parent Clone

A significant increase in suckering has occurred in only portions of two treatment areas, Champion Aspen and Dry Corners. In the case of the Dry Corners treatment area, aspen densities have increased dramatically over the density of the control. Sucker densities have increased from 500 to over 6900 in one instance.

What is more important, however is that the control area which represents much of the aspen on the site had only 20 mature trees per acre. This clone was overtopped by competing Douglas fir. Scattered throughout the area were small (4-6' tall) suppressed individual aspen trees. The removal of conifer allowed these sparsely stocked stands of aspen to produce the most dense and vigorous regeneration encountered in the study.

At the Champion Aspen treatment area, one site showed a significant ($p < 0.1$) increase in sucker production and one did not. The portion of the Hidden Bear treatment area where the aspen clone was cut and left in place was a disaster. A mature stand of 6-10" diameter aspen trees with an approximate density of 200 stems per acre of and 280 sprouts per acre was eliminated to produce sucker densities of 40-280 stems per acre. It is possible that aspen will be effectively eliminated at one if not both of these sites. At the Bear Gulch treatment area, most of the parent clone was left intact. Again, suckering did not significantly increase but aspen was not eliminated from this site. The site continues to produce suckers which may eventually develop into an understory or increase the area occupied by the clone.

Previous studies (Renkin 1994, Perala 1990) indicate that aspen suckering is correlated to basal area. This study shows that the relationship can be confounded by other factors. Well stocked vigorous clones do not always guarantee high levels of suckering. Also, poorly stocked aspen clones may have sufficient underground biomass to regenerate if other variables such as treatment favor regeneration.

Remeasurement Sites and *Cytospora*

The fate of the regeneration at Hartman Creek remains uncertain. The *Cytospora* infestation has nearly devastated what was once considered a successful attempt at aspen regeneration and was the model for other aspen treatments on the Deerlodge National Forest. Now it is uncertain if any of the sprouts will survive and grow into mature trees. West Creek also was a promising site. While the density of aspen suckers was less than Hartman Creek, it was probably sufficient to eventually produce a well stocked aspen clone that would resemble the parent clone. *Cytospora* again accounted for the decline of aspen present on the site.

The phenomenon of a widespread fatal *Cytospora* canker infection was repeated at the Bald Mountain treatment area. Initially two more study sites were selected, BM5 and BM6. At both of these sites the adult trees were cut and left in place. Relatively dense suckering resulted (approximately 4000 sprouts/acre-by ocular estimate). Prior to leaf flush in 1996 many of the stems appeared to be dead and were heavily infected with *Cytospora* cankers. After leaf flush many of the stems sprouted at the base or produced live branches and leaves at some point on the stem. At this time, plots were established and aspen sprout densities measured. Sucker densities ranged from 1720 to 2600 live stems per acre. Later in the summer, it appeared that a significant portion of the aspen that had resprouted subsequently died. At this point the sites were dropped from the study for purposes of comparison because a reliable estimate of sucker numbers was not possible. The *Cytospora* canker infection was confirmed by Forest Service Region 1 pathologists Jane Taylor and Blakey Lockman. The discovery of *Cytospora* at the Bald Mountain treatment area led to the diagnosis of *Cytospora* canker on the dead regeneration at both Hartman Creek and West Creek.

The reason for the *Cytospora* infections at the three sites remains unknown. The exact year that the sprouts became heavily infested cannot be determined for all of the areas, but most likely at BM5 and BM6 suckers were heavily infected during 1995. Of the three sites that were heavily infected by *Cytospora*, two, Bald Mountain and West Creek, occupy hydric soils. Hartman creek is on a dry south slope and may be susceptible to drought. Stresses that are associated with both excessive and insufficient soil moisture may have contributed to the infestation.

Jacobi (1996) found that stresses to aspen regeneration brought on by both excessive moisture and drought predisposed the suckers to infection by canker. Jacobi contends that regeneration failures due to *Cytospora* are not just isolated chance incidents. Conditions for excessive soil moisture occur approximately 26% of the time and conditions for low soil moisture occur 8% of the time on the sites studied in Colorado. Because microsite weather data is not available, historical soil moisture conditions remain unknown but most probably the conditions described by Jacobi (1996) occurred on the sites in this study in 1995 and maybe before.

Jacobi (1996) also noticed that trees on his study sites were severely infected with *Venturia macularis* the year before or the year of widespread shoot mortality. The *Venturia* may have provided an infection site for the *Cytospora* canker and a *Dothiora* canker that he was studying. *Venturia* was also present at two sites that had been burned near the Hartman Creek site. Both of these sites showed fairly high aspen density (1330-6850 sprouts/acre) when measured in 1996. The *Venturia* infection was relatively heavy at both of these sites but mortality due to *Cytospora* was not evident. It is possible that these sites escaped the moisture stresses that caused the mortality at Hartman Creek, but it is also possible that these two sites are just a year behind and face the same fate.

Summary

Aspen treatments on the Deerlodge National Forest have not been consistently successful. Problems range from poor responses to treatment to large scale sucker mortality due to *Cytospora* in the years following treatment. Fencing has been effective when applied to a treated site. Leaving high slash concentrations on a site did not change browse levels from untreated sites. Mechanical scarification proved successful as a treatment in an upland site. The basal area of existing clones did not predict aspen suckering response within the confines of this study. Riparian sites produced less suckering than upland sites. Acidic soils did not inhibit aspen regeneration. All these factors need to be taken into account when treating aspen on the Deerlodge National Forest with the goal of making aspen treatments more intentional than incidental.

Additional Research Needs

This study should not be construed as the consummate aspen treatise for the Deerlodge National Forest. It was intended to provide some insights regarding the success or failure of aspen treatments across the forest. As with most studies, it could have been more comprehensive. One glaring omission is the absence of a different treatment type in the riparian classification allowing for a comparison of treatment between the riparian and upland classifications. Such a comparison would have been valuable since it appears that slashing healthy aspen clones isn't consistently successful. Ideally one would have established a replicated split-block experimental design, applied the treatments and then waited for a period of years to measure the results.

The *Cytospora* infections were both illuminating and confounding. Confounding in that the data from two treatment sites was rendered useless, but illuminating in that before this study, browse alone was thought to be the reason for the aspen declines in the 1993 study area. *Cytospora*, or more accurately the conditions that lead to a widespread *Cytospora* infestation, is a major factor on the forest. The combination of factors needed to allow for the survival of aspen regeneration in times of climatic stress remains unclear.

The effects of treatment timing and its relationship, if any, to the lethal *Cytospora* infestations merits further investigation. The sites that experienced the widespread

Cytospora infections were treated in the spring, either prior to leaf flush, during or immediately after. Did cutting or burning the parent clones in the spring weaken the parent root system and make the regeneration more susceptible to *Cytospora* infection?

The most urgent need that this study detected was the need for monitoring aspen treatments on the Deerlodge National Forest. Clearly not all treatments are successful nor are they realistically expected to be, but if a treatment type is only occasionally successful and more often unsuccessful, its continued use only aggravates the problem of declining aspen on the Deerlodge.

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Appendix A

SOILS

Bald Mtn.

Two soil pits were constructed in the Bald Mountain area. The first was located in BM2. This location was selected as a representative site. The pit is located in a broad drainage in granitic soils underneath a well developed aspen canopy. The soil at this site is classified as a Argic Cryoboroll. The A_1 and A_2 horizons extend to a depth of 6". The A_1 is a very dark brown (10YR 2/2) loam and the A_2 is classified as a very dark grayish brown (10YR 3/2)sandy clay loam. The B_w horizon extents to 22" and is a dark grayish brown (10YR 4/2) sandy loam. The argillic horizon (B_t) begins at 22' and extends to about 30" in depth and is classified as a dark grayish brown (10YR 4/2) sandy clay loam. The C horizon begins at 30" and extends to 40+" and is a brown (10YR 5/3) sandy loam. Gleying was present at 60".

A second soil pit was constructed about 600' east of the first in BM3. The soil at this location was very similar to the first pit. The A_1 and A_2 horizons extend to a depth of 11" and were (10YR 3/1-4/1)sandy loams. The B_w horizon extends from 11" to 16" and is also a (10YR 4.5/2) sandy loam. The B_t extends from 16" to 25" and is a (10YR 3.5/1) silt. The C horizon begins at 25" and extends to 37+" and is a (5Y 4/1) gravelly sandy clay loam. The only difference noted at this location was the presence of gleying at 23" causing the soil designation to become an Oxyaquic Cryoboroll. This gleying is attributed to additional moisture that is concentrated at the site because it sits in a small bowl on a sideslope.

Champion Aspen

To describe soils in the area a soil pit was constructed in the control (CA3) and another located in CA2. The soil at the control site is classified as an Argic Cryoboroll. The A horizon extends to 7" and is a very dark grayish brown (10YR 3/2) gravelly loam. The first B horizon (B_{t1}) extends from 7" to 14" and is a dark grayish brown (10YR 4/2) very gravelly sandy clay loam. The second B horizon (B_{t2}) extends from 14" to 23' and is also a brown (10YR 5/3) gravelly very sandy clay loam. The C horizon extends to 40+" and is a brown (10Y R5/3) gravelly sandy clay loam. The soil is well drained despite the presence of a live stream less than 50' away.

The second soil pit was constructed approximately 300' up the drainage from the first pit. The soils at the second pit (CA2) were difficult to classify. They were on the border of being Typic Cryoborolls but the presence of gleying and moisture swayed the classification to Aquic Cryoborolls. The first A horizon (A_1) extends to a depth of 6" and is a black (10YR 2/1) silty loam. The second A horizon (A_2) extends from 6" to 12" and is also a very dark gray (10YR 3/1)silty loam. The B horizon (B_g) extends from 12" to 20" and is a light brownish gray (2.5Y 6/2) very fine sandy loam. The C horizon (C_g) extends from 20" to 37+" and is a light brownish gray (2.5Y 6/2) gravelly sandy clay loam. Soils at this site retain more moisture than at the pit at the control site. Gleying occurs at 13" and soils are moist throughout.

Dry Corners

Three soil pits were constructed in the Dry Corners treatment area. The first was constructed along a road cut adjacent to DC1. The second was located in the center of DC2, an area that appeared to have more available moisture than the other treatment sites. The aspen on this site were considerably taller than aspen on the other sites and the area is also located in a small bowl located on a sideslope.

The soil at the first pit located next to DC1 is classified as a Typic Cryochrept. No A horizon exists at this site. Beginning underneath the O horizon, an E horizon extends to 5" and is a grayish brown (10YR 5/2) gravelley sandy loam. The first B horizon (B_{w1}) extends from 5" to 13" and is a grayish brown (10YR 4.5/2) gravelly very sandy loam. The second B horizon (B_{w2}) extends from 13" to 27" and is also a dark grayish brown (10YR 4/2) gravelly very sandy loam. The C horizon extends from 27" to 40+" and is a light brownish gray (10YR 6/2) gravelly sandy clay loam. The site is fairly dry and well drained.

The second pit located in DC2 is very similar to the first site which was unexpected. No significant amounts of additional moisture that might account for the increased aspen growth is present. The soil is also classified as a Typic Cryochrept. An E horizon extends to 5" and is a dark grayish brown (10YR 4.5/2) gravelly sandy loam. The next horizon a B_w, extends from 5" to 13" and is also a dark grayish brown (10YR 4/2) gravelly sandy loam. The C horizon extends from 13" to 37" and is again a brown (10YR 5/3) gravelly sandy loam. This is another fairly dry site with well drained soils.

The third pit was located in the control site (DC3). Soils at this site are Typic Cryoboralfs. An A horizon extends to 2" in depth and is a dark brown (10YR 3/3) gravelly very sandy loam. The first B horizon, a B_{t1}, extends from 2" to 10" and is also a very dark to dark grayish brown (10YR 3.5/2) gravelly very sandy loam. The second B horizon, a B_{t2}, extends from 10" to 15" and is a brown (10YR 4/3) gravelly extremely sandy loam. A B/C horizon exists from 15" to 26" and is also a brown (10YR 4/3) gravelly extremely sandy loam. From 27" to 36+" is a C horizon which is a brown (10YR 4/3) gravelly loamy sand.

Hidden Bear and Bear Gulch

Two soil pits were constructed in this treatment area. The first was located in the control (HB5) that appeared to have the most available moisture. This pit is representative of the soils occurring in HB1 and HB2 which are located adjacent to the control in the same drainage. Soils at the first pit are classified as Pachic Cryoborolls. The A horizon extends to 11" and is a black (10YR 2/1) gravelly sandy clay loam. The B horizon, a B_w, extends from 11 to 18" and is a very dark gray to a very dark grayish brown (10YR 3.5/1) gravelly very sandy loam. The next horizon, a B/C, extends from 18" to 26" and is a very dark gray to a very dark grayish brown (10YR 3.5/1) gravelly extremely sandy loam. The C horizon extends from 26" to 40+" and is a dark grayish brown (10YR 4/2) gravelly extremely sandy loam. The water table was encountered at 27" and was filling the pit. Despite the water, the soils appear to be at least moderately well drained. No gleying was encountered.

The second soil pit was constructed in BG4 which is located in a different drainage approximately 500' up the hillside from HB5. The soils at this site are representative of the treatment area HB3. Soils are also classified as Pachic Cryoborolls. An A horizon extends to 16" which is a very dark gray (10YR 3/1) gravelly extremely sandy clay loam. The B horizon exists at a depth of 16" to 21" and is also a dark gray (10YR 4/1) gravelly extremely sandy clay loam. The C horizon, a C_g, extends from 21' to 38+" and is a grayish brown (2.5y 5/2) gravelly extremely sandy clay loam with strong brown (7.5YR 5/6) mottles. Gleying occurs at 24" with mottling also occurring in the C horizon. A live stream occurs within 50' of the pit but no water table was encountered suggesting that although gleying does occur, the surface is at least more well drained than the first pit.

Hartman Creek Soils

A soil pit was constructed on this site on a stream terrace above the bottom of the drainage. The soils on this site are classified as Typic Haploborolls. An A horizon extends to 3" in depth which is a very dark gray (10YR 3/1) gravelly very sandy loam. The first B horizon (B_{w1}) extends from 3" to 11" and is a very dark gray (10YR 3/1) gravelly extremely sandy loam. The second B (B_{w2}) horizon extends from 11" to 22" and is also a dark to very dark gray (10YR 3.5/1) gravelly extremely sandy loam. The C horizon extends from 22" to 40+" and is a dark grayish brown (10YR 4/2) gravelly sandy loam. This site is well drained and very dry. The occasional water flow in the draw bottom probably accounts for the occurrence of aspen at the site.

West Creek

Two soil pits were constructed at the West Creek treatment site. The first was located in the upper portion of the drainage near the bottom of the draw. The soils are Oxyaquic Ustifluvents. Sedimentation has resulted in several buried horizons. The first horizon, an A horizon extends to 20" in depth and is a dark gray (10YR 4/1) gravelly sandy clay loam. The next horizon, a B horizon extends from 20" to 25" and is a gray (10YR 5/1) fine sandy loam. Underneath is an A_b horizon extending to 28" which is a very dark gray (2.5Y 3/0) gravelly sandy loam. Next is a C_b horizon which extends from 28" to 32" and is a grayish brown (10YR 5/2) gravelly very loamy sand. Another A_b horizon extends from 32" to 34" which is a very dark gray (2.5Y 3/0) gravelly sandy clay loam. The next horizon is another buried C horizon, C_b which extends from 34" to 40" and is a gray (10YR 5/1) gravelly very sandy clay loam.

The second soil pit was located approximately 500' down the draw from the first site. Soils at this site are classified as Cumulic Haploborolls. Sedimentation again resulted in buried horizons at this site. The first A horizon extends to 20" and is a (10YR 2/1) gravelly silt. The second horizon, a C horizon extends to 26" and is a (10YR 5/3) gravelly very sandy loam. The third horizon is a buried A and extends from 26" to 38+". This horizon is a (10YR 3/1) silt. Both sites have a dark mollic epipedon that indicates a long term occupancy of the site by aspen community types. The *Populus tremuloides Calamagrostis canadensis* habitat type described by Hansen et. al (1995) best fits this site.

Appendix B

SITE MEASUREMENTS

Bald Mtn. 1

Aspen suckering was fairly light on the control site at 260 sprouts per acre. All the sprouts counted were recent, originating in 1996. None had frost damage and most appeared to be free from canker and defoliators. The average height of the tallest sprouts on each plot averaged 0.5 feet. Browsing was light (less than 33% of the sprouts had been browsed) and the height of the competing vegetation excluding the canopy was 0.5'. No recent ground disturbance such as scarification or charring from fire was present. Fuel loading at this site measure 8.3 tons per acre and consist of aspen trees which had died and fallen to the ground. The canopy is that of a well developed aspen clone. Diameters of the mature trees range from 7" to 14" and heights are from 60' to 85'. The clone averages approximately 300 trees per acre with a basal area of 36.8 square feet per acre. Some canker is present but the amount of disease in this clone seems to be consistent with many of the other mature aspen clones on the Deerlodge National Forest.

Bald Mtn. 2

Aspen suckering is approximately 300 sprouts per acre at BM2. Most of the suckers measured were older than one year. The height of the tallest suckers averaged around

0.5' with the tallest sucker at 1.0'. Browse was light, less than 33% and the height of the competing vegetation was approximately 0.5'. Damage to the aspen suckers was light, only one was frost damaged and most appeared to be free from canker and defoliators. No ground disturbance was observed. A well developed canopy also occupies BM2. The canopy is similar to BM1 and is probably part of the same clone. Basal area and heights of the trees were comparable to BM1 and canker is present to a similar degree. Fuel loadings averaged 4.47 tons per acre for the site and consisted mainly of aspen trees that had died and fallen to the ground.

Bald Mtn 3

Aspen suckering averaged 400 sprouts per acre. Height of the tallest suckers at each plot was 0.5'. Most of the sprouts at this site were recent. Browse activity was heavy with more than 66% of the sprouts showing evidence of browse. Ground disturbance averaged 70% mainly from charring. The height of the competing vegetation was approximately 1'. Fuel loadings measured 18 tons per acre and consisted mainly of the not completely stems of Douglas fir stems that had been left as a result of slashing.

Bald Mtn. 4

Sprouting measured 960 stems per acre. The height of the tallest sprouts was approximately 1.0'. Defoliators were present on many of the sprouts and browse activity was heavy across most of the site averaging 66% or more. Ground disturbance measured 80% across the site. The height of the competing vegetation averaged approximately

1.5’. Fuel loadings averaged 14.6 tons per acre and consisted of mostly slash which was not consumed by burning.

Champion Aspen 1

Aspen suckering averaged 1680 per acre. The height of the tallest sucker measured was 2.5’ with the average of the tallest suckers on the plots averaging 1.5’. Shepherd’s Crook, frost damage and defoliators and numerous dead stems were present. Browse conditions were light to moderate, heavy browse was noted at one plot, light browse at two and one had moderate use. Ground disturbance was light averaging only 4% for the site. The height of the competing vegetation measured 2’. Fuel loadings measured 36.7 tons per acre and consisted of the mature aspen trees that were cut and left in place. Slash heights across the site were from 2.5’ to 3’.

Champion Aspen 2 (CA2)

Aspen suckers numbered 840 per acre. The tallest sprout was 2.5’ with the average height of the tallest suckers on the plots at 1.5’. Shepherd’s Crook was present but not to the degree as in CA1 and less dead stems were noted. Browse activity was light to moderate. Three plots showed evidence of light browse and two plots showed moderate browse. No recent ground disturbance occurred and the height of the competing vegetation averaged 2.5’ across the site.

Champion Aspen 3

Aspen sprouts on the control site numbered 600 per acre. The tallest sprout measured 2' with the average of the tallest sprouts on the plots measuring 1.5'. Frost damage, defoliators and Shepherd's Crook were present in the sprouts. Browse evidence was sporadic. Heavy browse was noted in one instance but on the other two plots where aspen sprouts occurred, browse activity was light. No recent ground disturbance occurred on the site.

Most of the canopy is occupied by 10" to 15" aspen trees 60' to 70' tall but several gaps are present. The gaps are occupied by a younger component, trees 5" to 7" in diameter and 30' to 40' tall. The gaps are apparently caused by mortality to the older stems. Numerous dead stems exist in the openings. The overstory measured 200 trees per acre with a basal area averaging 11.2 square feet per acre.

Dry Corners 1 (DC1)

Aspen sprouts averaged 2920 per acre. The tallest sprout measured was 4' and the average height of the tallest sprouts on the plots was 4.5'. Sprouts appeared to be healthy and vigorous. Browse activity was light across the site, four plots showed light browse activity and only one plot experienced moderate browse. Ground disturbance averaged 30% across the site due mainly to scarification and the height of the competing vegetation was 1.0'. Fuel loadings averaged 3.33 tons per acre and consisted mostly of logging slash. Numerous lodgepole pine seedlings were intermingled with the aspen regeneration.

Dry Corners 2 (DC2)

Aspen suckers on DC2 numbered 6900 per acre. The tallest sucker measured was 10.5' and the average height of the tallest suckers on the plots was 7.5'. Suckers appeared to be healthy and vigorous. Some showed light frost damage. Browse activity at this site was moderate, three plots showed moderate browse activity, one showed heavy activity and one showed light. Ground disturbance averaged 30% mostly due to scarification, and the height of the competing vegetation was 0.5'. Fuel loading averaged 4.86 tons per acre and was mostly comprised of logging slash. A few lodgepole pine seedlings were noticed growing in the aspen regeneration.

Dry Corners 3 (DC3)

Aspen sprouting at the control site averaged 500 stems per acre. The tallest sprout measured was 4' and the average of the tallest sprouts on the plots was 3'. Some of the sprouts experienced light frost damage. Browse was moderate, two plots showed heavy browse, one showed moderate browse activity and two showed light activity. No recent ground disturbance occurred on the site. Height of the competing vegetation was approximately 0.5'. Fuel loadings averaged 2.17 tons per acre.

The canopy at the control site was dominated by Douglas fir. The aspen component consisted of overtopped aspen trees of 4" to 5" in diameter and 30' to 40' tall. The basal area of the aspen measured 0.9 square feet per acre and the adult aspen numbered approximately 20 per acre.

Dry Corners 4 (DC4)

Aspen sprouts numbered 1340 per acre. The height of the tallest sprout was 5' with the average of the tallest sprouts on the plots averaging 4'. Some light frost damage occurred on one of the plots. Numerous lodgepole pine seedlings are growing throughout the aspen regeneration. Browse activity was heavy at DC4. One plot showed moderate browse activity while the rest experienced heavy browse. Ground disturbance averaged 30% across the site and was the result of logging activity. The height of the competing vegetation averaged 1'. Fuel loadings measured 3.19 tons per acre and consisted mainly of logging slash.

Hidden Bear 1 (HB1)

Aspen sprouting was nearly non existent, only two sprouts were encountered on the five sample plots yielding 40 sprouts per acre. The sprouts were relatively tall, one measured 5.0' and the other was 2.0' tall. One of the sprouts had been browsed. No recent ground disturbance occurred on the sight and the height of the competing vegetation was 1.0'. Slash heights ranged from 1 to 4' and more across the site. Fuel loading were heavy, measuring 30.3 tons per acre and consisted of aspen that was cut and left in place. Standing water was observed on two sample plots.

Hidden Bear 2 (HB2)

Aspen sprouts numbered 280 per acre. The tallest sprouts measured 1.0' and the average height of the tallest sprouts encountered on the plots was also 1.0'. Browse was light on all the plots except one which showed heavy browse activity. No recent ground disturbance occurred on HB2. The height of the competing vegetation averaged 1.0'. Slash heights were similar to HB1. Fuel loadings were heavy at 25.59 tons per acre and consisted of the aspen trees that were cut and left on the site.

Hidden Bear 5 (HB5)

Aspen sprouts in the control site numbered 280 per acre. The tallest sprout measured was approximately 0.5'. The average height of the tallest sprouts on the plots was also 0.5'. In spite of heavy basal scarring on the large trees due to elk or moose chewing, browse on the aspen suckers in the control area was relatively light, only one plot showed heavy browse and the rest showed low browse activity. No recent ground disturbance occurred in the control area. The average height of the competing vegetation was 1.0'. The overstory consists of mature aspen trees ranging from 6 to 13" in diameter and from 55 to 65' tall. Canker infection seems to consistent with other aspen stands on the forest. The basal area of HB5 measured 17.74 square feet per acre and averaged 200 trees per acre. Fuel loading was relatively light at 2.06 tons per acre.

Bear Gulch 3 (BG3)

Aspen sprouts average 1300 per acre at this site. The height of the tallest sprout measured 1.0' and the average of the tallest sprouts on the plots was 0.5'. Browse activity was heavy at HB3. Of the four plots where aspen occurred, three showed evidence of heavy browsing. Ground disturbance averaged 34% across the site and was primarily the result of skidding logs around the aspen clone. The height of the competing vegetation was 0.5'.

Bear Gulch 4 (BG4)

Aspen suckering in the control measured 1040 stems per acre. The tallest sprout measured 1.0' and the average of the tallest plots encountered was 0.5'. Browse activity was moderate, three plots showed light browse and two plots showed heavy activity. No recent ground disturbance was encountered on the site. The height of the competing vegetation averaged 0.5'. The adult aspen at the site measured from 6 to 10" in diameter and were from 35 to 45' tall. The basal area of the aspen in the control averaged 9.2 square feet per acre. The control averaged 140 aspen trees per acre, many showing wildlife chews like HB5.

Remeasurement Sites

Hartman Creek

Aspen suckering averaged 13,500 stems per acre when measured 90 days after the burn in 1992. Suckering was described as "extensive with 15,000+ suckers per acre present in some areas..." (Rassman 1993). When the same plots were remeasured in 1996, live aspen stems were encountered on only eight plots yielding 140 live stems per acre. Numerous dead stems were present which showed evidence of *Cytospora* canker infection. In addition defoliators were present in the live aspen and browse was heavy across the site. Height of the competing vegetation averaged 2.5' and consisted mostly of Canadian thistle, snowberry and chokecherry.

West Creek

When measured 90 days after the 1992 burn, aspen sucker densities averaged 3800 stems per acre across the site. Because some of the upland plots could not be located in 1996, only the 10 riparian plots were remeasured. The riparian section yielded 210 stems per acre in 1996. The upland portion of the site appeared to have approximately the same densities. Numerous dead stems were noted and appear to have been infected by *Cytospora* canker. Height of the competing vegetation averaged 2' across the plots that were remeasured. The competing vegetation consisted mostly of Canadian thistle, snowberry and chokecherry. Browse was light across the site.