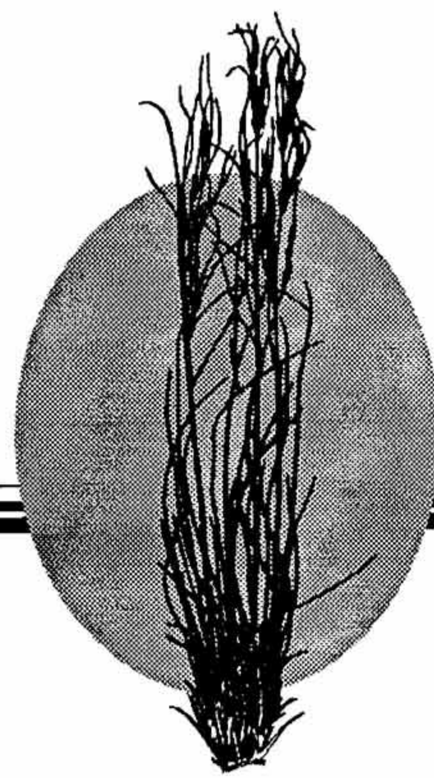
Chapter 3

Environmental Consequences



CHAPTER 3

ENVIRONMENTAL CONSEQUENCES

INTRODUCTION

This chapter discusses the impacts of the Bureau of Land Management's proposed vegetation treatment program, described in Chapter 1, on the natural and human environment detailed in Chapter 2 vegetation, climate and air quality, geology and topography, soils, aquatic resources, fish and wildlife, cultural resources, recreation and visual resources, livestock, wild horses and burros, special status species, wilderness and special areas, human health and safety, and social and economic resources. It must be stressed that, because this is a programmatic EIS covering a wide variety of treatment methods over a broad land area, the analysis addresses impacts at a fairly general level. (Site-specific impacts will be addressed in Environmental Assessments tiered to this document.)

The first section of this chapter describes the potential impacts each vegetation treatment method would have on those environmental components.

The basic outline of the chapter is as follows:

Section 1: Impacts of the Vegetation Treatment Methods

Impacts on a Resource Element (e.g., soils)
  Impacts of Manual Methods
    Impacts in the Sagebrush Region
    Impacts in the Desert Shrub Region
    Impacts in the Coniferous/Deciduous Forest Region

...

  Impacts of Mechanical Methods
    Impacts in the Sagebrush Region

...

  Impacts of Biological Methods

  Impacts of Prescribed Burning

  Impacts of Chemical Methods

Impacts on the Next Resource Element (e.g., vegetation)
    Impacts of Manual Methods

...

Impacts are discussed for each treatment method under each component (soils, vegetation, etc.). Impacts for each method are discussed within each vegetation analysis region for those environmental components for which the impacts are likely to vary from analysis region to analysis region. The impacts discussion is not broken down to the vegetation analysis region level for those components not likely to vary significantly at that level. The treatment methods may have short-term impacts, occurring only briefly immediately after an area is treated; long-term impacts, lasting for months or years after a treatment; and cumulative impacts, operating in conjunction with the impacts of other nearby treatments or over time if a given locality receives a number of treatments.

The second section of the chapter discusses the effects of the treatment program alternatives, comparing the probable effects of using a combination of treatment methods in implementing the proposed action with the likely effects of the four alternative programs, including "no action."

Section 2: Impacts of the Treatment Program Alternatives

Impacts on a Resource Element (e.g., soils)
  Impacts of the Proposed Program (Alt. 1)
    Impacts in the Sagebrush Region
    Impacts in the Desert Shrub Region
    Impacts in the Coniferous/Deciduous Forest Region

...

  Impacts of No Aerial Application of Herbicides (Alt. 2)
    Impacts in the Sagebrush Region

...

  Impacts of No Use of Herbicides (Alt. 3)

  Impacts of No Use of Prescribed Burning (Alt. 4)

  Impacts of "No Action" (Alt. 5)

Impacts on the Next Resource Element (e.g., vegetation)
  Impacts of the Proposed Program (Alt. 1)

This EIS addresses what may be termed cumulative impacts from two perspectives. First, because treatments are done on individual sites, the EIS addresses the potential adverse effects and benefits of the treatments done on the numerous program sites across the EIS area and the effects over time of those collective treatments. Again, this is done at a general level because only at the site-specific level, addressed in particular Environmental Assessments, can impacts at specified individual locations be evaluated. This first type of discussion will be found throughout the text of this chapter. Second, the EIS addressed cumulative impacts according to Council on Environmental Quality (CEQ) regulations (40 CFR 1508.7) as the incremental impact the proposed BLM program would have on the environment of the EIS area when added to past, present, or reasonably foreseeable future actions of other agencies or individuals. Where cumulative impacts were addressed, this analysis is found in separate resource element impact sections.

Principal aspects of the human environment that are not likely to be affected at all—climate, geology, topography—are not discussed in detail. Because 84 percent of BLM's proposed program consists of rangeland treatments, the discussion focuses on the effects of those treatments.

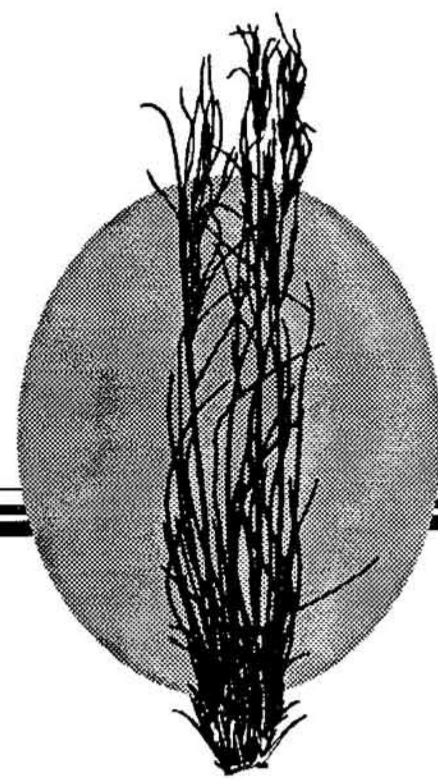
To determine the effects of the herbicides on human health, wildlife, and aquatic organisms, an herbicide risk assessment was conducted. Appendix E describes in detail the hazards of the 19 herbicides and of diesel oil and kerosene; estimates human, wildlife, and aquatic species exposures to the chemicals from application formulations commonly used on rangelands, forest lands, oil and gas sites, rights-of-way, and recreation sites; and analyzes the risk of adverse effects from those exposures. The results of the herbicide risk assessment are summarized in this chapter in the sections on Fish and Wildlife and on Human Health and Safety. The risk to human health from the fire and smoke from prescribed burning was analyzed in a prescribed burning risk assessment presented in Appendix D. The results are presented in this chapter in the section on Human Health and Safety.

For analyses in this chapter, the following assumptions were made: (1) that BLM will have the funding and personnel to implement the final decision, (2) that all standard operating procedures described in Chapter 1 and Appendixes C, E, and J will be applied, and (3) that the types and amounts of vegetation treatments will be applied as shown in Table 1-1 (Chapter 1).

Chapter 3

Section 1

Impacts of the Vegetation Treatment Methods



SECTION 1

IMPACTS OF THE VEGETATION TREATMENT METHODS

VEGETATION

Vegetation treatments would have beneficial and adverse effects on terrestrial vegetation within the EIS area. Target and nontarget vegetation in treated areas would be directly affected. The degree to which vegetation would be affected would depend on the types of treatment used and the number of acres treated under each alternative (see Table 1-1). The overall effect of treating vegetation would be to achieve the desired successional stage, to create a more stratified age structure for wildlife habitat improvement and fuel hazard reduction, to accelerate succession for forest management, and to reduce or eliminate populations of undesirable species in noxious weed eradication programs.

Mechanical treatments affect plants differently depending upon their vegetative reproduction capabilities. In general, woody plants have more negative effects than herbaceous plants. Biological methods will affect target and nontarget vegetation depending upon the abundance of the particular plant species and palatability to animals. Prescribed burning may greatly increase the growth of herbaceous plants and can help prevent wildfire. Vegetation effects of herbicides will depend on how closely related target and nontarget species are, the selectivity of the herbicide, and the application rate. The effects of some vegetation treatment methods on vegetation and soils are summarized in Table 3-1.

Table 3-1

Generalized Influence of Selected Brush Control Treatments on Vegetation and Soils

Kind of Brush Control	Influence on Vegetation		Influence on Soils
	Woody Plants	Herbaceous	
Selective Herbicides	Removes canopies; some plants resprout; dead plants left in place.	Grass cover typically increases; forbs reduced for growing season; composition changes toward grass dominance; unless grass is target, then composition may go to shrubs/ broadleaved species.	No physical effects.
Mechanical Top Removal			
Shredding	Removes top growth; many species regrow vigorously.	Grass cover increases, but improvement may be short term.	Minimal physical effects; woody debris mulches surface.
Roller Chopping	Generally same as for shredding.		Some imprinting of soil by roller blades; woody debris mulches surface.
Hand Slashing	Generally same as for shredding.		Minimal physical effects.

Table 3-1 (Continued)

Generalized Influence of Selected Brush Control Treatments on Vegetation and Soils

Kind of Brush Control	Influence on Vegetation: Woody Plants	Influence on Vegetation: Herbaceous	Influence on Soils
Entire Plant Removal			
Grubbing	Individual plants extracted; little or no regrowth.	General increase in herbaceous species.	Disturbance depends on woody plant density; pits left by extraction trap water.
Bulldozing	Individual plants extracted; little or no regrowth; small or limber plants may remain.	Grass cover increases in interspaces; forbs increase in disturbed areas. May get weedy species initially, but should revegetate to perennials.	Disturbance depends on woody plant density, but can be extensive; pits left by dozed plants trap water.
Chaining/Cabling	Large woody plants extracted; small or limber plants remain.	Grasses/forbs generally increase; seeding often used to expedite cover.	Disturbance depends on chain modification; pits left by extraction of larg plants; soil surface may be further disturbed by raking, or debris may be left in place.
Root Plowing	Woody plants removed by severing below ground line.	Grasses may be reduced; short-term increases in forbs, initial increase in bare soil; seeding often used to expedite cover.	Subsoil disturbance depth depends on woody species, surface disturbances may be extreme.
Disk Plowing	Woody plants mulched into the surface soil.	Grasses are reduced; short-term increase in forbs; initial increase in bare soil; seeding used to establish cover.	Complete surface soil disturbance.
Prescribed Burning	Short-term reduction in woody plant canopies; some woody plants often rapidly regrow.	Varies, but short-term decrease in herbaceous cover; fine mulch consumed. May be flush of herbaceous growth the same year because of an increase in available nutrients.	No soil disturbance but soil surface "bared" usually for a short time, depending largely on postburn weather.

Manual Methods

Manual methods are highly labor intensive and require periodic retreatment ranging from every 3 weeks during the growing season to annually, depending on the target species. These methods have been somewhat successful in controlling annuals and biennials in noxious weed control and vegetation removal along rights-of-way, recreation areas, pipelines, and so on. However, manual treatments have proven inefficient in controlling established creeping perennials in these situations. Manual methods are impractical for large-scale rangeland improvement projects and prescribed burning pretreatment.

With manual vegetation treatment, some degree of weed control would be achieved, but most weeds (including many noxious species) would spread as a result of ineffective control efforts. Undesirable vegetation would again increase. However, manual methods of vegetation treatment are selective. Nontarget species should not be adversely affected. Nontarget plants would benefit from reduced competition for water and nutrients.

Mechanical Methods

Direct effects on target and nontarget vegetation from mechanical treatments depend on how a particular method affects a species at its growing points and its vegetative or sexual reproductive abilities (Sosebee 1983). Indirect effects on nontarget vegetation depend on the availability of resources (water, minerals, light) previously used by the target species.

Because woody plants invest greater energy in perennial, above-ground structures, such as branches and twigs, top removal treatments generally have greater negative effects on woody plants than on herbaceous species, which annually replace their canopies. However, many woody plants can sprout from basal buds and may be reduced in size but are not killed by mechanical top removal. Britton and Wright (1983b) have listed sprouting response caused by mechanical control of various brush species (Table 3-2). Woody and herbaceous plants that reproduce vegetatively are tolerant of top removal by mechanical methods. Many species are flexible enough to bend rather than break during mechanical treatment.

Table 3-2

Sprouting Response of Brush Species after Mechanized Treatment in the Principal Rangeland Types in North America

Vegetation Type	Sprouters	Nonsprouters
Shortgrass Prairie	Mesquite Yucca Shinnery oak	
Mixed Prairie	Mesquite All oaks Redberry juniper Sumac Algerita[1] Prickly pear Cholla	Eastern red cedar Ashe juniper
Tallgrass Prairie	Sumac Western snowberry Lead plant Shrub oak Shinnery oak	Eastern red cedar
Fescue Prairie	Aspen Prairie rose Serviceberry Silverberry	
Palouse Prairie	Rabbitbrush	Big sagebrush
Semi-Desert Grass-Shrub	Velvet mesquite False mesquite Velvet-pod mimosa Algerita[1] Fourwing saltbush Winterfat	 Ocotillo Wheeler sotol Desert blackbrush Sagebrush

Table 3-2 (Continued)

Sprouting Response of Brush Species after Mechanized Treatment in the Principal Rangeland Types in North America

Vegetation Type	Sprouters	Nonsprouters
Semi-Desert Grass-Shrub (continued)	Skunkbush sumac Wright baccharis Shinnery oak Creosote bush	
Sagebrush-Grass	Greasewood Rabbitbrush Curlleaf mahogany	Big sagebrush Low sagebrush
Serviceberry	Snowbrush True mountain mahogany[1] Silver sagebrush Three-tip sagebrush[1] Horsebrush Antelope bitterbrush[1]	
Arizona Chaparral	Shrub live oak Sugar sumac Skunkbush sumac Redberry Catclaw Emory oak Yerbasanta True mountain mahogany Western mountain mahogany Hairy mountain mahogany	Desert ceanothus Mexican cliffrose Deerbrush Pointleaf manzanita
Oakbrush	Gambel oak Chokecherry Wood rose Snowberry Ninebark Serviceberry	Mountain lover Creeping barberry
Pinyon-Juniper	Serviceberry Wright silktassel Shrub live oak Antelope bitterbrush[1] Skunkbush sumac True mountain mahogany Chokecherry Winterfat Mockorange Snowberry Algerita[1] Rabbitbrush Four-wing saltbush Horsebrush Desert bitterbrush Curlleaf mountain mahogany[1] Broom snakeweed Mountain lover Yucca Fringed sagebrush	Big sagebrush Black sagebrush Desert Blackbrush

[1] Weak sprouters; antelope bitterbrush can sprout vigorously following burns at its upper elevational limits.

Source: Britten and Wright 1983.

Sexual reproductive characteristics are important in determining plant tolerance to mechanical treatments in general but are especially important in determining response to root cutting or removal. Characteristics associated with tolerance to mechanical treatments may include abundant seed production and dispersal, long-term seed viability in the seedbank, and rapid germination and seedling growth when environmental resources are available (Harper 1977). Top removal methods generally do not kill and may even spread more limber and sprouting species, but may greatly reduce brittle and nonsprouting species. Methods that remove the entire plant by plowing or cutting roots have the greatest effect on nontarget species and generally require subsequent revegetation.

Sagebrush

For more than 50 years, sagebrush-dominated rangelands have been treated by many different mechanical control methods (Blaisdell et al. 1982). Target species have generally been different subspecies of big sagebrush, as well as species of rabbitbrush; however, not all species of sagebrush can be considered undesirable (Johnson 1987). Most nontarget species are perennial brushgrasses and forbs but may also include shrubs such as bitterbrush and fourwing saltbush.

Railing and brush beating or shredding cause little damage to herbaceous species; however, these methods may release associated undesirable shrubs that sprout, such as rabbitbrush, horsebrush, and greasewood (Blaisdell et al. 1982, Roundy et al. 1983). In addition, herbaceous weeds, such as cheatgrass, halogeton, and medusahead may be released in the absence of desirable species when these species are removed during sagebrush control (Lancaster et al. 1987). Top control methods increase production of associated herbaceous species because sagebrush cover is reduced and soil water availability is increased (Sturges 1975). Grass production generally doubles after sagebrush removal and methods other than plowing and disking do not greatly change herbaceous composition. Plowing or disking are most recommended in areas with little herbaceous understory in which soil disturbance would help to prepare a seedbed for revegetation (Blaisdell et al. 1982, Cluff et al. 1983).

Adequate precipitation and favorable soil characteristics are important for successful revegetation following sagebrush control. Revegetation following plowing of sagebrush will result in dominance by weedy annual species if conditions are not conducive to desired species (Shown et al. 1969).

Although data are scarce, it should be expected that desirable shrubs associated with sagebrush, such as bitterbrush, cliffrose, western serviceberry, and fourwing saltbush, could be damaged by mechanical treatments, especially plowing. Canopy treatment methods, however, such as rotomowing, may actually stimulate bitterbrush growth if done at the proper height (Jones 1983).

In summary, mechanical treatments that control sagebrush by cutting or breaking the canopy tend to increase understory herbaceous species. Plowing of sagebrush can reduce desired species and is generally done where an understory of desired vegetation is inadequate to revegetate naturally. Desired results are achieved either by release of understory vegetation existing on the site through decreased competition with sagebrush, or by reseeding sites on which pre-treatment understory is inadequate to revegetate the site.

Desert Shrub

Mechanical or other vegetation control methods are generally not recommended on saltdesert shrubland or blackbrush and Mojave-Sonoran desert shrublands. Revegetation is usually necessary to increase the cover of desirable species on these lands, but successful revegetation is limited by low and erratic precipitation (Bleak et al. 1965, Jordan 1981, Cox et al 1982, Blaisdell and Holmgren 1984, Roundy and Young 1985). Mechanical treatments of most of these shrublands tend to decrease the cover of shrubs, including desirable saltbushes, and increase the cover of annual weeds, such as halogeton and Russian thistle. Because establishment of perennial vegetation in desert shrublands may require successive years of unusually high precipitation, natural revegetation is limited and vegetation disturbance is not recommended.

Southwestern Shrubsteppe

Many woody species in the southwestern shrubsteppe are able to resprout after top removal. Methods such as chaining and cabling may reduce large trees but increase smaller trees and undesirable shrubs, such as mesquite and species of acacia (Martin 1975). Chaining, cabling, and roller chopping, which pull over or break the canopy of woody plants on southwestern shrubsteppe ranges, do not destroy remnant stands of perennial grasses but may kill some herbaceous plants (Martin 1975). Removal of cholla does not necessarily increase production of herbaceous vegetation (Pieper 1971); however, removal of creosotebush and tarbush may greatly increase diversity and cover of other shrubs, grasses, and forbs (Beck and Tober 1985).

Rootplowing is the most effective method of mechanically controlling undesirable species in the southwestern shrubsteppe, but it also kills most perennial grasses and forbs that are unable to reproduce vegetatively (Vallentine 1980). Because root-plowing may kill more than 90 percent of the vegetation (Herbel 1984a), it is generally recommended only in conjunction with revegetation (Vallentine 1980). In areas of insufficient precipitation, revegetation may not be successful. Where precipitation is sufficient to permit successful revegetation, root and disk plowing increases the density and production of perennial grasses on southwestern shrub-steppe (Herbel et al. 1973, Cox and Jordan 1983, Cox et al. 1986).

In summary, nonplowing mechanical control methods may temporarily reduce woody species and increase herbaceous vegetation. Woody species will resprout and eventually redominate. Root-plowing reduces both woody and herbaceous vegetation but, when combined with revegetation, may increase production of and diversity of herbaceous species.

Chaparral-Mountain Shrub

Chaparral treatments are used to reduce woody vegetation and increase herbaceous vegetation for increased forage or water yield. Methods that reduce woody vegetation canopies have limited success because most chaparral species resprout from buds in the base, rhizomes, or roots (Cable 1975). Root-plowing is the most recommended mechanical treatment to control chaparral species and must usually be followed by revegetation because understory herbaceous vegetation is usually lacking or is reduced by plowing disturbance. Plowing and seeding of adapted grasses reduce woody vegetation and increase herbaceous production (Cable 1975). Mechanical treatments without revegetation would be expected to decrease shrub cover for a short time, but vegetation should quickly return to predisturbance conditions with the growth of resprouted shrubs.

Pinyon-Juniper

Mechanical treatment methods have been used extensively in pinyon-uuniper woodlands. Pinyon and juniper trees have extensive root systems and use soil water and nutrients more efficiently than most shrubs and herbaceous species (West 1984). The competitive ability of these trees allows them to dominate many sites to the eventual exclusion of understory species and to rapidly redominate when only partially controlled (Tausch and Tueller 1977, West 1984). Vegetation response to mechanical treatments is related to the type and amount of tree control, the plant species diversity of the site at treatment, and site climatic and soil conditions. Bulldozing, tree crushing, roller chopping, cabling, and most commonly, chaining are used to reduce pinyon-juniper cover and increase shrub and herbaceous forage.

Single chaining or cabling kills older trees and may result in short-term increases in herbaceous production, but young trees are not killed and rapidly regrow, returning the site to predisturbance composition and production (Aro 1971, 1975). Double chaining kills more trees than single chaining and results in greater release of herbaceous vegetation (Aro 1971, 1975). Windrowing is generally followed be revegetation and is most effective in converting woodland to grassland, although success depends on establishment of seeded species (Evans 1988). Bulldozing may be done to avoid damage to desirable shrubs, such as bitterbrush and cliffrose, and still reduce trees.

Successional patterns and production of different species after mechanical treatment vary greatly, depending on the site (West 1984). Vegetation response to mechanical treatments depends on the successional stage at the time of treatment and the type of plants that are killed. Production of most grass species (blue and sideoats grama, prairie junegrass, squirreltail, mutton bluegrass, and western wheatgrass) may increase after tree control. Forbs (ragweed, aster, redroot eriogonum, annual goldeneye, and sunflower) will also increase. Some cool-season grasses may actually have higher production under scattered alligator juniper trees than in the open (Clary and Morrison 1973). Removal of trees in this situation is not recommended because they help maintain cool-season grasses in the community.

Vegetation response to mechanical removal of pinyon and juniper has been found to depend on associated soils in some studies. O'Rourke and Odgen (1969) reported two to four times the production of perennial grasses on sites in Arizona with moist soil than on dry soil sites after mechanical removal of pinyon and juniper. Native perennial grasses (sideoats, blue, and hairy gramas), many forbs (sunflower, sweetclover, globe mallow, and spurge, for example), half shrubs (snakeweed and buckwheat), and shrubs (shrub live oak, manzanita) increased yields on some sites after mechanical removal of Utah juniper (Clary 1971). Areas initially lacking native perennial grasses did not advance in succession but were dominated by snakeweed and annual goldeneye. Increases in herbage production after mechanical treatment of pinyon-juniper trees in Arizona were greatest on sites with high annual precipitation, high pretreatment tree canopy, or high nitrate and nonlimestone soils (Clary and Jameson 1981). Vegetation composition of perennial grasses increased, while half-shrub vegetative composition decreased, and that of forbs changed little after tree control. Authors concluded that the site potential must be carefully considered in estimating understory response from pinyon-juniper control.

In summary, mechanical control of pinyon and juniper generally results in an increase in herbaceous annuals and perennials, as well as shrubs. This response is short-lived where trees are partially controlled and may be limited on dry sites because of low precipitation or shallow soils. Post-treatment vegetation is generally characterized by vegetation present in the community when it was treated. Communities lacking desirable herbaceous and shrub species generally continue to be dominated by existing weedy species, such as snakeweed and cheatgrass, unless revegetation is successfully applied. Mechanical treatment should be used to completely kill trees on sites with sufficient desirable species, precipitation, and soil depth to maximize desirable understory vegetation response.

Plains Grassland

The objective of mechanical treatment on plains grasslands has been to reduce cover of warm-season species, increase infiltration and nutrient cycling by breaking up compacted soils or sod-bound vegetation, and increase the production of cool-season grasses. Mechanical treatments will usually achieve these objectives, depending on the limiting factors of a particular site and the amount of disturbance. Where soils are fine-textured and have low infiltration rates, mechanical treatments may increase cool-season herbage production. Greater forage production was associated with greater spring soil water content on the furrowed areas. Ripping and contour furrowing of fine-textured loamy soils increased herbage production more in a drought year than in a year with normal precipitation (Griffith et al. 1985).

Furrowing of coarse-textured soils with high infiltration rates does not generally increase water storage and forage production (Valentine 1947, Branson et al 1966). However, mechanically disturbing sod-bound vegetation on sandy soils may increase herbaceous production. Plowing of clayey and sandy soils may initially decrease, then increase total herbaceous production (Rauzi 1975). Mechanical treatments may increase nutrient cycling and production of western wheatgrass as it reinvades areas of native grasses on sandy soils (Wright and White 1974).

In summary, mechanical treatments generally increase production of perennial grasses and forbs, increase infiltration and nutrient cycling, and may decrease production of warm-season grasses on plains grasslands.

Mountain/Plateau Grasslands

Mechanical treatments of mountain grasslands have been reported only as a precursor to revegetating grasslands dominated by undesirable herbaceous weeds. Shrubs such as big sagebrush and rabbitbrush have invaded these grasslands (Yoakum et al. 1969), where soils have become drier as a result of channel cutting and a lowered water table (Eckert et al. 1973a). Mechanical methods, such as rotobeating, railing, or cabling, have not been reported in the literature but could be used to destroy canopies of shrubs invading mountain or plateau grasslands. Such methods do not appreciably disturb the soil and would have limited impact on herbaceous plants that bend easily and are not uprooted, such as rushes and sedges, perennial grasses, and forbs.

Information on vegetation response of mountain grasslands to plowing, furrowing, and seeding is mainly from work done in Nevada (Eckert et al. 1973b), Eckert 1975). In those studies, plowing reduced production of cheatgrass and sedge and prepared a seebed for revegetation by desired species. Perennial grasses, such as various wheatgrasses, bromegrass, and fescue, in addition to legumes (alfalfa and sainfoin), were successfully established in furrows on plowed grasslands. These practices converted the vegetation from dominance by herbaceous weeds, such as cheatgrass and povertyweed, to desirable herbaceous perennial grasses and forbs. Production of native and seeded grasses and seeded legumes was high after treatment.

Coniferous/Deciduous Forests

Mechanical treatments aid in the germination of grasses and hardwoods. These treatments would also increase sprouting of shrubs, such as kinnikinnick and Gambel oak, which after repeated treatment, may form dense hedges. Mechanical treatment alone could result in stands of shrubs surrounded by dense cover of grasses and forbs (Newton and Dost 1981).

Biological Methods

Biological methods of vegetation treatment that may be considered for BLM use include grazing animals, insects, and pathogens. Grazing is the most significant tool available to make a change in cover, composition, and health of rangeland. The areas treated using these methods vary in size from one-quarter acre to 1,500 acres for insects or pathogens, to thousands of acres for grazing animals under a variety of grazing prescriptions. Insects and pathogens generally have less of an effect on nontarget vegetation, while the use of grazing animals as biological treatment has a greater potential for affecting nontarget vegetation.

The possible effects of biological control by grazing animals vary by analysis region. Moderate grazing by sheep may improve mountain/plateau grasslands as cattle range (Vallentine 1980). Grazing of sagebrush vegetation by cattle and sheep in the spring and early summer can increase the vegetative output of desirable shrubs for winter browse. Heavy fall grazing by sheep on these same ranges improved the range condition faster than no grazing at all (Vallentine 1980). Goats can be important biological control agents for woody plants, especially in desolate, semi-arid sites. Goats have been found to be effective on oaks, mesquite, chamise, and sumac on desert shrublands, southwestern shrub-steppes, and chaparral (Vallentine 1980), increasing the species diversity of these areas. Negative impacts from biological control by grazing animals can be mitigated and positive effects accentuated with proper planning and management of a grazing system.

The impacts of biological treatment by insects and pathogens on vegetation will generally be slight. In most cases, the target plants will remain standing, though they may be weakened or unable to reproduce, thus reducing noticeable and immediate effects. Over time, the composition of the plant community may change, as the native plants regain their competitive edge. Any insects or pathogens used for general vegetation treatment would be carefully tested for host specificity, thus reducing or eliminating possible negative effects on native vegetation.

Prescribed Burning

Prescribed burning (Figures 3-1 and 3-2) is used to manage unwanted plants, especially woody species that compete with herbaceous species for water, nutrients, and space; to remove the excessive litter accumulation in some herbaceous species that may ignite, smolder for a long time, and kill the herbaceous species growing points; to modify species composition; to enhance herbaceous productivity; to manage plant community structure; to improve quantity and quality of wildlife habitat; and to reduce fire hazard from surface fuel buildup.

Figure 3-1. Helicopter igniting a prescribed burn.

Figure 3-2. Crew member monitoring prescribed burn aimed at improving forage and wildlife habitat.

The use of fire affects the productivity of plants and has a significant effect on plant competition. In areas where prescribed burning is not used, plant communities may be affected by increased plant competition. The extent of these impacts depends upon numerous interacting factors that determine the ultimate response of a particular ecological system to fire. These factors include weather conditions before and after a burn; time of the year (whether plants are growing or dormant); physical features of the site; particular species; plant life form (shrub, grass, tree, and so forth), method of reproduction, stage of maturity and vigor; amount of fuel available and its moisture content; severity and intensity of the burn; rate of fire spread; flame length; depth and duration of heat penetration into organic and soil layers; and frequency of fires. Prefire and postfire management also have an effect on the composition and productivity of plant communities.

Fire can have a significant effect on postfire plant productivity. Productivity may significantly decrease during the initial postfire recovery period, then increase after 1 or several years. Productivity may increase after the first growing season. Total productivity may not change significantly, but it can shift among classes of plants on the site, such as from conifers that are killed by a fire to shrubs, grasses, and forbs. Total vegetative productivity may actually decrease but shift from less desirable to more desirable species, as from woody plants to grasses and forbs. Immediate productivity increases are usually more likely if significant amounts of vegetative reproduction or regeneration occur, than if the site must reestablish from seed.

Fire has a significant effect on plant competition by changing the numbers and species of existing plants, altering site conditions, and inducing a situation in which many plants must reestablish on a site. In a postfire situation, established perennial plants that are recovering vegetatively usually have an advantage over plants that are developing from seed, because they can take up water and nutrients from an existing root system while seedings must develop a new root system. Sprouting plants may rapidly develop a crown that can shade out other plants or limit their growth. Natural regeneration of shrubs may severely limit growth of naturally occurring or planted conifers because of competition for light or moisture (Stein 1986). Grass seeded for postfire erosion control in forested areas may overtop conifer seedlings. In chaparral areas they may compete with sprouts and seedlings of native plants

(Barro and Conard 1987). Litter from seeded grasses may also increase the flammability of the site to much higher levels than would occur if only native vegetation recovered on the site (Cohen 1986 as cited in Barro and Conard 1987). A second fire after a short-term interval might kill all seedlings of native species before they have produced much seed. Therefore, numbers and vigor of native plants would be further reduced. Cheatgrass seedlings can grow roots at much cooler soil temperatures than many native perennial grass seedlings and use up soil moisture in the spring before other species get their roots down into the soil profile (Thill et al. 1984).

On sites that are not burned, some species may have a competitive advantage. For example, junipers can take up increasing amounts of soil water in sagebrush/grass communities they have invaded and eventually exclude most other species because of moisture limitations. Grass production tends to decrease as sagebrush cover increases, again because of competition for water. Young stands of conifers that develop in the absence of fire beneath mature overstories of ponderosa pine compete with the mature trees for moisture and nutrients, weakening them and making them susceptible to insects and disease. Depending upon the site, prescribed fire or fire in combination with other treatments is the most efficient and ecologicaly sound way to manage these plant communities.

If burning occurs in close association with heavy use of the plant community by livestock or wildlife, either before or after the burn, plant recovery may be delayed or prevented because heavy prefire use may deplete plant carbohydrate reserves. Heavy postfire use of perennial plants in the first growing season after a fire is likely to cause the most harm, particularly in arid and semi-arid range communities (Trlica 1977). Livestock and wildlife are often attracted to burned areas because of increased palatability, availability, and the earlier spring greenup that often occurs on burned rangelands and grasslands. Depending on the plant community and its production capabilities, some use after the first full growing season may not have a negative effect, and indeed may be desirable, as in tobosagraaa communities. In most cases, however, two full growing seasons of postfire rest are necessary before plants can sustain much utilization (Wright and Bailey 1982). A longer recovery period is necessary if weather has been unfavorable for growth or if establishment of plants from seeds is required to completely revegetate the site. Desert plants required more than 7 years of recovery after moderate defoliation (Cook and Child 1971, as cited in Trlica 1977), and some shrubland sites may require this long a period pf postfire rest if recovery of browse species is desired.

For some plant communities in poor condition or dominated by undesired species, it may be necessary to artificially reseed the area after burning because natural revegetation by desired species is unlikely to occur. Tradeoffs are made in prescribed burning. Short-term undesirable effects on preferred species have to be accepted to obtain the desired results on target species. If undesirable species that respond positively to prescribed fire are present on the site, it may be possible to choose a prescription for burning that will favor other species. In some situations, a better choice may be to avoid burning that site and select another treatment method that will produce optimal desired effects.

The observed responses of plants to burning are dependent upon the above factors and other localized conditions in each of the impact analysis areas. Because these factors determine the outcome of a particular prescribed burn, onsite management decisions can alter fire effects to meet specific goals. In general, prescribed fires are planned with specific goals and conducted under constraints to ensure that the fire is contained, that fire and resource objectives are met, and that long-term site productivity is maintained or enhanced.

A particular plant species may or may not be considered desirable on a treatment site, depending on the specific objective of the treatment. For example, less sagebrush would be desired on a site where the objective was to improve elk summer range than if the objective were to improve sage grouse habitat. The following discussion of fire effects by vegetation analysis region reflects this idea in that it describes the effects of fire on particular species without giving a qualitative judgment of whether a plant is desirable. That determination will be made on a site-specific level according to the individual goals of the management plan. The fire ecology of rangeland is discussed in greater detail in Appendix F.

Sagebrush

The effect of fire on grasses in the sagebrush analysis region depends upon the growth form and how season of burning influences soil moisture and other environmental and prescribed burning conditions. Many of the dominant grass species of the sagebrush analysis region are fairly fire resistant and can produce new shoot growth even after moderate-to-high-severity burns.

When desirable understory plants are present within the sagebrush community, prescribed fire can release these species. Spring or fall fires are most desirable and effective because the soils are moist and cool, and the burning is more selective. Sprouting shrubs such as bitterbrush, mountain snowberry, and gamble oak respond favorably, and perennial grasses are benefited. Burning can be used to increase edge effect and increase plant diversity (Bowns 1990).

Repeated or early summer burning reduces perennial grasses and may allow cheatgrass to invade and maintain populations (Wright and Bailey 1982). Bunchgrasses that contain dense plant material in their bases are more damaged than coarse-stemmed and rhizomatous species (Wright and Bailey 1982). Needle-and-thread grass, Thruber needlegrass, and Idaho fescue are the dominant grasses that are most easily harmed by fire in this analysis region (Tirmenstein 1987a, Tirmenstein 1987b, Bradley 1986c). All of these plants have an accumulation of dense culms at their base that tend to concentrate heat if the fire occurs during a dry period, although Thurber needlegrass has somewhat less density of basal fuel. Large diameter bunches of these three species have all been reported to sustain more damage from fire than smaller diameter bunches. Both needlegrass species have been observed to reproduce from seed after fires. The greated amount of damage to these plants occurs either if they are burned when actively growing or have green tissue; when they are more sensitive to fire temperatures; or when basal material is very dry, can ignite and smolder, and can concentrate heat. Prescribed fires with an objective of enhancing or maintaining grasses would not be scheduled when key species are more sensitive to fire. Bunchgrass plants that survive a fire can return to preburn coverage and production within 2 years (West and Hassan 1985), but the recovery time may be shorter or much longer, depending on the amount of damage sustained by the plant, its recovery potential, site productivity, postfire weather, and postfire animal use.

Big sagebrush and other nonsprouting shrubs are almost always killed by fires and may take decades to recover preburn status in the community (Harniss and Murray 1973). The rate of reestablishment depends on the size of the area burned, postfire grazing management practices, and the subspecies of sagebrush. For example, silver sagebrush plants resprout vigorously after spring burning but may suffer extensive mortality after fall burning (White and Cusive 1983). Big sagebrush is a valuable forage plant on critical deer winter range and should be protected from fire in these areas (Vallentine 1980). Examples of desirable forage shrubs in the sagebrush region that are damaged by fire are curlleaf mountain mahogany and cliffrose. Target sprouting shrubs, such as greasewood, may be top-killed by fire but will resprout as soon as conditions are favorable (Blaisdell 1953, Britton and Ralphs 1978). Bitterbrush is a species of special interest because it has valuable forage and browse qualities. It reproduces from seed and by resprouting. Because bitterbrush plants die of old age, fire seems to be necessary for maintenance of the species, even though mortality of plants during any fire may be high. Mortality is minimized by burning when soils are moist, either in the spring or late in the fall after plants have become dormant and rain has fallen. Mortality is highest when fuel consumption is high.

Perennial forbs generally respond better to burning than do bunchgrasses (Britton and Ralphs 1978), probably because their growing points are protected by soil layers to a greater extent than are grasses. Fall burning does not harm most forbs because many of them are dry and disintegrated by that time (Wright 1985). However, forbs that are still green are still very susceptible to fall fires (Wright 1985), as are forbs such as some of the Antennaria spp. and Phlox spp. (Pechanec and Stewart 1944) that have growth points at the surface. Perennial forbs can recover from summer burning in 1 year (West and Hassan 1985). Balsamroot has been observed to respond very well to even a summer wildfire after drought conditions, because it sprouts each year from well below the soil surface (Miller 1987).

Desert Shrub

Vegetation manipulation treatments are not often practiced on salt desert shrub, blackbrush, or Mohave and Sonoran Desert shrublands (Jordan 1981), and those attempted have had limited success. Fire frequency in these vegetation types is historically low. However, wildfire incidence has increased in some of these areas because of the presence of exotic annual grasses (Lotan and Lyon 1981, Patten and Cave 1984). Many areas of the Mohave and Sonoran Deserts are too dry in most years to produce enough fuel to carry a fire. Fires occur in the Sonoran Desert northeast of Phoenix only after 2 years of above average precipitation that encourages growth of annuals (Rogers and Vint 1987). Creosotebush communities rarely burn because of low herbaceous cover (Sampson and Jesperson 1963, as cited in Korthuis 1988b).

Many shrubs, trees, and cacti of the hot desert can be severely affected by burning because they are not adapted to fire. Paloverde, burroweed, bursage, broom snakeweed, ocotillo, and creosotebush are examples of desert species that can suffer high mortality rates from burning (Wright and Bailey 1982), although higher mortality rates seem associated with fires that occur under more extreme burning conditions. Creosotebush susceptibility to fire is apparently highest in June, and it has been reported to sprout after fires during other times of the year. Large numbers of triangleleaf bursage seedlings have been reported after fires in Arizona (Rogers and Steele 1980, as cited in Korthuis 1988a), and broom snakeweed can rapidly reestablish from light, wind-dispersed seed after a fire (Young 1983, as cited in Tirmenstein 1987c).

The following species occur in both Mohave desert and cold desert shrub types. Shadscale, fourwing saltbush (Wright 1980), black greasewood

(Young 1983, as cited in Tirmenstein 1987d), and winterfat (Dwyer and Pieper 1967) have been reported to resprout vigorously after a fire, although August and September wildfire in southwest Idaho killed 95 to 100 percent of winterfat plants (Pellant and Reichert, as cited in Holifield 1987a). These southwest Idaho shrub communities may be somewhat atypical of winterfat communities because they are so far north in their distribution. Cool-season grasses predominate, summer precipitation is rare, and grasses are usually dormant for long periods of the summer, and are thus flammable, compared to warm-season dominated communities to the south where greenup is maintained or occurs intermittently all summer in response to showers (M. Pellant, pers. comm. 1989). Winterfat is reported to have good tolerance for fire when dormant (Wasser 1982, as cited in Holifield 1987a). Fourwing saltbrush has also been reestablished successfully from seed after a fire in central Utah (Clary and Tiedemann 1984, as cited in Tirmenstein 1986a). Spiny hopsage, a resident of both hot and cold deserts, generally resprouts after being burned and is least susceptible to fire during summer dormancy (Rickard and McShane 1984, as cited in Holifield 1987c).

Southwestern Shrubsteppe

The most common use of fire in southwestern shrubsteppe areas is to control woody species, such as snakeweed, burroweed, creosotebush, and especially velvet mesquite. While high kills of velvet mesquite are rare (Wright and Bailey 1982), the species is moderately affected by fire, depending upon plant size and fuel load near the plant (Cable 1965). Most small mesquite plants can be top-killed; resprouting occurs and only periodic burning can maintain a grassland aspect (Martin 1983). Low shrubs, such as false mesquite, are only moderately affected by fire and can increase after burning (Reynolds and Bohning 1956). Ocotillo, Wheeler sotol, larchleaf goldenrod, and paloverde can be severely damaged by fire (Wright and Bailey 1982). Additionally, many cactus species are susceptible to fire damage (Cable 1965, Wright and Bailey 1982, Martin 1983).

In general, perennial grasses are mildly to severely harmed by fires during dry years but quickly recover during wet years (Wright and Bailey 1982). Burning may stimulate seedling emergence in some species (Ruyle et al. 1988). Fire has the greatest benefit to tobosa, big sacaton, and alkali sacaton ranges. Of the dormant perennial grasses, black grama is most seriously affected by burning because it is a stoloniferous grass with growing points right at or near the surface. Postfire recovery is slow and is hindered by postfire drought (Canfield 1939, Reynolds and Bohning 1956). If a postfire drought period is confounded by moderate grazing, black grama may never achieve preburn status in a community (Canfield 1939). In areas where annual precipitation is higher, black grama is not excessively damaged even by hot summer fires (Wright and Bailey 1982).

Chaparral-Mountain Shrub

The ecological effects of fire in chaparral communities are complex because of the diversity of this community type. Chaparral shrub species are highly flammable because of their high surface area-to-volume ratio, high fuel bed porosity, and high leaf oil content (Lotan and Lyon 1981). They may sprout, reproduce from seed, or both; but without fire, nonsprouting shrubs will be greatly reduced in the community (Keeley and Zedler 1978). Chaparral stands grow rapidly after fire and take about 25 years to mature and senesce (Lotan and Lyon 1981).

Fire can be a good tool for thinning dense chaparral and encouraging palatable nonsprouting species. Nonsprouting species, like point leaf manzanita, cliffrose, and desert ceanothus, maintain themselves by prolific seedling growth following burns (Keely and Zedler 1978). Scrub oak, leather oak, and mountain mahogany are sprouting species that are enhanced by burning (Keeley and Zedler 1978, Wright and Bailey 1982).

Shrub live oak (turbinella oak) is the dominant species in many stands of Arizona chaparral, resprouts vigorously from root crowns after most fires (Davis and Pase 1977, as cited in Tirmenstein 1988a), and can also sprout from adventitious buds on its roots. Fuels are frequently limited in shrub live oak communities, and it is difficult to make a fire carry through a stand (Pond and Cable, as cited in Tiemenstein 1988). Scrub oak, western and hairy mountain mahogany, and leather oak are sprouting species that are enhanced by burning (Keeley and Zedler 1978, Wright and Bailey 1982).

Although grasses and forbs are not abundant in chaparral stands, annual forbs and grasses are enhanced the first year after a fire (Wright and Bailey 1982). Perennial forbs, such as brodea and lilies, are also common after burns (Wright and Bailey 1982).

The dominant plant of the mountain shrub community is Gambel oak, which can resprout vigorously after fire, both from lignotubers and from rhizomes. However, wildfire can greatly decrease vigor and growth of postfire sprouts where considerable amounts of soil heating occur. In some areas where fires have burned with less severity, indicated by the presence of residual stem bases, shrubs sprout vigorously, reaching heights of 6 feet in 6 years (T. Zimmerman, pers. comm. 1989).

A major objective for burning mountain-shrub communities is to resize them, making browse more palatable for wildlife, and increasing accessibility by reducing shrub thickets. Wright and Bailey (1982) cite several authors who feel that oakbrush communities should not be burned because herbage yield and species composition are not improved unless they are artificially seeded. Sites burned in west central Colorado not only have vigorous resprouts after August prescribed fires, but also have shown excellent recovery of elk sedge (T. Zimmerman, pers. comm. 1989). While some of the species of mountain shrub communities might be harmed by fires that occur under extremely dry conditions, most prescribed fires would be designed to enhance sprouting or establishment of new individuals from seed.

Pinyon-Juniper

Mature stands of pinyon and juniper are frequently too open or contain insufficient herbaceous fuel to carry a fire (Lotan and Lyon 1981). However burning can easily kill pinyon species and nonsprouting juniper, especially trees less than 4 feet tall (Dwyer and Pieper 1967). Larger trees require heavy amounts of fire fuel within their canopy coverage to crownkilled (Jameson 1962). Where understories include sagebrush, large pinyon and juniper trees can be killed by fire (Bruner and Klebenow 1978).

Postfire recovery of five of the six species of pinyon and juniper after fire is dependent upon seed reproduction, and thus the rate of reinvasion depends on distance to seed source, the size of the burned area, and the presence of dispersal agents. Pinyons and junipers do not produce seed until they are about 20 to 30 years old.

Older trees generally become more fire resistant as bark thickens and the crown becomes more open, and may be able to survive low intensity fires. It is difficult to kill trees in fairly closed stands of pinyon-juniper because there is little live or dead fuel on the surface, and a prescribed fire will not carry unless there are extremely high winds, a situation in which risk of fire escape is high. A normal treatment in pinyon-juniper stands is to chain or manually cut the trees, leave the slash scattered, wait several years for grasses and shrubs to recover, and then burn the site. This removes most of the dead fuel, greatly reduces the fire hazard, and kills any residual or newly germinated pinyon and juniper trees. If a site is mechanically or manually treated only, it will probably have enhanced forage and browse production for about 20 years. Prescribed burning of the site about 3 to 5 years after treatment, once an understory has established, will maintain the productive character of the site for about 50 years (West 1979, as cited in Tiemenstein 1986b, Wright et al. 1979, as cited in McMurray 1986b). Understory recovery in pinyon stands is very closely related to the type and number of residual plants on the site (McMurray 1986b, McMurray 1986c). If tree dominance has seriously depleted remnant shrub, forb, and grass plants, and the soil seed reserve, the site will have to be artificially reseeded after fire (McMurray 1986b), particularly in areas where invasion by annual grasses is possible. If high rates of forage utilization (which reduce fuels) and fire exclusion continue to be practiced on sites invaded by pinyon juniper, tree density will continue to increase, and pinyon and juniper will continue to expand onto shrub- and grass-dominated sites (Burkhardt and Tisdale 1976). An active management program that includes prescribed fire will be necessary to reduce the amount of tree encroachment and maintain the character and productivity of the original plant community.

Sprouting shrubs, such as western serviceberry, true mountain mahogany, chokecherry, winterfat, fourwing saltbush, rabbitbrush, and horsebrush, may regrow quickly postburn (Wright et al. 1979), while shrubs such as bitterbrush, broom snakeweed, and curlleaf mountain mahogany may or may not resprout, depending upon fire and postfire conditions. Cliffrose may be completely eliminated. Alligator and redberry juniper are sprouting junipers that can be killed by fire (Wright and Bailey 1982).

Burning grass results in responses similar to those seen in sagebrush-grass communities. Large bunchgrasses are more affected than small grasses with coarse stems, and rhizomatous species tolerate fire well (Everett 1987a). Perennial forbs are usually only slightly damaged by fire, except those mat-forming species such as Antennaria spp. (Wright and Bailey 1982, Everett 1987a). Cheatgrass may increase after burning in these communities (Wright and Bailey 1982) if it is present in the stand or in the area before burning, if few residual native bunchgrass plants remain on the site, or if good postfire grazing management practices are not followed. If bunchgrass communities are in good condition when the site is treated, cheatgrass may persist for only a few years. On site sites, cheatgrass never appears (Klebenow et al. 1976).

Plains Grassland

Prairie shortgrasses are generally harmed by fires during dry years. Buffalograss, annual bluegrass, and western wheatgrass may take 3 or more years to recover (Wright and Bailey 1982). During years with above normal spring precipitation, these grass species can tolerate fire with no herbage yield reduction following the first growing season (Wright 1974a). Red threeawn, sand dropseed, Muhlenbergia spp., wolftail, and galleta are all harmed by fire during dry years but tolerate it better during wet years (Dwyer and Pieper 1967, Wright 1974a). Burning usually increases production of sand bluestem and switchgrass but decreases little bluestem production where these grasses occur (Wright and Bailey 1982).

Important mixed prairie grasses include tobosagrass (effects described in southwestern shrub-steppe), green needlegrass, sideoats grama, prairie sandreed (reedgrass), and sand dropseed. Green needlegrass is similar to other needlegrasses in that it is fairly sensitive to fire, although the effect can be moderated by burning conditions and site characteristics. Green needlegrass is more negatively affected if a fire occurs when soils are dry or where plants are large in diameter and have more fuel (Wright and Klemmedson 1965, as cited in Tirmenstein 1987e). Sideoats grama is most seriously damaged by fire during very dry years and is tolerant of fire during exceptionally wet years (Wright and Bailey 1980), or when it is dormant (Wasser 1982, as cited in Tirmenstein 1987f). Prairie sandreed is a strongly rhizomatous grass that is fire tolerant when dormant and revegetates a burned area with new shoots from rhizomes. It has responded more favorably to spring fires than to fall fires, which reduced it significantly (Lyon and Stickney 1976, as cited in Uchytil 1988). Vine mesquite and Arizona cottontop do well after fire during periods of good soil moisture (Box et al. 1967, Wink and Wright 1973).

The tolerance of forbs to burning depends upon the timing of the fire relative to active plant growth (Wright and Bailey 1982). Those forbs that start growing after the burning season are least affected, because they have the entire growing season to recover from any injury that the fire may have caused.

Important species of shrubs not previously mentioned are honey mesquite, sand shinnery oak, cholla, and several species of sumac. Honey mesquite, with its exceptional ability to resprout, is almost impossible to kill by burning after it is about 1 foot tall, and even the seedlings are fairly fire tolerant (Wright et al. 1976, as cited in Wright and Bailey 1982). Sand shinnery oak sprouts prolifically after fire, and density of stems has been reported to increase 15 percent after burning (McIlvain and Armstrong 1966, as cited in Wright and Bailey 1982). Young cholla plants can be killed by fire, but those taller than 1 foot were hardly damaged by burning in New Mexico, probably because the short grasses could not generate long enough flames to damage the upper part of the plants (Dwyer and Pieper 1967, Heirman and Wright 1973, both as cited in Wright and Bailey 1982).

Mountain/Plateau Grassland

The effect of fire upon many of the dominant shrubs and grasses in the mountain/plateau grasslands analysis region was discussed in some detail in the section on the sagebrush analysis region. Species covered in that section include big sagebrush, rabbitbrush, horsebrush, western wheatgrass, bluebunch wheatgrass, Idaho fescue, and needle-and-thread areas. The literature does not indicate any significant differences in fire effects for these species that are characteristically related to analysis region, so the information will not be repeated here.

Other important shrubs of the mountain/plateau grasslands include silver sagebrush, fringed sagebrush, shrubby cinquefoil, and prickly pear cactus. Plains and mountain silver sagebrush are an exception to most sagebrush species because they are moderately resistant to fire, being able to produce sprouts from roots and rhizomes. Sprouting decreases as fire severity and heat penetration into the soil increases, particularly after fall fires when the soil is dry. Silver sagebrush rapidly regains preburn cover after spring fires, although coverage is decreased significantly after many fall fires (McMurray 1987a, McMurray 1987b). Fringed sagebrush is reported to be a weak sprouter after fire (Wright et al. 1979, as cited in Tirmenstein 1986c), although response to fire is variable. The most beneficial effects were reported after early spring fires (Anderson and Bailey 1980, as cited in Tirmenstein 1986c), and mortality has been reported after both spring and fall fires. Fringed sagebrush is a prolific seed producer, and seed may remain viable for many years and germinate when conditions are favorable. Postfire reproduction from soil-stored seed does occur. A range of responses to fire have been reported for shrubby cinquefoil. The plant has a wide-ranging distribution and likely ecotypic variability that affects its ability to sprout. Whether a particular plant sprouts after a fire apparently relates to site characteristics, season of burn, fire intensity, and burn severity. Cinquefoil has a been observed to produce sprouts from buds on its root crown, rhizomes, and prostrate stems that survived the fire. Survival is most often reported after spring fires. Shrubby cinquefoil can also reestablish through an abundance of wind-dispersed seed (Tirmenstein 1987g). The effect of fire upon prickly pear varies with plant height, stem moisture content, and the amount of associated fuel, because the plant itself will not burn (Humphrey 1974, as cited in Holifield 1987e). It can resprout from any surviving root crowns and by adventitious rooting of remaining pad (Holifield 1987e). Postfire death of prickly pear is often caused by postfire damage by insects, rodents, rabbits, and livestock, or by dehydration (Holifield 1987e).

Important native grasses of the mountain/plateau grasslands that have not been previously discussed include rough fescue, oatgrasses, and mountain brome. Rough fescue is a large-diameter, coarse-stemmed bunchgrass that seems well adapted to periodic burning. It is susceptible to damage from fires during hot dry weather, although it has benefited from spring sand fall prescribed fires. In areas where it has not been grazed or burned for many years, accumulations of litter may ignite and smolder for a long time after a flaming front has passed, causing significant basal bud mortality. Fescue is also particularly sensitive to burning during the activate growing season (Sinton 1980 in McMurray 1987e). Antos et al. (1983, as cited in McMurray 1987e) suggest that the most beneficial fire frequencies for rough fescue are about every 5 to 10 years. Little information is available about the response of oatgrasses to fire, although other oatgrass species in the Pacific Northwest are reported to be moderately resistant to fire. One-spike oatgrass, a densely tufted to matted perennial bunchgrass, was reported to increase in basal cover after two spring prescribed fires in southwest Montana (Nimir and Payne 1978). Mountain brome, a short-lived perennial bunchgrass with shallow roots regained 76 percent of its preburn cover within 12 weeks, compared to a control, after one of those same spring fires studied by Nimir and Payne.

The native grass species of the Palouse grasslands of eastern Washington and Oregon and northern Idaho include bluebunch wheatgrass, Idaho fescue, and Sandberg bluegrass. They have been replaced in many locations by introduced exotics, including Kentucky bluegrass, cheatgrass, medusahead, and other bromes. Severe summer fires can kill bluebunch wheatgrass and Idaho fescue in this area, although cover of these plants was not affected by cool fires (Daubenmire 1970). Cheatgrass will continue to expand at the expense of native perennials because it is so widely established and so highly flammable. It will burn when native perennials are still actively growing and much more sensitive to fire heating. Medusahead is a highly flammable exotic annual that is capable of replacing cheatgrass in many areas, particularly where soils have high clay content. It can be somewhat controlled with fire if it is burned after it is cured but before seeds are dispersed from the stalk. Many of the seeds are destroyed, and fewer seedlings will germinate. Medusahead will then offer less competition to the seedlings of seeded grasses that are usually sown on these sites after burning (Ahlenslager 1987b).

Coniferous/Deciduous Forests

Prescribed burning can be an effective management tool in forested vegetative communities in the West. Fire is used to reduce surface fuels on clearcuts as well as in the understories of fire resistant trees; to remove understory reproduction in ponderosa pine, Douglas-fir, and western larch forests, which provide a fuel ladder to the overstory; to thin overstocked stands of trees; to prune lower branches from trees; to create seedbed; to reduce vegetative competition with naturally regenerated or planted conifers; to enhance forage values; to maintain and improve browse quality and quantity; and to rejuvenate old stands of deciduous trees.

Understory burning at planned intervals is the best way to manage sites with ponderosa pine, Douglas fir, and western larch the dominant tree species. If all fires are excluded from these forests types, which historically had high frequencies of understory fire, the eventual result can be the weakening of the stand, an increase in activity of bark beetles, and an increase in the proportion of dead trees. Fuels and/or bug-killed trees lead to stand-destroying fires. Many acres in the West have had fire excluded for 50 to 75 years, and some of the fires in recent years are likely a result of the accumulation of fuels and insect activity.

Slash from thinning and selective logging can be burned to reduce fire hazard without harming the residual trees in these communities. Ponderosa pine is generally not clearcut, but clearcuts in Douglas-fir and western larch are often burned to manage the fuels, prepare seedbed and planting spots, and manage competing plants. Without fire, ponderosa pine and Douglas-fir sometimes invade grasslands, and prescribed fire can be easily used to eliminate these trees when they are young.

Most conifers produce only by seed after a fire, and prescribed fire can produce favorable conditions for nearly all conifers. Burning ponderosa pine forests will increase grasses and top-kill shrubs, such as chokecherry, western serviceberry, and bitterbrush, which will sprout the next year. In general, fire is beneficial to grasses and forbs in ponderosa pine associations but not where shrub understories dominate (Wright and Bailey 1982). Burning of Douglas-fir forests increases shrubs such as snowbush, ceanothus, western serviceberry, common snowberry, and sticky currant. In some Douglas-fir areas, ponderosa pine and quaking aspen may become fire climax species. Although easily killed by surface fires, quaking aspens quickly sprout from roots, making the tree a superior competitor in many Douglas-fir and spruce-fir forests.

The lack of understory herbaceous fuel caused by livestock grazing precludes the occurrence of fire in most aspen stands (Jones and DeByle 1985). Without fire, conifers invade many aspen stands, gradually eliminating the aspen, because aspen sucker replacement is often insufficient to replace overstory aspen mortality (Schier 1975). Aspen communities on sites not suited for conifer establishment may eventually be replaced by grasses and shrubs (Schier 1975). Suckering is prevented by the presence of mature trees as the trees and roots gradually deteriorate. Loss of aspen stands because of this phenomena has been observed in several Western States. A fire that occurs in an aspen stand that is still producing a few suckers, or in a mixed aspen-conifer stand is likely to result in the rejuvenation of the aspen stand. The amount of postfire suckering is enhanced by warmer soil temperatures, which usually occur as a result of the blackened soil surface and reduced thickness of the litter and organic layer (Jones and DeByle 1985). As is true for rangeland sites, an aspen site must be rested from grazing until the community recovers to some degree (Brown and Simmerman 1986). Wildlife use can be regulated to some extent if a large enough burned area is selected, or if several areas in the same general vicinity are burned, thus dispersing use over a greater acreage.

The understories of ponderosa pine, Douglas fir, and western larch communities are all adapted to fire. Some later successional species that may have established because of fire exclusion might not be favored, but the natural shrub, forb, and grass associates of these species would recover by sprouting or from seed stored in the forest soil organic layer (duff) after fire. The exact response varies by fire prescription, season, moisture condition, and plant species, a topic that would be covered in a site-specific environmental assessment.

Slash burning potentially could do more harm to a site than prescribed underburning because of the presence of large amounts of slash on the soil surface. An objective for slashburning may be to kill some of the understory species so that less competition is present for trees that might be planted. Specific ranges of moisture content of large diameter fuels, duff, and soil can be selected for the fire prescription that will have the desired effect on understory vegetation, with consideration given to the effects of burning on the soil. One effect of this treatment, which is perhaps more closely associated with the removal of the forest overstory than of the burning itself, is that plants that require sunlight will do better after the treatment than those that require shade. This change in dominant species, or species present, would persist until the forest overstory again develops to the point where it provides a good cover of shade.

Chemical Methods

Annual plants are generally more sensitive than perennial plants to chemical treatments because they have limited food storage organs and annual plant populations are greatly reduced if plants are killed before producing seed. Perennials are most sensitive when exposed to herbicides during periods of active growth. Exposure to herbicides during active growth and before plants become reproductive also will have the greatest negative effect on populations of many annuals. The ability of annual or perennial plants to maintain viable seeds in the soil for several years reduces their susceptibility to herbicides. Control of some woody plants on some sites may open the community to dominance by annuals (Evans and Young 1985).

Susceptibility of perennial plants to herbicides depends largely on their ability to resprout after aerial shoots are damaged (Table 3-3). Plants that have the ability to resprout after aerial shoot damage are generally least sensitive to herbicides. These plants are damaged most when exposed to herbicides when translocation to meristematic areas and to roots is active (Sosebee 1983). This generally occurs only when soil temperatures are adequate for root activity and soil water is available. These plants are generally less susceptible to foliar-applied herbicides with limited exposure periods, such as 2,4-D, than to soil-active herbicides, such as tebuthiuron, that persist in the soil long enough to be taken up when optimum translocation conditions occur.

Differences in active growth periods and phenology of nontarget and target species that correspond to differences in sensitivity to herbicides can be used to minimize damage to nontarget species. For example, damage to bitterbrush while spraying 2,4-D to control sagebrush can be minimized if spraying is done between the time when new bitterbrush leaves appear and when twig elongation and flowering occurs (Hyder and Sneva 1962).

The greater the similarity of target and nontarget species in a given plant community, the greater the damage to nontarget species during herbicide treatments. Because many broadleaf herbaceous and woody plants are considered target species on many rangelands, herbicides such as 2,4-D and dicamba, which selectively control broadleaf plants, are often used. These herbicides damage grass and grass-like plants very little but may damage nontarget broadleaf forbs and shrubs (Blaisdell et al. 1982). Use of dicamba at a rate greater than 4 pounds acid equivalent/acre (a.e./acre) can damage certain grass species. On the other hand, use of dalapon to control weedy grasses will have little effect on associated broadleaf plants but may damage nontarget perennial grasses.

Response of nontarget species to broad-spectrum herbicides, such as glyphosate and tebuthiuron, may be highly dependent on the rate of application. Damage to nontarget species is minimized if they are tolerant of these herbicides applied at rates sufficient to kill target species. For example, picloram applied at rates sufficient to kill rabbitbrush may initially reduce growth of associated perennial grasses, but grass production may eventually increase as shrubs die and grasses recover (Tueller and Evans 1969).

Plants may vary greatly in their sensitivity to different herbicides (Sosebee 1983). Effectiveness of herbicides may vary with different climatic and soil

Table 3-3

General Description of Vegetation Susceptibility to Herbicides

Herbicide	Selectivity and Vegetation Susceptibility
Amitrole	Use is no longer proposed. BLM has reexamined the risk assessment and examined additional data. BLM has determined that amitrole is no longer considered for proposed use in this document. Amitrole will be deleted in the Record of Decision.
Atrazine	Selective. Broadleaf and grassy weeds are susceptible.
Bromacil	Nonselective. Annual and perennial grasses, broadleaf weeds, and some woody species are susceptible.
Chlorsulfuron	Selective. Most broadleaf weeds and some annual grassy weeds are susceptible.
Clopyralid	Selective. Many broadleaf annual and perennial weeds and woody plants are susceptible.
2,4-D	Selective. Broadleaf weeds and dicots are susceptible.
Dalapon	Since drafting this document, producers are no longer manufacturing formulations registered for proposed use. Therefore, dalapon is no longer considered for use.
Dicamba	Selective. Annual and perennial broadleaf weeds, brush, and vines are susceptible.
Diuron	Selective at low rates, nonselective at higher rates. At low rates, germinating broadleaf and grass weeds are susceptible. At higher rates, most plants are susceptible.
Glyphosate	Nonselective. Most plants are susceptible.
Hexazinone	Nonselective. Annual and biennial weeds, woody vines, and most perennial weeds and grasses are susceptible.
Imazapyr	Nonselective. Annual and perennial weeds, deciduous trees, vines, and brambles are susceptible.
Melfluidide	Nonselective. Suppresses vegetative and seedhead growth in many species.
Metsulfuron Methyl	Nonselective. Broadleaf weeds and annual grassy weeds are susceptible.
Picloram	Nonselective. Most annual and perennial broadleaf weeds and woody plants are susceptible.
Simazine	Selective. Broadleaf and grass weeds are susceptible.
Sulfometuron Methyl	Nonselective. Annual and perennial grasses and broadleaf weeds are susceptible.
Tebuthiuron	Nonselective. Most plants are susceptible.
Triclopyr	Selective. Woody plants, broadleaf weeds, and root-sprouting species are susceptible.

Source: Weed Science Society 1979.

conditions. Soil-applied herbicides are less effective on fine-textured soils relative to coarse-textured soils, because herbicide molecules may be adsorbed to clay colloids. Response of nontarget plant species to herbicides depends not only on their susceptibility to the herbicide directly, but also on their response to a decrease of target plant species in the community. The herbicides proposed for prescribed burning pretreatment, sagebrush control, and saltcedar eradication are selective, yielding no adverse effects on grasses. Proposed treatments to saltcedar are limited to hand treatment of cut stumps with picloram or triclopyr herbicides applied by paint brush. Picloram used in saltcedar eradication programs may kill or damage interspersed nontarget trees through translocation from saltcedar roots to soil to other roots. Vegetation removal needs (for example, rights-of-way, pipelines, drilling pads, and administrative sites) would be accomplished with broad spectrum, nonselective herbicides that would affect most perennial plants, annuals, and biennial grasses, sedges, rushes, and broadleaf plants. Maximum weed control measures may require either selective or nonselective chemicals, depending upon individual situations.

Sagebrush

In the sagebrush analysis region, herbicides are used to control woody plants, such as species of sagebrush and rabbitbrush, as well as herbaceous weeds, such as cheatgrass and medusahead, (Evans et al. 1979). This discussion will consider effects of herbicides commonly used on grasses, shrubs, and forbs.

Herbicides have been most commonly applied to sagebrush rangelands to control species of sagebrush and rabbitbrush and to increase production of perennial grasses (Blaisdell et al. 1982). When desirable understory plants are present within the sagebrush community, prescribed fire can release these species. Chemicals can be used for the initial treatment or to maintain the stand once sagebrush density increases or it invades the stand. Because it selectively injures broadleaf plants, but not grass or grass-like plants, 2,4-D has most frequently been used to reduce woody species and increase production of native grass stands and to renovate seeded grass ranges (Table 3-4). When 2,4-D is applied in the spring when temperatures and soil water are conducive to active growth, sagebrush mortality is high and grass production is increased (Alley 1956, Fisser 1968, Tabler 1968, Sturges 1973, and Evans et al. 1979).

Table 3-4

Mortality of Forbs on Areas Sprayed With 2,4-D to Control Big Sagebrush

Species	Mortality
Achillea millefolium	Unharmed
Agastache urticifolia	Light
Agoseris ssp.	Moderate
Antennaria microphylla	Light
Aplopappus sp.	Unharmed
Arenaria congesta	Unharmed
Arnica fulgens	Light
Aster foliaceus	Unharmed
Aster scopulorum	Moderate
Astragalus convallarius	Unharmed
Astragalus miser praeteritus	Unharmed
Astragalus salinus	Unharmed
Astragalus stenophyllus	Heavy
Balsamorhiza sagittata	Heavy
Calochortus macrocarpus	Unharmed
Castilleja spp.	Heavy
Comandra umbellata	Light
Crepis acuminata	Unharmed
Delphinium depauperatum	Unharmed
Delphinium glaucescens	Unharmed
Erigeron corymbosus	Light
Eriogonum heracleoides	Light
Eriogonum ovalifolium	Unharmed
Galium boreale	Unharmed
Geum triflorum	Heavy
Geranium viscossissimum	Unharmed
Helianthella uniflora	Heavy
Linum lewisii	Unharmed
Lithospermum ruderale	Moderate
Lupinus caudatus	Heavy
Lupinus laxiflorus	Heavy
Lupinus leucophyllus	Moderate
Lupinus sericeus	Heavy
Mertensia oblongifolia	Heavy
Opuntia polyacantha	Unharmed
Penstemon radicosus	Light
Penstemon spp.	Heavy
Perideridia gairdneri	Unharmed
Phlox canescens	Light
Potentilla gracilis	Heavy
Potentilla spp.	Heavy
Rumex sp.	Unharmed
Senecio integerriumus	Light
Solidago sp.	Unharmed
Trifolium macrocephalum	Heavy
Viola spp.	Unharmed
Zigadenus paniculatus	Heavy

Note: Ratings: unharmed; light, 1 to 33 percent kill; moderate, 34 to 66 percent kill; heavy, 67 to 100 percent kill.

Source: Blaisdell et al. 1982

If understory grasses are lacking, if site potential is low, and if shrub mortality is limited, grass production response to 2,4-D is also limited but is not decreased by spraying. Ineffective control of sagebrush and rabbitbrush usually results in redominance by these species (Johnson and Payne 1968). Where perennial grasses are lacking, controlling sagebrush with 2,4-D and revegetating with adapted grasses greatly increase grass production (Evans et al. 1986). Sites dominated by low sagebrush species have lower potential for grass production after sagebrush control than sites dominated by big sagebrush

(Evans et al. 1979). This productive potential may be too low to justify treatment in many cases (Blaisdell et al. 1982). Even though 2,4-D may injure grass seedlings the first year it is applied (Baker 1958, Klomp and Hull 1968a), this is generally not a problem. Established grasses are tolerant of 2,4-D and should produce increased seed crops for seedling establishment in subsequent years when 2,4-D is no longer present in the environment.

In contrast to perennial grasses, broadleaf shrubs and forbs may be sensitive to 2,4-D atrates applied to kill sagebrush (up to 3 lb a.e./acre). Certain important forage species of forbs, such as arrowleaf balsamroot and milkvetch, are damaged by 2,4-D, while others, such as hawksbeard and geranium, are not. Treatment of sagebrush communities that have high forb density could greatly reduce their production and change the community's relative composition. Blaisdell et al. (1982) emphasize the importance of carefully considering species composition of mixed sagebrush communities before treatment with 2,4-D. Although desirable grasses would be increased, some desirable forbs and shrubs may be reduced.

Picloram (0.5 lb a.e./acre) is often mixed with 2,4-D to increase control of rabbitbrush while controlling sagebrush (Evans et al. 1979).

Picloram may be active in the soil for a few years after application and is potentially more damaging to perennial grasses than 2,4-D alone. Picloram (0.25 to 0.5 lb a.e./acre) decreased production of wheatgrass the first 2 years after its application, but control of sagebrush and rabbitbrush and grass recovery resulted in increased grass production after that time (Tueller and Evans 1969). Picloram (0.5 and 1.5 lb a.e./acre) decreased stands of smooth brome but not intermediate wheatgrass (McCarty 1979). In that study, application rates of picloram (0.25 to 1 lb a.e./acre) recommended to control musk thistle did not reduce nutritional quality of these grasses. Most perennial grasses are more tolerant of picloram than many shrubs and forbs (Vallentine 1980). Application of picloram to control rabbitbrush and forbs in the sagebrush analysis region should be expected to decrease production of shrubs and desired forbs. Picloram may initially decrease production of grasses, but grass production should recover as picloram dissipates.

Tebuthiuron, a broad-spectrum herbicide, has a long period of activity in the soil and may be more effective than 2,4-D in controlling sagebrush. However, tebuthiuron may damage grasses and other desirable plants. In Oregon, tebuthiuron application rates (1.8 lb a.e./acre) sufficient to control sagebrush (more than 90 percent mortality) decreased production of perennial grasses 2 years after application (Britton and Sneva 1983a). Tebuthiuron (1 lb a.e./acre) caused chloroses but did not reduce cover of perennial grasses, such as western wheatgrass, june grass, and needlegrasses, in Wyoming (Whitson and Alley 1984). In that study, blue grama, cheatgrass, and prickly pear were tolerant of tebuthiuron at rates of up to 1 lb a.e./acre. On sagebrush and horsebrush sites in Idaho, grass production increased and stayed the same, respectively, after tebuthiuron (0.5 to 1 lb a.e./acre) application (Murray 1988). Initial decreases in perennial grass production should probably be expected after most tebuthiuron applications. Application of high rates of tebuthiuron (1 lb a.e./acre) may decrease perennial grasses and allow annual grasses, as well as rabbitbrush, which is tolerant of tebuthiuron, to increase (Clary et al. 1985).

Tebuthiuron may damage and reduce production of desirable and undesirable shrubs associated with sagebrush. Woody, succulent, and herbaceous species vary in their sensitivity to tebuthiuron; and tebuthiuron is less effective on clayey than on sandy soils because of its soil adsorptivity. Because of this, additional extensive testing of tebuthiuron is necessary to determine the sensitivity of different species on different sites and more accurately determine vegetation responses to this herbicide. In general, it should be expected that sagebrush would be more damaged than many associated shrubs and grasses at moderate tebuthiuron application rates of 0.5 to 1 lb a.e./acre.

Atrazine is the most often recommended herbicide for chemical fallow of cheatgrass-infested rangelands before revegetation with perennial wheatgrasses (Evans et al. 1969a). Although perennial grass seedlings are sensitive to atrazine (McCarty 1979), the fallow technique allows control of annual grasses, conservation of soil nitrogen and water, and loss of atrazine activity during the fallow year before seeded wheatgrasses emerge. Most broadleaf plants and grasses are sensitive to atrazine. However, injury to these plants is not usually a concern because atrazine treatment of cheatgrass rangelands is usually followed by revegetation with desired species.

Amitrole, bromacil, dalapon, dicamba, and simazine also have been evaluated for cheatgrass control (Canode et al. 1962, Evans et al. 1969b). Although wheatgrass seedlings are tolerant of dicamba (Klomp and Hull 1968b) and dalapon is more injurious to grasses than herbs, most of these herbicides are injurious to perennial grasses and broadleaf plants. Their application on sagebrush rangelands would generally reduce annual forbs and grasses and injure perennial grasses and forbs. Their use would usually be followed by revegetation, as is the case with atrazine.

Treatment of medusahead communities with dalapon or diuron may result in dominance of cheatgrass (Evans et al. 1969b, Young and Evans 1972).

Cheatgrass is less desirable than perennial grasses but more desirable than medusahead. Herbicide treatments to control medusahead are most often followed by revegetation with perennial wheatgrasses (Young et al. 1969).

Desert Shrub

Although many desert shrublands may be dominated by undesirable species, vegetation manipulation by plant control and revegetation is difficult (Jordan 1981, Blaisdell and Holmgren 1984) (see discussion on effects of mechanical treatments). Control of dominant woody species must be followed by revegetation with desirable plants. Revegetation is usually unsuccessful on these shrublands because of the low and erratic precipitation. Treatment with herbicides would generally be expected to reduce plant cover and increase wind erosion. Soil-applied herbicides may persist many years in the Mohave Desert and retard plant reestablishment (Hunter et al. 1978).

Southwestern Shrubsteppe

Herbicides are mainly used to control woody species, such as mesquite, creosotebush, and snakeweed, in the southwest grassland (Martin 1975, McDaniel 1984). When these plants are successfully controlled, production of herbaceous vegetation may greatly increase (Cable 1976, McDaniel et al. 1982, Gibbens et al. 1987). Application of phenoxy herbicides, such as 2,4-D, to mesquite causes minimal damage to associated plants, which are generally not actively growing in late spring when these foliar-applied herbicides are most damaging to mesquite (Martin 1975). However, more recently developed herbicides, such as picloram, tebuthiuron, and dicamba, are more effective than 2,4-D in controlling many southwestern woody plants.

Picloram is recommended for controlling snakeweed (0.5 to 1 lb a.e./acre) (McDaniel 1984), and it moderately controls creosotebush and whitethorn acacia (up to 1 lb a.e./acre) (Schmutz 1967) and is more damaging to prickly pear (2 to 4 lb a.e./acre) than dicamba (2 to 4 lb a.e./acre) (Wicks et al. 1969). Picloram (0.5 to 1 lb a.e./acre) may damage desirable shrubs, such as seedlings of fourwing saltbush (Martin et al. 1970) and mature false mesquite, as well as perennial forbs (Martin and Morton 1980). Treatment of southwestern grasslands with picloram may reduce shrubs and sensitive forbs and grasses but over all should increase grass production.

Tebuthiuron is more effective than other herbicides in controlling creosotebush, and tarbush (Jacoby et al. 1982, Cox et al. 1986, Gibbens et al. 1987). However, tebuthiuron is injurious to many grasses and forbs, especially if applied during active growth (Baur 1976). Tebuthiuron treatments (0.4 lb a.e./acre) in New Mexico reduced woody vegetation and greatly increased perennial grass and annual forb production (Gibbens et al. 1987). Tebuthiuron significantly reduced brush species, including creosotebush, tarbush, wolfberry, fourwing saltbush, snakeweed, and mariola. Perennial grass basal areas were initially reduced by treatment, but total grass production of bush muhly, threeawn, bristlegrass, alkali sacaton, spike dropseed, and fluffgrass combined was 11 times greater on the treated than untreated area after 4 years. Perennial forbs, such as desert holly and hairyseed bahia, were decreased slightly by tebuthiuron treatment. Production of annual forbs, mainly desert Baileya, round leaf wildbuckwheat, and Russian thistle, was seven times higher on the treated than untreated area. Tebuthiuron applied at rates from 0.35 to 0.9 lb./acre effectively controlled sand shinnery oak and increased grass production several times (Jones and Petit 1984). Studies in New Mexico show tebuthiuron treatments of shinnery oak at 0.5 lb./acre application rate reduced shinnery oak, increased productivity of grasses, and resulted in a mixed community of grasses, forbs, and oak (Gebel 1987).

Control of creosotebush by tebuthiuron (0.4 to 1.3 lb a.e./acre) allowed seeded grasses to persist and native grasses to increase on sites in Arizona and Mexico (Cox et al. 1986). Southwestern grasslands treated with moderate rates of tebuthiuron (less than 1 lb a.e./acre) should generally have decreased woody plant production and increased herbaceous production. Certain sensitive grass, forb, and shrub species would be replaced by more tolerant species. Moderate application rates and strip treatments are recommended to minimize damage to desirable sensitive species. High rates of tebuthiuron (2 to 4 lb a.e./acre) necessary to maximize control of some species, such as mesquite (Meyer and Bovey 1979), could greatly damage understory species. Moderate application rates and strip treatments are recommended to minimize damage to desirable sensitive species.

Dicamba has been used to control undesirable herbaceous and woody species in the Southwest (Halifax and Scifres 1972). Although dicamba (2 and 4 lb a.e./acre) has been reported to injure grasses, such as blue grama and western wheatgrass (Wicks et al. 1969), established grasses usually tolerate it at application rates (0.5 to 1 lb a.e./acre) used to control rangeland brush and weeds (Halifax and Scifres 1972).

In summary, many species are sensitive to the rates and types of herbicides that are effective in controlling woody plants in the southwestern shrubsteppe. However, herbicidal treatment usually decreases woody plant growth and increases growth of grasses. Herbaceous production usually initially decreases then increases after a few years as woody species die and herbaceous species recover and respond to reduced competition.

Chaparral-Mountain Shrub

Herbicides are used alone or in conjunction with burning, mechanical treatments, and revegetation to decrease the numbers of woody plants and increase herbaceous production in chaparral ranges. Response of shrub live oak and Gambel oak to herbicides has been studied most because these oaks are difficult to kill and dominate many areas (Van Epps 1974, Cable 1975). Most herbicides used to control chaparral shrubs are more damaging to shrubs and forbs than to grasses. These include phenoxy herbicides, such as 2,4-D, and soil- and foliar-applied herbicides, such as bromacil, dicamba, picloram, and triclopyr. When these herbicides effectively defoliate or kill overstory shrubs, grass production may double (Marquiss 1972, 1973). Burning and reseeding followed by phenoxy herbicide treatments greatly reduced oak, manzanita, ceanothus, and other shrubs and increased grass production by 770 lb/acre in Arizona (Tiedemann and Schmutz 1966). Cable (1975) indicates that chaparral areas can produce about 900 lb/acre of native or seeded perennial grasses if crown cover of sprouting shrubs is held to less than 5 to 10 percent by burning and herbicide applications.

Phenoxy herbicides, such as 2,4-D, have generally been less effective than more recently developed herbicides in controlling shrubs. For example, picloram is very effective in killing birch leaf mountain mahogany, sugar sumac, and yellowleaf silktassel (Davis and Pase 1969). Dicamba and picloram used with 2,4-D are highly injurious to menziesia, nine-bark, redstem ceanothus, and willow (Ryber 1970). Some herbicides are more effective in killing the target species and less injurious to the understory species than others. For example, triclopyr (up to 3 lb a.e./acre) controlled Gambel oak better than picloram (up to 1.2 lb a.e./acre) and was much less injurious to understory forbs, such as aster, yarrow, and lupine, in southwestern Colorado (Bartel and Rittenhouse 1979). Picloram and phenoxy herbicide treatments of chaparral should generally be expected to decrease shrub and forb cover and increase grass cover (Van Epps 1974, Kufeld 1977). Picloram treatment of chaparral sites that shed water to valley croplands could injure sensitive crops, such as cotton (Davis and Ingebo 1973). Burning Arizona chaparral 5 weeks after picloram treatment greatly reduced picloram residue but also decreased brush control (Johnsen and Warskow 1980).

Broadcasting bromacil pellets controls chaparral shrubs and causes little damage to understory grasses (Hibbert et al. 1974). Tebuthiuron is more effective than picloram in controlling some species of oak, but it also may be more damaging to understory grasses (Pettit 1974).

In general, herbicide treatments of chaparral will decrease shrub and forb cover and increase grass cover and production. Partial shrub control will result in a return to shrub dominance. High application rates necessary to control some resistant species, such as shrub live oak and Gambel oak, may drastically reduce understory perennials and allow invasion and dominance by annuals. Integrated brush management using fire, herbicides, and revegetation where necessary can convert many chaparral sites to highly productive grasslands.

Pinyon-Juniper

Picloram and tebuthiuron are soil active and are the main herbicides used to treat pinyon and juniper (Johnsen 1987). Different species of juniper vary in their sensitivity to these herbicides, but more species are sensitive to picloram than tebuthiuron. Tree mortality varies with species, site, rate, and type of application (Johnsen 1987). Response of understory species to treatment is dependent on the tree mortality and on the sensitivity of the understory species to the herbicides. Both picloram and tebuthiuron persist in the soil for some years and may injure understory grasses, shrubs, and forbs. Individual tree treatments with these herbicides may be more effective in controlling the trees and less injurious to understory species than broadcast applications (Evans et al. 1975, Johnsen 1987). Evans et al. (1975) discouraged broadcast treatments of picloram because many stands lack sufficient understory species to respond to tree control, and species that are there may be injured by picloram. They recommended spot treating of pinyon-juniper stands with picloram or using picloram as a followup treatment after chaining. They also cautioned that using picloram on some sites could result in dominance by annual grasses, such as cheatgrass or medusahead, because they are resistant to picloram (Evans and Young 1985).

However, Johnsen (1987) notes that picloram applied to individual trees caused little damage to associated understory species and that aerially applied picloram (4 lb a.e./acre) did not damage blue grama or side-oats grama grasses in Arizona. In contrast, tebuthiuron may kill understory grasses and forbs several feet away from individually treated trees. High rates of aerial-applied tebuthiuron (4 lb a.e./acre) killed cool-season grasses in Arizona. However, the lower recommended aerial application rates of both picloram and tebuthiuron (2 lb a.e./acre) resulted in good stands of perennial grass within 5 years on sites that had residual grass stands at treatment.

Plains Grassland

Herbicides are used on plains grasslands to control some woody plants, such as sand sagebrush (Bovey 1964) and fringed sagebrush (Smika et al. 1963), but are mainly used to control noxious herbaceous weeds, which include musk thistle (Roeth 1979), Canadian thistle (Gallagher and Vanden Born 1976), knapweed (Hubbard 1975), ragweed (McCarty and Scifres 1972), and leafy spurge (Bowes and Molberg 1975). Herbicides also are used to help establish forage grasses (Morrow and McCarty 1976). Herbicides most commonly used include 2,4-D, picloram, and dicamba. Bromacil and atrazine may also be used for weed control before seeding perennial grasses. Atrazine may be used to increase protein content and drought tolerance of grasses, such as blue grama (Houston 1977).

Control of broadleaf plants by selective herbicides, such as 2,4-D, usually increases grass production. Application of 2,4-D (2 lb a.e./acre) to mixed prairie decreased broadleaf shrubs and forbs, such as fringed sagebrush, curly cup gumweed, star lily, milkvetch, hairy aster, blue-bells, and evening primrose, and increased some grasses and forbs, such as thickspike wheatgrass, western wheatgrass, and globe mallow (Hyder 1971). Control by 2,4-D (2 lb a.e./acre) of weedy forbs, such as annual saltbush, kochia, and Russian thistle, increased production of needlegrass and wheatgrass (Nichols and McMurphy 1969).

Picloram may damage sensitive grasses as well as broadleaf plants. Picloram (1 lb a.e./acre) applied with or without 2,4-D controlled snakeweed and prickly pear and initially damaged blue grama and needle-and-thread grass (Gesink et al. 1973). The grasses recovered and had increased production 5 years after treatment. Needle-and-thread grass was more tolerant to picloram than blue grama, and production increased on needle-and-thread grass plots treated at low rates. Picloram may selectively reduce forbs and some grasses. Picloram (0.75 to 4 lb a.e./acre) decreased yarrow, aster, and ironweed, and some grasses, such as blue and hairy grama, but picloram did not decrease little and big bluestem, indiangrass, or switchgrass (Arnold and Santelmann 1966). These studies illustrate how picloram may affect plant community composition when species of different sensitivity are present.

Herbicides commonly used on plains grasslands for weed control before revegetation may initially damage grass seedlings. Picloram (0.75 to 3 lb a.e./acre) reduced seedling emergence of side-oats grama, big bluestem, switchgrass, and blue grama, but big bluestem was more tolerant than the other species (Arnold and Santelmann 1966). Picloram (0.5 lb a.e./acre) controlled knapweed and allowed establishment of wheatgrasses (Hubbard 1975). Creeping red fescue and timothy were tolerant of picloram (0.25 lb a.e./acre) and dicamba (0.5 lb a.e./acre) used to control Canada thistle if they were seeded one growing season after herbicide application (Gallagher and Vanden Born 1976).

Atrazine may be used to control annual weeds in warm-season grasses that are normally tolerant, except at the seedling stage (Bahler et al. 1984). Seedlings of Caucasian bluestem and switchgrass were more tolerant to atrazine (3 ppm in greenhouse soil) than indiangrass, sideoats grama, and blue grama (Bahler et al. 1984). Atrazine (1.8 lb a.e./acre) applied to a shortgrass prairie in Colorado controlled annual forbs and grasses and reduced the frequency of cool-season grasses, such as squirreltail, western wheatgrass, and needle-and-thread grass (Houston 1977). Frequency of warm-season grasses, such as blue grama, threeawn, and sand dropseed increased, as did that of some perennial forbs, hairy gold aster, and rush skeleton plant.

Applications of selective herbicides, such as 2,4-D, on plains grasslands may be expected to increase grasses and decrease broadleaf species. Applications of picloram and atrazine to control noxious herbaceous and woody weeds or to control annuals before revegetation may favor or disfavor certain broadleaf and grass species, depending on relative herbicide sensitivity. These herbicides can greatly change the composition of mixed prairie communities.

Mountain/Plateau Grasslands

Mountain and plateau grasslands have generally been treated with herbicides when they are dominated by weedy shrubs and forbs. Application of 2,4-D (3 lb a.e./acre) to degraded meadows in Colorado controlled silver sagebrush and decreased forbs such as agoseris, eriogonium, sneezeweed, lupine, and vetch, as well as dandelion and cinquefoil (Turner 1969). In that study, grasses and sedges increased greatly in cover and production after shrub and forb control. Species composition of grasses did not change greatly after herbicide treatments, and some forbs, such as cinquefoil, though initially set back, had high frequency 9 years after treatment. In Wyoming, application of 2,4-D (1,2 and 4 lb a.e./acre) decreased the cover and production of forbs such as lupine, avens, agoseris, pussytoes, arnica, and cinquefoil (Hurd 1955). Some forbs, such as yarrow, sandwort, cerasticean, and bedstraw, were tolerant of 2,4-D, while others, such as aster, eriogonium, and phlox, were moderately sensitive to the herbicide. Cover and production of grasses and sedges increased relative to untreated plots. Application of 2,4-D (1, 2, 3 and 4 lb a.e./acre) to mountain grasslands in Nevada to control iris also greatly reduced dandelion and yarrow the first year after treatment (Eckert et al. 1973b). Production of slender wheatgrass, Nevada bluegrass, and meadow barley greatly increased after iris control. Treatment of mountain grasslands with selective herbicides, such as 2,4-D, can be expected to increase production of grass and grasslike plants and decrease production of shrubs and forbs. Forbs that are tolerant of 2,4-D or can readily reestablish from seed will persist in the meadow communities.

Coniferous/Deciduous Forests

Chemical treatments would affect the species composition, size, density, and vigor of the vegetation in coniferous/deciduous forests. These impacts may range from complete control of target vegetation to negligible damage, depending on species, chemicals used, dosages, and timing of applications.

Herbicides such as picloram, triclopyr, glyphosate, and atrazine may result in brush and hardwood defoliation, top kill, and minimal resprouting. These treatments would temporarily reduce competitors, increase the amount of light reaching conifers and other desirable species, and decrease bush and grass competition for soil, moisture, and nutrients. Impacts would be greater on plant sprouts and seedlings than on full-grown plants. Using herbicides can increase the growth rate of conifer seedlings stressed by competition. Herbicide injections would leave trees standing and would create additional fire hazards from the dead needles or leaves.

CLIMATE AND AIR QUALITY

Climate

Because the factors influencing climate are so large in scale compared with the size of any individual proposed vegetation treatment, none of the vegetation treatment methods would have any significant impact on the climate.

Global carbon dioxide and methane levels are increasing, and have been called "greenhouse gases," implying their increased concentrations may lead to changes in precipitation and temperature (both in timing and intensity). All vegetation is important in the processing and recycling of oxygen and carbon through photosynthesis. By converting carbon dioxide into oxygen and plant fiber, carbon is "fixed;" removed from the atmosphere until the plant material either decomposes or burns. Grasslands may fix carbon at a faster rate than woody vegetation types, but the total mass of fixed carbon is much less. Of the treatment methods considered, prescribed burning has the greatest potential for adding carbon dioxide and fine particulate matter to the atmosphere.

Although the "greenhouse effect" theory is very popular, the probability of its occurrence and potential effects are unknown at this time. To validate the theory, a multi-year, multi-million dollar research program was established by President Bush, and is administered by the interagency Committee on Earth Sciences. The Bureau of Land Management is a participating agency in this research.

Air Quality

The most significant impacts on air quality would be moderate increases in noise, dust, and combustion engine exhaust generated by manual and mechanical treatment methods; smoke from prescribed burning; and moderate noise and minimal chemical drift from aerial application of herbicides. Impacts would be temporary, small in scale, and quickly dispersed throughout the EIS area. These factors, combined with standard management practices (stipulations), minimize the significance of potential impacts. Federal, State, and local air quality regulations would not be violated.

Potential air quality impacts are assessed before project implementation. Site-specific plans are reviewed for compliance with applicable laws and policies, and existing air quality is inventoried so that changes associated with BLM proposals may be determined. Additional mitigation may be incorporated into specific project proposals to further reduce potential impacts. For example, prescribed burning activities must comply with the BLM Manual, Sections 9211.31(E), Fire Planning, and 9214.33, Prescribed Fire Management, to minimize air quality impacts from resulting smoke. This procedure requires compliance with individual State and local smoke management programs that specify the conditions under which burning may be conducted. Similarly, standard management practices for aerial application of herbicides limit the amount of drift into nontarget areas.

Manual and Mechanical Methods

Fugitive (wind-blown) dust from manual or mechanical equipment would have a localized, temporary impact. Power equipment and machinery exhaust would emit carbon monoxide, sulfur dioxide, and nitrogen dioxide; however, the quantities would be so small that their isolated and temporary use would not cause significant impacts. Noise levels could approach 90 decibels (dbA) for short time periods, but no long-term impacts are anticipated. Impacts would not vary significantly by vegetation analysis region. Standard management practices would limit impacts to the immediate vicinity of the treatment area.

Biological Methods

Biological treatments, which do not use machines or chemicals, have little potential to affect air quality. Biological treatments may cause minor odors because of confined animals, but these effects would be restricted to the immediate treatment area and would dissipate rapidly. Impacts would not vary significantly by analysis region, because the area treated by biological methods remains nearly constant for all alternatives.

Prescribed Burning

Particulate matter, volatile organic compounds, and carbon monoxide are the primary pollutants emitted during prescribed burning that would affect air quality. Compliance with local smoke management programs would minimize these effects. The timing, vegetation type, size of burns, fuel arrangement and moisture, ignition techniques and patterns, and weather conditions are all specified to keep smoke amounts within acceptable limits. The actual level of impact depends on a combination of all these factors, but regardless of the burning conditions, air-quality regulations would be met. The health effects of prescribed burning are described later in this chapter and detailed in Appendix D.

Table 3-5 summarizes air pollutant emissions due to prescribed burning by program alternative. Potential cumulative impacts may occur when multiple prescribed fires occur simultaneously. In the Pacific Northwest (where cumulative impacts are most likely), smoke management committees limit burning by Federal, state and private groups to minimize cumulative impacts.

Table 3-5

Annual Prescribed Burning Pollutant Emissions by Program Alternative (tons)

	Program Alternative				
Pollutant	Proposed Action	No Aerial Herbicide	No Herbicide	No Burning	No Action
Carbon Monoxide	29,400	36,500	37,100	0	23,900
Nitrogen Oxides	1,300	1,700	1,700	0	1,100
Sulfur Dioxide[1]	—	—	—	—	—
Total Suspended Particulates	4,800	6,300	6,400	0	4,200
Inhalable Particulates	3,200	4,100	4,200	0	2,700
Volatile Organic Compounds	6,300	8,400	8,600	0	5,800
Acres Burned	97,765	132,290	136,390	0	92,680

[1] Sulfur dioxide emissions are negligible.

Fuel Loading:

Chaparral	- 3 tons/acre
Coniferous	- 6 tons/acre
Grasslands	- ½ ton/acre
Pinyon-Juniper	- 5 tons/acre
Sagebrush	- 3 tons/acre
Activity fuels	- 15 tons/acre

Fuel Consumption: 100 percent.

Emission Factors: U.S. Environmental Protection Agency (1989).

Chemical Methods

Spray drift and volatilized chemicals from aerial, ground vehicle, and hand applications of herbicides could occur, but would not significantly affect air quality. Spray droplets of 100 microns and less are most prone to drift, and may be carried long distances before reaching the ground. Standard management practices that can minimize these impacts include using spray equipment designed to produce 200- to 800-micron-diameter droplets and prohibiting spraying when the wind speed exceeds 6 miles per hour or blows in the wrong direction. Health risks associated with chemical drift are discussed later in this chapter and are detailed in Appendix E. Ester formulations of 2,4-D or triclopyr applied in diesel oil are prone to volatilization; all other herbicides are less volatile. The use of ground vehicles and aircraft to apply the herbicides could temporarily cause noise levels to reach 90 dbA; however, no long-term effects are anticipated.

GEOLOGY AND TOPOGRAPHY

Geology interacts either directly or indirectly with all other environmental factors. For example, the rock type of a specific area can exert a major influence in controlling soil development, vegetation community composition, and plant growth rates. Soil moisture retention is indirectly related to the geologic material and weathering conditions. The environmental resources that are most closely associated with the geology include soil resources and water resources. The possibility of increased soil erosion or accumulation of chemical herbicides in soils are potential impacts of the various vegetation treatments. Alternative treatment programs are specifically identified and discussed in the Soils section. Potential impacts to water resources from either increased sediment yields or increased chemical herbicides resulting from vegetation treatments are discussed in detail in the Aquatic Resources section. Although these related resources may be affected, the implementation of vegetation treatment alternatives and the application of the methods considered in this EIS are not expected to directly affect geologic resources.

Topography typically is linked to the area geology and also is a consequence of many interacting environmental factors. The topography of an area may serve to restrict the distribution of certain vegetation communities because of the climate associated with that area's elevation. Certain topographic highs (mountain ranges) influence weather patterns and cause a "rain shadow" effect on much of the interior regions of the American West, causing leeward areas to receive less moisture than the windward areas. Treatment programs that use mechanical equipment (that is, tilling, bulldozing, etc.) have the recognized capacity to produce minor changes in the topographic landscape. However, the implementation of vegetation treatment alternatives and the application of the methods considered in this EIS are not expected to substantially affect topography.

SOILS

Vegetation treatments may affect the physical characteristics of soils directly, alter the abundance and types of vegetation that may shield soils from erosion, or alter the presence and abundance of soil microorganisms or larger organisms that contribute to overall soil quality.

Manual Methods

The disturbance of soils caused by manual methods of vegetation treatment should be negligible. Because manual vegetation methods generally are reserved for small isolated areas (because of labor expenses) and because they do not directly affect the surficial organic layer of the soil, this treatment method will not be evaluated on an analysis region basis. Overall, manual treatment effects on soils should be minimal compared with those that may occur with the mechanical treatments described in the following sections.

Mechanical Methods

The effects of mechanical treatments on soils and their hydrologic characteristics depend on the following: (1) soil exposure following treatment; (2) the direct effect of soil disturbance on soil properties; and (3) the site conditions, especially precipitation pattern and slope. Mechanical methods include two general types: (1) methods such as mowing and roller chopping, which remove top growth but do not directly disturb the soil, and (2) methods such as plowing and chaining, which can remove the entire plant, including roots, and directly disturb the soil (Blackburn 1983).

Plant and litter cover protect the soil, and roots hold the soil in place, so lack of plant cover is highly correlated with runoff and erosion on rangelands (Rauzi 1960, Rauzi and Fly 1968, Branson et al. 1981). Any reduction in cover by vegetation manipulations would tend to increase runoff and erosion on rangeland watersheds. Mechanical treatments are designed to increase plant cover by encouraging the growth of nontarget species already present or by facilitating artificial revegetation. Vegetation treatment aimed at reducing woody species and increasing herbaceous species greatly reduces water runoff and erosion while improving soil stability. Where revegetation is necessary to produce desired cover after plant control, the hydrologic response to control may be greatly dependent on the success of revegetation. For example, disk plowing sagebrush and drilling beardless bluebunch wheatgrass reduced bareground by 30 percent and decreased runoff and erosion at sites in Colorado (Lusby 1979). However, plowing and unsuccessful revegetation of sagebrush in Nevada decreased infiltration rates (Gifford 1968, Jager 1972). Effects of mechanical vegetation manipulation on soils must be evaluated with respect to the effects of the treatment on total vegetation cover compared to nontreated rangeland.

The direct effects of mechanical disturbance on soils depend on the type and extent of disturbance, the soil texture and structure, and the soil water content when disturbed. Although little data are available on the direct effects of mechanical disturbance on rangeland soils, literature from tillage of agricultural soils suggests some principles. Soil aggregate stability is necessary for high infiltration rates and soil stability. Aggregate stability is maintained by vegetation cover, which protects the aggregates from raindrop impact, and by soil organic matter, which holds aggregates together (Tate 1987). Lack of soil aggregation results in formation of a surface crust, especially on fine-textured soils, which reduces infiltration, soil aeration, and associated plant growth (Cary and Evans 1974). Some rangeland soils have pronounced vesicular crusts in the interspaces between tree, shrub, and grass plants. These crusts have poor structure and much lower infiltration rates than the well-aggregated soils under the shrubs or trees (Blackburn and Skau 1974). Mechanical treatment disturbance of these and other crusted soils could be expected to increase infiltration for a while, but unless soil vegetation cover, organic matter, soil aggregation, and porosity are increased in association with vegetation response to the treatment, the crusts will reform and infiltration will continue to be low. Thus, the effects of mechanical treatments on crusted soils are highly dependent on vegetation response after treatment. A high cover of vegetation protects and maintains soil aggregation by reducing raindrop impact and by adding organic matter (Cary and Evans 1974).

Mechanical treatments such as disking or tilling are designed to aerate, lift, twist, shear, and incorporate the surficial vegetative cover and organic matter into the soil. This mixing adds important organic nutrients to the root zone and facilitates the establishment of newly planted vegetation. However, mechanical treatments may possibly increase runoff and erosion on some highly sloping sites, especially the fine-textured, unstable, crusted soils that are present on some sagebrush and desert shrub rangelands. In addition, the mechanical treatment and suppression of nitrogen-fixing vegetation (that is, Ceanothus spp.) may result in a dramatic reduction in the abundance of nitrogen-fixing bacteria. Recovery of infiltration rates and sediment control on some sites generally occurs with time, depending on the speed of natural or artificial revegetation and replacement of vegetation cover.

Soil texture and morphology also affect soil response to mechanical treatments. Coarse-textured soils with initially high infiltration rates and clayey soils with low infiltration rates generally would be expected to change little after direct mechanical disturbance. However, if the mechanical treatment creates furrows or pits to hold water or breaks up a shallow soil layer of limited permeability, infiltration may be increased (Brown et al. 1985). Herbel (1984a) recommended no mechanical treatment of sandy soils in windy areas because of the resulting increase in wind erosion when vegetation cover is lost.

Effects of mechanical treatments also are highly dependent on precipitation pattern and ground slope. Temporary loss of vegetation cover from mechanical treatments may result in increased erosion from high-intensity summer thunderstorms; however, erosion from gentle winter snow and rainfall probably would be limited. For example, converting sagebrush to grass by plowing and seeding reduced summer rainfall runoff but increased snowmelt runoff (Lusby 1979). Because most of the sediment production and runoff was associated with summer runoff, the conversion decreased erosion and runoff overall.

Many mechanical methods are limited to ground slopes of less than 30 percent; however, erosion hazards are greatest on slopes greater than 20 percent (Jordan 1981). Thus, mechanical methods have the potential to greatly increase erosion on steep slopes but in practice are most frequently used on gentle slopes where the erosion hazard is limited.

A recognition of the negative impacts of recurrent disturbance has resulted in an emphasis on minimum tillage of agricultural soils (Donahue et al. 1977). Hutten and Gifford (1988) found that frequently plowed agricultural soils had overall lower infiltration rates and higher sediment production than adjacent rangeland soils. Although the frequency of rangeland soil disturbance with mechanical plant control is much less than that of tilled agricultural soils, mechanical compaction of rangeland soils has long been identified as a potential problem (Lull 1959). Direct impacts associated with mechanical disturbance will be highly site- and treatment-specific, but negative impacts would be most expected on fine-textured soils lacking organic matter and soil structure with low aggregate stability and a tendency to form a crust. Soil compaction symptoms and causes have been discussed by Robertson and Erickson (1978). Compaction from mechanical treatments of rangeland soils should be much less than agricultural soils. Heavy machinery driven over rangeland soils to control vegetation may compact surface and subsurface soils and reduce aggregation. Range management equipment that disturbs the soil may break down large aggregates to smaller, less stable aggregates. Compaction is especially pronounced on wet and poorly drained soils.

The general impacts of mechanical treatments on rangeland vegetation and soils have been summarized by Blackburn (1983). Cutting and mowing methods, such as roller chopping, result in minimal physical soil disturbance and may produce soil-protecting mulch. The soil disturbance produced by grubbing, bulldozing, and chaining/cabling increases with increased density of the woody target species. Soil disturbance by these methods may be extensive, but pits created by plant extraction and debris left in place may trap water and limit runoff and erosion. Rootplowing and disk plowing completely disturb the surface and sometimes the subsurface soil.

Conversion from woody to herbaceous vegetation would not necessarily increase water yields from rangeland watersheds, but if vegetation cover is maintained by existent and seeded herbaceous plants after mechanical disturbance, runoff and erosion should decrease. Revegetation to replace lost cover would be recommended to reduce potential erosion on windrowed sites. Increased surface roughness after mechanical disturbance may decrease runoff and erosion of some noncrusting soils as long as vegetation cover is not greatly reduced. Coarse-textured soils of many rangelands would continue to maintain similar infiltration and sediment production rates after mechanical treatment.

Although various literature sources discuss the efficacy of mechanical control treatments, data that detail the impacts of these treatments are sparse (Blackburn 1983). Sagebrush and pinyon-juniper sites have been most studied to determine effects of mechanical treatments on soils and hydrology. Impacts of plant control on soils and hydrology are extremely variable because of interactions of weather, control method, vegetation response, soil properties, and post-treatment management (Blackburn 1983). Because these interactions are not understood in detail, predictions of treatment responses are difficult to make on specific sites that have not been researched.

Sagebrush

Since 1940, millions of hectares of sagebrush have been cleared in the Western United States. The limited information on impacts from mechanical disturbance varies with the site and treatment (Blackburn 1983). Parker (1979) has reviewed the various mechanical methods for controlling sagebrush, and Blaisdell et al. (1982) discuss their application to specific sites.

Disk plowing of sagebrush and drill seeding of beardless bluebunch wheatgrass in Colorado quadrupled herbaceous forage production and decreased summer runoff and annual sediment yield by 75 and 80 percent, respectively, on a watershed scale (Lusby 1979). Infiltration decreased and sediment production increased after plowing sagebrush and unsuccessfully seeding perennial grass in Nevada on silt-loam soils (Gifford 1972). The failure to replace vegetation cover and the crusted nature of these fine-textured soils may account for the negative response to plowing in this study. Similar crusted soils in Nevada had increased sediment production after disturbance by off-road vehicles (Eckert et al. 1979).

On a sagebrush site in Idaho, infiltration rates decreased after plowing and seeding grass but recovered after 6 years (Gifford 1982). Hydrologic characteristics of some sagebrush sites in Nevada were similar or improved 6 to 17 years after plowing and seeding the grass (Blackburn and Skau 1974). In these studies, the presence of a vesicular crust most negatively affected infiltration. Soils with a vesicular crust that are disturbed are highly unstable and may produce suspended sediment with intense rainshowers. Blackburn and Skau concluded that mechanically converting sagebrush to grass may not affect infiltration rates of soils without a vesicular crust and may, only after some time, improve infiltration rates on soils with a vesicular crust, possibly as vegetation cover, soil organic matter, and aggregate stability increase. In another study in Nevada, plowing and seeding grasses reduced infiltration rates and increased sediment production immediately after treatment, but after 2 years infiltration rates were recovering and sediment production was similar to that of control plots (Brown et al. 1985). In this study, furrows created by plowing and seeding retarded runoff, indicating a possible lower erosion hazard from mechanical disturbance than would be inferred from infiltration-rate data alone.

In summary, mechanical disturbance to control sagebrush may or may not initially adversely affect soil hydrologic properties, and adverse effects tend to decrease with time after disturbance. There is a lack of watershed-scale data and data on specific soil structural characteristics as affected by mechanical disturbance in the sagebrush ecosystem. The movement of suspended sediment from the usual gentle slopes of the sagebrush rangelands is not known (Eckert et al. 1979). Most of the precipitation on sagebrush rangelands falls in the winter as snow or gentle rains and would not be expected to greatly erode disturbed soils. However, infrequent, highly localized, intensive summer thundershowers could erode recently disturbed soils. Effects of mechanical control on sagebrush soils probably are most dependent on the replacement of lost vegetation cover by desired species.

Desert Shrub

Mechanical or other methods of plant control generally are not recommended for desert shrubland (see section on Vegetation). Replacing perennial plant cover by revegetation is usually necessary after plant control. Revegetation is rarely successful, so disturbance of existing plant cover tends to increase annual weed cover and bare ground.

Mounds associated with shrubs on some soils of the desert shrubland have well-aggregated soils with much higher infiltration rates (Blackburn 1975) and a higher concentration of nutrients than soils between the mounds (Charley and West 1975). Mechanical disturbance of these soils could reduce infiltration rates and nutrient cycling, resulting in less vegetation cover and increased bare ground and erosion hazard. Although slopes of these rangelands usually are gentle, runoff and water erosion can be high due to high-intensity rainstorms resulting from the inherently low vegetation cover. Disturbance of shrub mounds, and especially shrub interspaces with unstable, fine-textured, vesicular-crusted soils, can greatly increase sediment production (Eckert et al. 1979). Loss of vegetation cover would be expected to greatly increase wind erosion on these lands (Herbel 1984a).

Southwestern Shrubsteppe

Mechanical methods, such as chaining and rootplowing, have been used to control woody plants, especially mesquite, throughout the Southwest (Jordan 1981). Most of the literature on hydrologic and soil impacts associated with mechanical mesquite control is from Texas (Blackburn 1983). Soils in the Southwest are vulnerable to erosion by high-intensity summer rain showers. Although Martin (1975) observed that increases in mesquite may accelerate sheet and gully erosion in semidesert grassland, there is a lack of research evaluating hydrologic responses to mesquite control. Rootplowing of honey mesquite increased infiltration and reduced sediment production of shrub interspaces on the Texas Rolling Plains (Brock et al. 1982).

Plant cover is most important in maintaining high infiltration rates after mechanical disturbance on the clay-loam soils of this region. Complete denudation of a mesquite-buffalograss community in Texas, using herbicides and shredding, decreased infiltration and increased runoff and sediment production (Bedunah and Sosebee 1985). Shredding and power grubbing of mesquite resulted in runoff and sediment production similar to untreated plots. Rootplowing of creosotebush sites on coarse-textured soils in Arizona reduced runoff by increasing surface roughness and detention storage and by increasing plant cover (Tromble 1976). In a subsequent study in New Mexico (Tromble 1980), rootplowing creosotebush and seeding grasses resulted in less vegetation cover and lower infiltration rates than untreated areas. Infiltration rates increased on rootplowed areas after 4 years, when seeded grass cover had increased.

Mechanical treatments may increase infiltration of some soils in the Southwest by increasing surface roughness. Because vegetation cover is extremely important in protecting the soil from high-intensity thundershowers, the change in cover after treatment generally determines any change in runoff or erosion. Mechanical control should be used only on sites with a high potential for natural or artificial replacement of vegetation cover after removal of undesirable species.

Chaparral-Mountain Shrub

Since chaparral vegetation occurs on steep and rocky terrain, mechanical control methods have had limited application (Ffolliott and Thorud 1975). Rootplowing, which is possible on only about 2 to 8 percent of chaparral (Pond 1961), is considered to be the most effective mechanical method for chaparral control (Cable 1975). Rootplowing of live oak on the Edwards Plateau created large storage depressions and reduced runoff by 20 percent (Richardson et al. 1979). Grubbing shrubs and seeding perennial grasses reduced erosion by 99 percent over a 7-year period in Arizona, probably by greatly increasing grass basal area and ground cover (Rich 1961).

Roby and Green (1976) have reviewed other methods of mechanical treatment of chaparral. They observed that chaining and disking may disturb the soil and increase erosion hazards, while chopping methods that leave roots intact and produce a mulch have less potential for causing erosion. Because successful mechanical control by rootplowing is only possible on the more gentle slopes and is always accompanied by restoration of groundcover by revegetation, it is not expected to adversely affect soils and hydrology in the chaparral type. Control by topkill methods, such as chaining and shredding, reduces live plant cover and briefly increases erosion hazard, but most plants quickly resprout from basal buds and cover is rapidly restored. Although severe erosion could occur on steep slopes if high-intensity rainfall occurs before plant cover reestablishment, some treatment practices can be done on contour to help mitigate the problem.

Pinyon-Juniper

The low precipitation and resulting small surface-water budget of pinyon-juniper watersheds results in low ground-water recharge, runoff, and erosion compared to many watersheds (Hawkins 1987). Because much of the hydrologic activity is soil-water recharge rather than runoff, hydrologic prediction techniques are not easily applied and are limited by lack of site-specific calibration data (Hawkins 1987). Thus, information on the response of pinyon-juniper soils to mechanical treatments is mainly from empirical studies on specific sites, and reasons for varying responses are not easily determined.

Mechanical methods used to control pinyon-juniper include chaining or cabling, bulldozing, and handslashing (Blackburn 1983). These trees are controlled not only to increase forage production, but also to increase water yield from selected watersheds. Cabling Utah juniper on the Beaver Creek watershed in Arizona created pits that trapped overland flow and resulted in water yields and sediment production similar to those in untreated areas (Skau 1961, 1964). Chaining, grubbing, girdling, and handslashing 25 percent of the pinyon-juniper did not change water yield of the Corduroy Creek watershed in Arizona (Collings and Myrick 1966). In southern Utah, chaining and windrowing pinyon-juniper debris slightly reduced infiltration and increased streamflow, while double-chaining and leaving debris in place resulted in infiltration and water yield similar to that of untreated sites (Gifford 1975, Williams et al. 1972). Sediment production from chained pinyon-juniper sites in Utah generally was no greater than that from untreated woodland except when the debris was windrowed (Williams et al. 1969, Gifford et al. 1970, Gifford 1975).

These studies emphasize again that treatments that reduce cover, such as windrowing, have the greatest potential for increasing erosion. In Nevada, Blackburn and Skau (1974) found no statistical difference in infiltration or sediment production between chained and untreated pinyon and juniper communities measured 3 and 11 years post-treatment. The chained areas had a grass cover from revegetation and showed a trend toward less sediment production than untreated areas. In general, mechanical treatments of pinyon-juniper on coarse-textured soils do not appear to significantly affect runoff and erosion. Although leaving debris in place to cover the soil instead of windrowing reduces erosion potential, using chaining treatment operations combined with prescribed burning operations of the debris and planting of desired vegetation species has been particularly successful. Site-specific conditions and treatment program objectives determine the variety of treatment methods and their general application.

Plains Grasslands

Mechanical treatments of plains grasslands (generally tilling or ripping to break up compacted soils and sod-bound vegetation) are conducted to reduce less desirable warm-season species and to increase production of cool-season species (Griffith et al. 1985). Because the treated slopes are gentle and plant cover recovers rapidly after disturbance, water erosion potential generally is low. Tilling and ripping are done in strips to prevent large ground cover loss and to avoid the type of wind erosion that occurred on tilled lands in the 1930s (Lorenz 1986). Tillage associated with interseeding increased soil water content and evidently released nutrients by increasing soil weathering and organic matter decomposition (Wright and White 1974). Strip mechanical treatments on plains grasslands generally result in positive rather than negative soil water relations for plant growth and have positive hydrologic responses.

Mechanical treatments generally increase soil water storage by trapping snow and increasing infiltration (Wright and Siddoway 1972, Neff and Wight 1977). For example, contour tilling in Montana decreased runoff in late fall and early spring and increased snow accumulation (Neff and Wight 1977). This increased over-winter soil water recharge .44 and 1.56 inches on saline upland and on pan-spot range sites, respectively. Tilling increased soil water content and decreased salinity of the surface soil in Montana (Branson et al. 1966). The leaching of salts associated with furrowing was seen as beneficial in that study because pretreatment salinity was high enough to reduce the osmotic potential of the soil solution and reduce plant growth.

In summary, mechanical treatments of plains grasslands generally would result in increased aeration and mixing of organic material. Recovery of infiltration rates and sediment control on some sites generally occurs with time and probably is dependent on natural or artificial revegetation and replacement of vegetation cover. Increased surface roughness after mechanical disturbance may decrease runoff and erosion of some noncrusting soils as long as vegetation cover is not greatly reduced.

Coarse-textured soils of many rangelands continue to maintain similar infiltration and sediment production rates after mechanical treatment. Conversion from woody to herbaceous vegetation does not necessarily increase water yields from rangeland watersheds (Blackburn 1983), but if vegetation cover is maintained by existent or seeded plants after mechanical disturbance, runoff and erosion should not increase. Revegetation to replace lost cover is recommended to reduce potential erosion on windrowed sites. Plains grassland slopes are gentle, and plant cover would recover rapidly after disturbance, so water erosion potential generally would be low.

Mountain/Plateau Grasslands

Mountain/plateau grasslands are similar to plains grasslands, except that they are not as laterally extensive, are often surrounded by higher elevation areas, and may be immediately adjacent to forest communities. Mechanical treatments of these grasslands, conducted by furrowing or ripping to break up compacted soils and sod-forming vegetation, generally would result in increased aeration and mixing of organic material.

Tillage associated with interseeding increased soil water content and evidently released nutrients by increasing soil weathering and organic matter decomposition (Wright and White 1974). Strip mechanical treatments on mountain/plateau grasslands generally result in positive rather than negative soil water relations for plant growth and have positive hydrologic responses. Mechanical methods of vegetation treatment may increase runoff and erosion on some sites, especially those with fine-textured, unstable, and crusted soils. Recovery of infiltration rates and sediment control on some sites generally occurs with time and probably is dependent on natural or artificial revegetation and replacement of vegetation cover. Increased surface roughness after mechanical disturbance may decrease runoff and erosion of some noncrusting soils as long as vegetation cover is not greatly reduced.

Coniferous/Deciduous Forest

Mechanical treatments in forests consist primarily of slash piling of cut vegetation and scarification (soil preparation) using crawler tractors to facilitate the establishment of newly planted seedlings. The mechanical methods typically used in the forest ecosystem have a higher potential than any other vegetation management method for direct impacts to soils (Newton and Norgren 1977). Soil disturbances from scarification and construction of tractor trails may cause soil compaction (Froehlich 1973). Reductions in rooting depth (USDA 1988), soil productivity (Froehlich, 1973), and mycorrhizal fungal mycelia (Perry and Rose 1980) may be associated with this compaction. Mycorrhizal fungal mycelia are particularly important for water and nutrient uptake in most plant species and are closely linked to soil productivity. Because soil compaction problems resulting from vegetation treatment operations are intensified when soils are saturated, limiting these types of operations to drier periods can minimize detrimental soil compaction and subsequent reductions in soil productivity. The construction of slash piles also may remove some of the protective duff layer from forest soils. This duff disturbance may increase the potential for accelerated surface erosion and removal of productive topsoil, especially on steeply sloped areas. Mechanical treatment programs that use wheeled or crawler tractors in timber harvesting and planting are designed to limit mechanical methods to those stable, low-sloped areas that are not highly susceptible to erosion and soil removal.

Biological Methods

Biological methods of vegetation treatment that BLM may consider using include grazing animals, insects, and pathogens. The size of areas used for biological treatment would depend on the target plant species and the method of treatment. The areas treated using these methods would vary in size from one-quarter acre to 1,500 acres for insects or pathogens, and 5 to 500 acres for grazing animals. The impacts of these treatment methods will vary depending on the size of the treatment area and the method used. Insects and pathogens generally should have a lesser impact because of the slower, more "natural" action of this method, while the use of grazing animals for biological treatment has greater potential for impacts because of the animals' greater size and more immediate disturbance of the sites. Most studies of the effects of grazing on soils deal with general grazing practices. The main effects on soils caused by grazing include compaction of wet soils from trampling and surface erosion on hillsides due to loss of plant cover from overgrazing. However, these effects usually would not occur when grazing practices follow a specifically planned vegetation management program.

Livestock would be closely controlled to prevent damage to desired vegetation. This supervision of the livestock, in addition to fencing and upslope water developments, also would be used to keep livestock from concentrating in wet areas and overgrazing to the point that desired vegetation is damaged. Livestock could potentially create a disturbance of lichen and moss cover in certain areas and increase soil surface exposure, although proper grazing management practices should minimize any adverse impacts. Possible impacts would vary according to site, depending on size and the grazing management techniques used. In general, impacts will be negligible on smaller biological treatment sites and slight on larger sites.

There is little potential for direct soil impacts from insect and pathogen biological vegetation treatments because these programs are longer in duration and slower in action than many other treatment methods and usually leave the target plants standing, thereby reducing the effects to the soil. The organisms used in biological treatment methods are directed at modifying the frequency and occurrence of certain targeted plant species and have little interaction with soil.

Prescribed Burning

Fire plays both an evolutionary and ecological role in shaping most ecosystems in the West; however, prescribed burning has gained widespread acceptance as a land management tool only in the past two decades (Wright and Bailey 1982). Prescribed burning techniques allow managers to perform burns under previously set conditions. Prescribed fires usually are staged under burning conditions that may not only mitigate or limit adverse impacts to soils, but also actually improve soil conditions. This discussion will concentrate on fire effects from prescribed burns rather than wildfires. Results from studies of wildfires are difficult to interpret because of the widely varying environmental conditions under which they occur and the fact that these conditions are rarely documented. Nor are these fires carefully monitored in most instances (Wright 1974b, Buckhouse 1985).

The following discussion of prescribed fire impacts will describe general effects of fire on soils/watersheds, followed by specific effects on the various impact analysis areas. However, even when discussed by vegetation type, ecological effects of fire are at best only generalized. Specific effects must be considered individually for each combination of region, climate, vegetation association, soil type, and plant or animal species (Ahlgren and Ahlgren 1960), along with the specific objectives for the site to be treated.

Prescribed burning affects soils primarily by consuming litter; organic soil layers; down, dead, and woody fuels; and vegetative cover (Wright and Bailey 1982). Fire may alter soil chemical properties, nutrient availability, postfire soil temperature, microorganism populations and their activity rates, physical properties, wettability, and erosion.

The degree to which these characteristics are affected in the short term depends on the ignition technique used; dead fuel, live fuel, organic layer, and soil moisture at the time of burning; thickness and packing of the litter layers; depth and duration of heat penetration into organic and soil layers, as well as maximum temperature attained at different depths within the profile; soil type; and soil texture. Nutrient losses from the site and postfire erosion are closely related to topography, remaining plant cover, frequency and area of bare soils, and the timing and severity of postfire precipitation events with respect to postfire litterfall and vegetative recovery. A significant storm can wash ash from the surface, removing many of the nutrients released in the ash. Gentle rains can carry some of these nutrients into the soil profile. Many of the nutrients released in ash can be taken up by rapidly growing vegetation. Net nutrient losses caused by consumption of organic matter may be counterbalanced by increased availability of nutrients formerly locked in complex organic forms that cannot be used by plants. Activity of decomposing and nitrogen-fixing organisms may also change, further affecting the postfire nutrient balance.

Changes in soil chemical properties, including soil nutrients, caused by burning usually include an increase in soluble nitrogen, phosphorus, potassium, sulfur, magnesium, sodium, and calcium, and an increase in soil pH, which means a decrease in soil acidity (Fuller et al. 1955, Summerfield 1976). Carbon-nitrogen ratios are reduced because of the nitrogen increase and subsequent carbon decline caused by burning (Fuller et al. 1955). Losses of nitrogen and sulfur from mineral soils can occur as a result of volatilization, but conflicting results have been reported (Wright and Bailey 1982). Very severe (high-heat) fires usually result in net soil losses of nitrogen, calcium, and magnesium (Stark 1977, De Bano and Conrad 1978). Infiltration and percolation of water also may leach these nutrients in addition to raising the pH of the soil, altering soil chemistry, and changing ground-water and surface-water quality. Soil cation-exchange capacity also may decrease after severe burns (Wright and Bailey 1982).

The percentage of nitrifying bacteria in soil that are killed depends on the depth and duration of soil heating, which varies significantly among fires. This is true for any group of soil microorganisms. Microorganism populations decline immediately after a burn (Jurgensen et al. 1979) but can quickly recover to greater than preburn numbers (Wright and Bailey 1980). Nitrifying bacteria, however, are extremely sensitive to fire over wet and dry soil and do not recover quickly after a burn (Dunn and DeBano 1977). The threshold temperature level is lower in wet soil than in dry soil, and the amount of soil heating is generally regulated through the prescription in the prescribed fire plan. Heterotrophic bacteria respond to heating in a similar manner as nitrifying bacteria, but at higher temperatures (Dunn and DeBano 1977). Fungal responses to burning are not consistent (Ahlgren and Ahlgren 1965). However, when related to metabolic processes, microbial populations are not adversely affected by prescribed burning (Wright and Bollen 1961, Jorgensen and Hodges 1971, Summerfield 1976).

The effect of fire on soils is closely related to the burn severity and the heat pulse to the soil, which is the result of the combustion of all fuels during flaming, glowing, and smoldering combustion. Significant amounts of deep soil heating occur only if there is long-duration burning in thick organic layers or accumulations of dead woody debris. Moisture content of thick organic layers, large-diameter dead fuels, and soil are critical determinants of the depth of heat penetration because wet fuels do not burn and moist soils limit the depth of soil heating (Frandsen and Ryan 1986). There is a close relationship between fireline intensity (the rate of heat released per foot of fire line during flaming combustion) and flame length. However, there is little relationship between the heat released during flaming combustion and soil heating. Most of the heat from flames rises and does not heat the soil. A high intensity fire with long flame lengths will cause little soil heating except at the immediate surface if subsurface fuels and soils are moist.

Studies generally agree that prescribed burning causes no appreciable change in soil mineral fractions (Beaton 1959, Summerfield 1976), although the heat of very severe fires may render a soil structureless and alter porosity and infiltration rates (Ralston and Hatchell 1971). However, a fire this severe is not likely to be staged in the vegetation types in the EIS area under prescribed conditions. Measurable changes in aggregation and permeability in soil surface layers also have been reported (Scott and Burgy 1956). Soil aggregate stability is maintained by vegetation cover protection (Tate 1987).

Depending on the severity and duration of a fire, some moderately permeable soils may develop resistance to wetting through the distillation of organic compounds (Wells et al. 1979, Wright and Bailey 1982, Holechek et al. 1989). Water-repellent layers are most common in shrub communities on dry, sandy soils (DeBano et al. 1976), but also occur in forest soils (Zwolinski and Ehrenreich 1967).

Vegetative cover, in addition to supplying organic material to the soil, also provides a structural shield to the ground surface. Removal of vegetation and litter exposes mineral soil and subjects the surface to raindrop impact, increasing overland flow and subsequent soil loss (Wright and Bailey 1982, Holechek et al. 1989). Soil creep and debris flow also can occur after soil is exposed (Wright and Bailey 1982).

The most important factors determining whether significant amounts of postfire erosion will occur are the amount of residual vegetation and organic matter remaining, the rate and amount of vegetative recovery, the timing of the vegetative recovery with respect to season and severity of precipitation events, and slope. In forested sites, litterfall of scorched conifer needles can significantly cover the soil. When planning a prescribed fire on erodible soils, these effects can be mitigated by prescribing the fuel and organic layer moisture, thus minimizing the amount of organic layer removal; timing the fire so that vegetative recovery begins soon after; and leaving unburned areas of vegetation.

Sagebrush

Most chemical and soils effects in sagebrush as a result of prescribed fire are limited to the areas beneath sagebrush plants where most of the litter has been consumed because these are the only areas where high enough temperatures are generated to cause heating of associated soils to any significant depth. The major concern when burning is the postfire possibility of wind and water erosion (Summerfield 1976). The likelihood of erosion increases with slope and the length of time that the area remains sparsely vegetated. Wind erosion of significant amounts of topsoil is possible. For this reason, treatment planning must consider the timing of the burn with regard to the growing period of native vegetation and the time when any planted species might germinate and grow, as well as the seasonal occurrence of high winds or major precipitation events. Most soils in the sagebrush-grass areas are derived from basalt, and soil texture varies from loamy to clayey, although extensive areas have soils derived from rhyolite, loess, lacustrine, alluvium, and limestone (Wright et al. 1979).

In general, studies indicate that the chemical and physical properties of soil on sagebrush sites are affected as discussed in the introduction of prescribed burning effects on soils. Organic matter, pH, and nitrogen may be increased in soil surface layers (Summerfield 1976), but Blaisdell (1953) reported no pH change after sagebrush-grass burning. Burning sagebrush and leaf mulch may produce water repellency in soils under sagebrush plants (Salik et al. 1973). Although burning while the soil and mulch are cool and damp will reduce or eliminate this potential (Salik et al. 1973), pure stands of sagebrush may burn extremely hot (Wright and Bailey 1982).

Desert Shrub

Desert soils are not characterized by large amounts of organic matter, and desert fires do not seem to substantially alter soil characteristics (Patten and Cave 1984). As in all shrub communities, the presence of woody fuel is the most important factor contributing to high soil temperatures. Although heat produced by the comsumption of highly flammable shrubs like blackbrush will alter soil properties directly under the plants (Callison et al. 1985), Patten and Cave (1984) reported no changes in soil water repellency nor temperatures after fire. However, soil stability problems may result from loss of perennial plant cover (Callison et al. 1985, Patten and Cave 1984).

Southwestern Shrubsteppe

Because of site variation and moisture conditions, there are few apparent trends on the effects of burning on semidesert grasslands on soil chemical properties (Uechert et al. 1978). Nitrogen losses in grassland fuels can be considerable, but total nitrogen losses for mineral soils after burning appear negligible (Sharrow and Wright 1977a). Increased soil temperatures after burning may enhance soil organic matter breakdown (Sharrow and Wright 1977b) and act to accelerate the plant uptake and availability of certain essential nutrients contained in organic matter complexes. Physical properties were unaffected on heavy clay soils after a desert grass-shrub fire (Uechert et al. 1978). Although soil-water infiltration has been shown to be two to three times higher with litter cover than bare soil (Bentner and Anderson 1943), burning had little effect on infiltration in a mesquite/tobosa-grass community (Uechert et al. 1978). Soil losses from prescribed burning generally are small in these communities (Wright and Bailey 1982, Uechert et al. 1978).

Chaparral-Mountain Shrub

Chaparral soils are relatively infertile and lower in nutrients than soils developed under grasslands (De Bano et al. 1977). Because organic matter is consumed, the soil chemical properties changed by burning are pH, cation-exchange capacity, nitrogen, sulfur, divalent ions, and potassium. After burning, pH in chaparral soils generally is higher, but the increase may be slight (Sampson 1944). After fires, nutrient availability in the surface soils increases as does cation-exchange capacity, although some portion of total nitrogen and potassium are lost by volatilization and other mechanisms (De Bano et al. 1977, Dunn and De Bano 1977, De Bano and Conrad 1978). Fire in chaparral can improve soil conditions by recycling nutrients and removing allelopathic chemicals that inhibit seed germination. Nitrifying and heterotrophic bacteria in chaparral soils are sensitive to fire and can be killed at temperatures of 100° and 210° C (212° F and 410° F), respectively, depending on soil moisture conditions (Dunn and De Bano 1977). Fungi are not consistent in their response to fire (Dunn and De Bano 1977).

Physical properties of soil, such as aggregation, also are affected by the organic matter consumed during a fire, reduced water movement, aeration, and increased bulk density (De Bano et al. 1977). Brushfires in chaparral could further decrease infiltration by producing a water-repellent soil layer, although this effect can be mitigated through the choice of a prescribed fire prescription and soil moisture regime when burning. Soil movement following burning in chaparral communities usually is positively related to fire severity, slope, and postfire precipitation patterns (Wright and Bailey 1982). Potential erosion loss would vary with vegetation reestablishment, steepness of slope, storm intensity, and storm duration.

Pinyon-Juniper

Soil properties affected by burning on pinyon-juniper communities include reduced infiltration rates (Buckhouse and Gifford 1976a) and increased amounts of phosphorus, potassium, nitrogen, and carbon for the first year following debris pile burns (Gifford 1981). Overland flow from burned areas contained greater amounts of potassium and phosphorus than from unburned areas (Buckhouse and Gifford 1976b). Broadcast burning of chained and/or manually cut juniper is the best way to manage the site to prevent rapid takeover by small residual surviving juniper.

Burning of pinyon-juniper slash piles may be detrimental in some situations because soils may be sterilized by the concentrated heat, resulting in nutrient losses and declines in watershed quality (Everett and Clary 1985); however, in some cases, burning may be the only safe way to remove the slash piles. Leaving pinyon-juniper slash material in place, rather than concentrating slash in piles, will reduce the potential for adverse impacts to the soils caused by localization of soil heating beneath fuel piles, as well as limit additional soil compaction caused by machinery used to pile or windrow the debris. Slash material burned in this fashion also releases nutrients such as nitrogen and phosphorous to the soil for immediate seedling uptake. Prescribed burning of a site several years after trees are chained or manually cut increases the length of the effective treatment because it kills residual trees or newly established tree seedlings. Additionally, the burning of windrowed slash eliminates visual conflicts, reduces survival of young or rooted juniper and pinyon trees, and eliminates habitat for rodents and rabbits (which may increase seeding survival and establishment). Removal of shrubs and trees from pinyon-juniper communities by fire generally does not affect erosion. The treatment of shrubs and trees in pinyon-juniper communities by prescribed burning, in conjunction with good management practices, should not significantly affect the rate of soil erosion. Burning of cabled or manually cut juniper 3 years post-treatment reduced the fire hazard and killed residual trees and new juniper seedlings in central Oregon and also resulted in decreased erosion because of the release of existing understory plants and establishment of new plants, which caused a significant increase in protective vegetative cover over the watershed in comparison to the unburned area (Lent 1989).

Plains Grasslands

Burning in plains grassland communities is a widespread practice. The removal of litter and soil organic matter has similar effects on soil aggregation and infiltration as in other regions. Excessive litter accumulations may reduce microorganism activity (Wright and Bailey 1982) and nitrification; nitrogen-fixation and ammonification are increased by pH and the increased concentration of electrolytes after burning. Soil losses after burning on grasslands should be minimal because the grassland sod root systems and rhizomes remain in place, thereby facilitating rapid vegetation recovery and limiting the possibility of erosion.

Mountain/Plateau Grasslands

The impacts of prescribed burning in mountain/plateau grassland communities are similar to those of the plains grasslands. As such, the prescribed burning of these grasslands also may indirectly affect the soil through removal of litter and soil organic matter. Severe (high-temperature) burns on dry sites (such as the drier grasslands of the Colorado Plateau) may form a water-repellent layer in the soil (USDA 1988). This direct impact to soil infiltration rates typically is avoided by the burn prescription (program design), which evaluates the various parameters that control the burn conditions (fuel loading, fuel moisture content, and soil moisture conditions) and authorizes the burn to proceed only when field conditions are conducive for a successful and effective burn. Like the plains grasslands, soil losses after burning on mountain/plateau grasslands should be minimal because the grassland sod root systems and rhizomes remain in place, thereby facilitating rapid vegetation recovery and limiting the possibility of erosion.

Coniferous/Deciduous Forest

The effect of burning on forest soils is closely related to the varying fire severities (temperatures) that are possible. Burning consumes organic matter on top of the soil and may consume some of that in the soil surface (Fowells and Stephenson 1933), although prescribed burning can be conducted to minimize duff removal (Fuller et al. 1955) and heat penetration into soil. Organic matter reduction is correlated to the reduction in total nitrogen on the forest floor; however, nitrogen accumulation occurs in the 0-to-2-inch soil layer (Wells et al. 1979). Phosphorous, potassium, calcium, and magnesium may increase in the 0-to-2-inch layer of forest soils post-burn (Wells et al. 1979), although Cambell et al. (1977) reported lower potassium levels in soil of burned areas than in unburned control plots. Prescribed burning apparently does not alter soil microorganism populations to the extent that soil metabolic processes would be impaired (Jorgensen and Hodges 1971); rather, the increase of soil temperatures could enhance soil metabolic processes by causing increased rates of nutrient cycling and increased nitrogen availability because of greater activity of decomposing and nitrogen-fixing bacteria.

Severe burning generally occurs only when levels of moisture in fuel, duff, and soil are low. In most cases prescribed fire would not be done under these circumstances. The main influence of severe burning on forest soil physical properties is to decrease soil permeability to water; light burning only slightly affects the physical soil properties (Fuller et al. 1955). If consumption of heavy fuels such as forest slash occurs, fires may decrease soil aggregates and porosity and increase bulk density for up to 4 years (Holechek et al. 1989). Also, some forest soils may develop a temporary resistance to wetting (Holechek et al. 1989), on sites where soil heating was concentrated beneath burning accumulations of heavy fuels. Temporary increases in overland water flow and erosion may result where severe fires denude soil cover and change soil physical properties (Hendricks and Johnson undated, Holechek et al. 1989). Dry ravel, the gravity-induced movement of soil particles, can increase after a fire, with the amount critically related to the steepness of slope, the amount of vegetative and organic cover remaining, and the rate of vegetation recovery (B. Clark, pers. comm. 1989). However, BLM-prescribed fire plans are written with prescriptions that mitigate these negative effects, primarily by burning forested areas under moisture regimes that ensure the maintenance of residual organic cover and/or result in fairly rapid vegetative recovery.

Chemical Methods

Most of the proposed herbicides are liquid formulations that are applied onto the foliage of the targeted vegetation, although soil also may be a major receptor for these chemicals, because whether applied aerially or by truck-mounted and backpack units, some of the applied herbicide is deposited onto the soil. Granular formulations release the herbicide into the soil plant root zone with subsequent chemical uptake and absorption by the targeted plants. Removal of solid stands of vegetation by chemical treatment may result in short-term, insignificant increases in surface erosion that would diminish as vegetation reoccupies the treated site. The speed of site revegetation and the plant composition of the new vegetation would depend on the persistence and selectivity of the herbicide used. Table 3-3 gives a general description of vegetation susceptibility to herbicides.

Although herbicides would not alter a soil's physical properties, there may be indirect effects on soil microorganisms. Depending on the application rate and the soil environment, herbicides can either stimulate or inhibit soil organisms. When herbicide-treated vegetation decomposes, the resulting pulse of organic matter to the soil can support increased populations of microorganisms. Soil microorganisms can metabolize herbicides and often are reported to be responsible for herbicide decomposition (Norris and Moore 1981). However, certain herbicides may inhibit microorganism growth or may produce more toxic effects and increase microorganism mortality rates.

Potential adverse impacts on soils from the use of herbicides primarily are related to possible toxic effects on soil organisms or changes in the community composition of these organisms. Many herbicides bind strongly to soils, thus making them unavailable to soil microbes. Only herbicides that are dissolved in water can be absorbed by microbes and thus impart toxic effects. Those herbicides that are soluble and are not strongly adsorbed to soil will be most available to bacteria. For example, 2,4-D, picloram, and hexazinone are likely to be available, while sulfometuron methyl and triclopyr are minimally soluble and glyphosate is strongly bound to soil, thus making them unavailable to bacteria. Conclusive data on this topic is lacking. Because the use of herbicides does not directly impact the surficial organic layer of the soil structure, this treatment method will not be evaluated on an analysis region basis.

AQUATIC RESOURCES

Ground water is used extensively in the West as a domestic water supply ranging from 90 percent of the population in Arizona, Idaho, Nevada, and New Mexico to less than 50 percent in Colorado, Oklahoma, and Oregon. These water sources vary in depth and aerial extent, and it is not uncommon for BLM lands to be above or near them.

Recent ground water studies have shown a greater number of water supplies to be contaminated with pesticides. Generally, shallower supplies are at greater risk than deeper ones. Contaminants have been shown to include a number of insecticides and herbicides. It is generally recognized that these pesticide contaminants originate from agricultural lands and poor application practices.

The EPA in response to the concern for ground water contamination developed a rating system to delineate ground-water contamination vulnerability. This system, known as DRASTIC (Aller et al. 1985), has been used nationwide and uses factors of depth to water, net recharge, aquifer media, soil media, topography, impact to unsaturated zone, and gross hydraulic conductivity to identify potential vulnerability areas. Figure 2-8 shows those vulnerability areas for the EIS area. Most of the areas in Figure 2-8 are in the low and moderate vulnerability category. However, the information presented in EPA (1987) was constructed with very general data and may over or underestimate vulnerability. For example, areas having higher than normal recharge patterns would not be identified. Such areas would have a higher vulnerability than is shown on Figure 2-8. Care should be taken to make sure the DRASTIC system is applied properly at the site-treatment level.

Manual Methods

Manual methods should not increase peak flows because plant water use would be little affected. Stream nutrients and sediment loads would not increase because litter and duff would be left intact and revegetation would not be suppressed.

Mechanical Methods

The impacts of mechanical treatments on aquatic resources depend on their impacts on soil hydrologic characteristics (discussed under Soils). The following discussion draws on the Soils section impacts analysis to analyze impacts of mechanical treatments to surface- and ground-water resources.

When mechanical treatments greatly reduce vegetation cover, particularly on sloping sites, general and storm runoff of precipitation will increase, with a concomitant increase in overall stream volume and peak volume. Loss of vegetation cover results in erosion potential and subsequent increases in stream sediment loads. Mechanical methods can greatly increase erosion on steep slopes but in practice are most frequently used on gentle slopes where the erosion hazard is limited. When treatments improve the soil infiltration rates, particularly on the more level sites, percolation of precipitation to ground-water sources will increase.

Surface Water

Treatments aimed at reducing woody species and increasing herbaceous species greatly reduce water runoff and erosion and improve soil stability (Branson et al. 1981). Mechanical treatment that allows growth of desirable vegetation with greater cover than before treatment generally should result in decreased runoff and erosion. Therefore, the hydrologic response to control may be greatly dependent on the success of revegetation.

Temporary loss of vegetation cover from mechanical treatments may result in increased erosion and resulting sedimentation from high-intensity summer thunderstorms; however, erosion from winter snow and gentle rainfall will be limited (Lusby 1979). Recovery of infiltration rates and sediment control generally occurs with time, with interim losses depending on the speed of natural or artificial revegetation and replacement of vegetation cover.

Conversion from woody to herbaceous vegetation would not necessarily increase water yields from rangeland watersheds; however, if vegetation cover is maintained by existent and seeded herbaceous plants after mechanical disturbance, runoff and erosion should decrease. Revegetation to replace lost cover would be recommended to reduce potential erosion on windrowed sites. Increased surface roughness after mechanical disturbance may decrease runoff and erosion of some noncrusting soils as long as vegetation cover is not greatly reduced. Coarse-textured soils of many rangelands would continue to maintain similar infiltration and sediment production rates after mechanical treatment (Brown et al. 1985).

Effects vary regionally, as discussed in the Soils section. For example, mechanical methods to control pinyon-juniper are used to increase water yield from selected watersheds (Blackburn 1983). Cabling juniper can increase the amount of total dissolved solids, cations, and anions in runoff compared to untreated lands. Chaining and windrowing pinyon-juniper debris may reduce infiltration and increase streamflow, while double-chaining and leaving debris in place may not affect infiltration and water yield (Gifford 1975, Williams et al. 1972).

Most of the precipitation on sagebrush rangelands falls in the winter as snow or gentle rains and would not be expected to greatly erode disturbed soils. On a watershed scale, disk plowing of sagebrush and drill seeding beardless bluebunch wheatgrass in Colorado quadrupled herbaceous forage production and decreased summer runoff and annual sediment yield by 75 and 80 percent, respectively (Lusby 1979).

Ground Water

Soil aggregate stability, which is necessary for high infiltration rates, is maintained by vegetation cover, which protects the aggregates from raindrop impact, and by soil organic matter, which holds aggregates together (Tate 1987). Direct impacts associated with mechanical disturbance will be highly site- and treatment-specific, but negative effects would be most expected on fine-textured soils lacking organic matter and soil structure with low aggregate stability and a tendency to form a crust. Lack of soil aggregation results in formation of a surface crust, especially on fine-textured soils, which reduces infiltration. Mechanical treatment of crusted soils could be expected to increase infiltration for a while, but effects would be highly dependent on vegetation response after treatment (Cary and Evans 1974).

Coarse-textured soils with initially high infiltration rates and clayey soils with low infiltration rates generally would be expected to change little after direct mechanical disturbance. However, if the mechanical treatment creates furrows or pits to hold water or breaks up a shallow soil layer of limited permeability, infiltration may increase (Brown et al. 1985). The soil disturbance produced by grubbing, bulldozing, and chaining/cabling may be extensive; however, pits created by plant extraction and debris left in place may trap water and limit runoff and erosion (Blackburn 1983).

Effects on ground-water recharge vary regionally by the specific mechanical treatment used and by the success of revegetation, as discussed in the section on Soils. For example, rootplowing of creosotebush sites on southwestern shrubsteppe, coarse-textured Arizona soils reduced runoff by increasing surface roughness and detention storage and by increasing plant cover (Tromble 1976). Rootplowing of creosotebush and seeding grasses in New Mexico resulted in less vegetation cover and lower infiltration rates than in untreated areas (Tromble 1980). Infiltration rates increased on rootplowed areas when seeded grass cover had sufficient time to increase. Infiltration rates decreased after plowing sagebrush and unsuccessfully seeding perennial grass in Nevada (Gifford 1972).

Biological Methods

Studies of grazing effects on water resources usually are limited to discussions of general grazing practices. Grazing may minimally increase stream concentrations of nutrients. Livestock with access to streams may increase bacteria in the water, which should drop to base levels within a few days after livestock removal. Mitigation (stock tanks, alternative water supplies) are intended to prevent water contamination and streambank damage, so risks of contamination of public water supplies should be minimal.

Heavy grazing may increase stormflows by reducing soil infiltration capacity and plant water use. Heavy grazing likely would reduce soil infiltration capacity by 50 to 90 percent (Blackburn 1983, Patric and Helvey 1986, Wood et al. 1987), but infiltration would remain sufficient to absorb all but the most intense rainstorms (Patric and Helvey 1986). Light-to-moderate grazing would reduce infiltration by less than 50 percent. These impacts will vary according to site, depending on size and the grazing management techniques used. In general, impacts should be negligible on smaller sites conducted under careful BLM management plans, and the overall impacts from this method should be negligible.

The potential for impact from biological treatment by insects or pathogens is lower than that from grazing. The vegetative cover of the treatment area will remain constant, decreasing effects on runoff and infiltration. In most cases, the target plants would remain standing, although weakened or unable to reproduce.

Prescribed Burning

Prescribed fire may increase stream nutrients, stormflows, and sediment loads. In general, the amount of increase depends on fire severity.

Slash burns may produce minor increases in concentrations of some nitrogen compounds and cations; however, drinking-water standards should not be exceeded even by severe burns. Underburns and grassland burns would have no significant effect on nutrients.

Moderate slash burns may increase stormflow volumes and peaks to streams by reducing the water used by remaining vegetation. Severe burns would cause greater increases by exposing mineral soil and promoting surface runoff.

Underburns and grassland burns would be light to moderate. Underburns would not affect water quality, and grassland burns would affect it for only a few weeks until grass regrows. These burns would not significantly affect stormflows.

Chemical Methods

Herbicides applied to the land may enter surface or ground water. Herbicide use also may produce minor increases in stream nutrients, stormflows, and sediment yields.

Surface Water Impacts

Entry of herbicides into surface water is discussed in the risk assessment (Appendix E). Herbicides may enter streams during treatment through accidental direct application or drift, or after treatment through surface or subsurface runoff. To pollute the water, they must be present in the water at concentrations high enough to impair water quality at a point of use.

Direct application of herbicides to surface water may occur if aircraft accidentally fly over streams, lakes, or ponds during pesticide application. Risks of direct application are highest for right-of-way maintenance because the linear flight path may cross many streams. Peak concentrations would depend mostly on the application rate and degree of overflight; these have commonly been 2.1 to 2.4 parts per million (ppm) in field studies where overflight was substantial (USDA 1988).

Drift of herbicides into surface water would depend on the application method, existence of buffer zones, and weather. Drift potential would be least for ground-applied pellets and greatest for aerially applied fine droplets. Buffer zones reduce drift impacts on sensitive areas, while wind increases drift impacts. Peak concentrations from aerial spraying of fine droplets with 50- to 70-foot buffer zones commonly have been 0.130 to 0.148 ppm in field studies (USDA 1988). Mitigation requires buffers of 100 feet (aerial), 25 feet (ground-vehicle), and 10 feet (ground-hand), and nozzles producing large (200-micron) droplets, so peak concentrations in surface waters from herbicide drift should rarely exceed 0.05 ppm (Appendix E). Large droplets do not travel as far as small droplets, so the larger the droplet size, the less extensive the drift during application.

After treatment, herbicides may enter streams by subsurface flow or by movement in ephemeral channels. Key factors that would affect peak concentration include the presence of buffers, storm size, herbicide properties, soil properties, and downstream mixing and dilution.

Impacts would be minimal in perennial and intermittent streams because they are protected by 10-foot (ground-hand), 25-foot (ground-vehicle), and 100-foot (aerial) buffers. Herbicides applied along these streams must move through the buffer in subsurface flow and are subject to dilution and mixing in transit. Impacts may occur, however, in ephemeral streams, which often do not have buffers. Herbicides applied directly to them usually are picked up in streamflow by the first storm large enough to create flow in the channels.

Large storms rarely produce high concentrations because herbicides are diluted by large water volumes, while small storms may not produce enough flow to move herbicides into streams. Therefore, intermediate storms often produce higher concentrations of pesticides in streams relative to the other two situations because the resulting streamflow is sufficient to mobilize the herbicides but not large enough to substantially dilute the material.

The amount of herbicide available for movement from the site of application with surface or infiltrating water will be determined, in part, by the herbicide's persistence. Herbicide persistence is usually expressed in terms of "half-life." This is the typical length of time needed for one-half of the total amount applied to break down to substances that are no longer of toxicological concern. While a herbicide's soil half-life in practice is influenced by local conditions such as soil type and climate, it is useful for describing the relative rates at which various herbicides are broken down in the soil. Table 3-6 gives field half-lives for the 19 herbicides proposed for use in the EIS. Half lives are divided into three categories, "non-persistent" herbicides are defined as having a typical soil half-life of less than 30 days, "moderately persistent" herbicides as having a typical soil half-life of 30 to 100 days, and "persistent" herbicides as having a typical soil half-life of more than 100 days. These values are considered most representative of the values reported in the literature, as the rate of degradation by natural processes is not only dependent on herbicide chemistry, but also environmental factors. Sunlight, temperature, soil and water pH, microbial activity and other soil characteristics may effect the breakdown of herbicides. Soil organic matter, and soil properties such as moisture, temperature, aeration, and pH all affect microbial degradation. Microbial activity increases in soils that are warm, and moist with a neutral pH. In addition to microbial action, chemical degradation of herbicides can occur by reaction with water, oxygen or other chemicals in the soil. As soil pH becomes extremely acidic or alkaline, microbial activity usually decreases, however these conditions may favor rapid chemical degradation. Sunlight can also be an important pathway of herbicide degradation. Some of the factors that affect herbicide photodegradation include the intensity and spectrum of the sunlight, length of exposure, the application site or method, and the properties of the herbicide that make it more or less stable when exposed to sunlight.

In addition to degradation, these herbicides may be unavailable for movement with surface or infiltrating water due to volatilization and plant uptake. Volatilization is the loss of herbicide vapors to the atmosphere from plant and soil surfaces. The rate of volatilization is determined by the herbicide's vapor pressure and how strongly it is adsorbed. Vapor pressures for the herbicides proposed for use in the EIS are given in Table 3-6. The higher the vapor pressure the greater the potential for loss due to volatilization. Also, higher temperature usually results in increased volatilization. The degree of plant uptake is partially determined by the herbicide's water solubility. The more water soluble a herbicide is, the greater the possibility for plant uptake. In addition, for those herbicides applied to foliage, interception of the spray by foliage will reduce the amount of herbicide reaching the soil surface where it is available for movement with surface or infiltrating water. Foliar residues are usually more susceptible to photodegradation and volatilization. By contrast, those herbicides applied directly to the soil surface have a greater possibility of movement with surface or infiltrating water.

Soil adsorption is also important in determining mobility in surface or infiltrating water. Adsorption of a herbicide varies with the properties of the chemical, as well as the soil's texture (relative proportions of sand, silt, and clay), moisture level, and amount of organic matter. Soils high in organic matter or clay tend to be the most adsorptive, and sandy soils low in organic matter least adsorptive. Therefore, the higher the organic matter content of the soil, the more adsorptive the soil and the less likely the herbicide is to move from the point of application. The degree of herbicide adsorption is often represented by the ratio of the amount of herbicide in the soil water to the amount adsorbed to the soil. This ratio is called the adsorption coefficient or Kd. The degree of adsorption depends on both the herbicide and the soil properties. The Kd for a herbicide is soil specific and will vary with soil texture and organic matter content. Another herbicide adsorption coefficient, which is less soil specific is called the Koc. The Koc is the Kd divided by the percent of organic carbon in the soil, a major component of soil organic matter. The higher the value for Kd or Koc, the greater the adsorption. Water solubility and Koc values for herbicides proposed for use in the EIS are given in Table 3-6.

Groundwater contamination occurs when herbicides move with the infiltrating water through the soil profile to the water table. The closer the water table is to the surface, the more likely that it may become contaminated. In some situations, herbicides that are tightly bound to the soil may only move a few inches from the point of application regardless of the amount of infiltrating water, whereas in other situations herbicides have been shown to move many feet. Herbicides that are highly water soluble, relatively persistent, and not readily adsorbed by soil particles (low Kd or Kos) have the greatest potential for movement. In addition, relatively level sandy soils low in organic matter are the most vulnerable to groundwater contamination due to their lower adsorptive capacity and higher infiltration rates. Soil characteristics and environmental conditions vary widely over the proposed treatment areas in the EIS. Herbicide properties which determine the likelihood of movement with infiltrating water and a leaching index based upon the work of Goss (1988) are given in Table 3-6. The leaching index is a relative ranking of the 19 herbicides based upon their chemical properties only. The higher the value, the greater the potential that the herbicides will move through the soil profile with infiltrating water. This ranking suggests that imazapyr, clopyralid, picloram, tebuthiuron, and metsulfuron methyl have the greatest potential for movement, with glyphosate being the least mobile. Prediction of actual amounts of these herbicides that may reach groundwater must also consider the method and rate of application, as well as the soil characteristics and other environmental and climactic factors described above.

Table 3-6

Chemical and Environmental Properties of Herbicides Used on Rangeland

Herbicides	Soil Half-life days (range)[1]	Solubility mg/1	Koc ml/g	Leaching Index[2]	Vapor Pressure mm Hg
Non Persistent (half-life of less than 30 days)					
2,4-D acid	10 (2-16)	890	20	2.70	8.0x10-6
2,4-D esters	10 (2-41)	1E[3]	1000E	1.00	
Dicamba salt	14 (3-35)	400000	2	4.24	0
Mefluidide	2 (2)	180			1.0x10-4
Sulfometuron methyl	20 (20)	70(pH7)[4]	78(pH7)	2.74	6.0x10-16
Moderately Persistent (half-life of 30 to 100 days)					
Atrazine	60 (18-120)	33	100	3.56	2.9x10-7
Bromocil acid	60 (60-360)	700	32	4.44	3.1x10-7
Clopyralid amine salt	30 (12-70)	300000E	6	5.46	0
Diuron	90 (30-328)	42	480	2.58	6.9x10-8
Glyphosate amine salt	47 (21-60)	900000E	24000E	-0.64	0
Hexazinone	90 (30-180)	3300	54	4.43	2.0x10-7
Imazapyr acid	90 (90-712)	11000	100E	6.45	less than 1x10-8
Picloram salt	90 (20-277)	200000E	16	5.46	0
Simazine	60 (11-149)	6	130	3.49	2.2x10-8
Triclopyr ester	46 (30-90)	23	780	1.84	1.3x10-6
Persistent (half-life of more than 100 days)					
Chlorsulfuron	160 (28-160)	7000(pH7)	300(pH7)	3.36	4.6x10-6
Metsulfuron-methyl	120 (14-180)	9500(pH7)	35(pH7)	5.11	2.5x10-12
Tebuthiuron	360 (13-450)	2500	80	5.36	2.0x10-6

[1] Most representative half-life value and range of reported values (Wauchope et al. 1991).

[2] Relative ranking of leaching potential using the equation L.I. = Log(Half-Life)*(4-Log(Koc)), (Goss 1988).

[3] E-estimate, probable error: solubility: less than 3X, Koc: 3-5X, or wide range in reported values (Wauchope et al. 1991).

[4] Solubility and Koc are a function pH, values given are for pH7.

Surface runoff can carry herbicides mixed in water or bound to eroding soil. The severity of herbicide runoff depends on several factors, many of which influence the rate of water infiltration into the soil. These include the grade or slope of an area, the texture and moisture content of the soil, the amount and timing of rainfall, and the presence of vegetation or plant residues. These conditions vary widely over the proposed treatment areas in the EIS. Herbicide properties which determine the likelihood of movement with surface water are given in Table 3-6. For conditions resulting in moderate to high infiltration rates, the likelihood that the herbicide will remain close to the soil surface may determine availability for movement with surface runoff. Under these conditions, glyphosate, diuron, triclopyr, and chlorsulfuron have the greatest potential to be available for movement with runoff. However, the low water solubility of chlorsulfuron, and diuron would indicate that the majority of the runoff loss would be associated with soil erosion. Without soil erosion, little runoff loss would be expected. For conditions where infiltration is low, those herbicides with high water solubility and low Koc values would be most likely to move with surface runoff. These include dicamba, clopyralid, and picloram, as well as the relatively persistent metsulfuron-methyl. As with infiltration, prediction of actual amounts of these herbicides in runoff must consider the method and rate of application, as well as the soil characteristics and other environmental and climactic factors described above.

Herbicide movement in ephemeral channels is little affected by herbicide mobility because buffers are seldom used and herbicides may be applied directly to the channel. Herbicides can be mobilized in solution or with sediment. Peak concentrations in field studies have ranged from 0.18 to 0.55 ppm (USDA 1988).

Dilution and mixing sharply reduce herbicide concentrations downstream through water inflow and turbulence. As watershed size doubles, peak herbicide concentration should drop to one-quarter of its initial level (Neary et al. 1983). For example, a peak concentration of 0.4 ppm in an unprotected ephemeral stream with a 10-acre watershed will likely drop to 0.04 ppm by the time it reaches a perennial stream with a 50-acre watershed.

Mitigation requires buffer zones along perennial and intermittent streams. Mixing and dilution sharply reduce concentrations delivered by ephemeral streams. Normal application of herbicides at typical rates may produce sporadic peak concentrations of some herbicides in small, headwater perennial streams. These concentrations may range up to 0.04 to 0.05 ppm in some cases. Even applying EPA's most stringent drinking-water standard (0.1 ppm for 2,4-D) across the board, these concentrations pose minimal risks to water quality for public health or aquatic biota. Risks from accidental direct application may be high on some corridor maintenance projects treated aerially. Because picloram affects many vegetable crops at concentrations as low as 0.010 ppm (Baur et al. 1972), it should be used with care near water used for irrigation.

Ground-Water Impacts

After treatment, herbicides may move through the soil and into underlying ground-water aquifers by leaching. To pollute ground water, they must then move laterally at concentrations high enough to impair water quality at a point of use. Key factors affecting peak concentration are herbicide properties, soil, depth to water table, and distance to the point of use. Applied at typical rates, herbicides should never occur in ground-water supplies at concentrations exceeding a small fraction of EPA's most stringent drinking-water standards.

Herbicide mobility and persistence greatly affect potential for leaching. Mobility depends on solubility and adsorption; persistence depends on degradation mode and rate. As discussed earlier, the most potentially mobile herbicides are 2,4-D, picloram, and, to a lesser extent, hexazinone, and the most persistent ones are tebuthiuron, picloram, and glyphosate. Mobility and persistence properties suggest that herbicides with at least a moderate leaching potential include 2,4-D, dicamba, hexazinone, imazapyr, picloram, and tebuthiuron.

Herbicides move most easily through sands, which are the most porous soils and have the least adsorption potential. The potential for ground-water contamination increases as the depth to the water table and the distance to the point of use decrease.

Field studies of herbicides applied at typical rates have shown that sulfometuron methyl and triclopyr did not leach to shallow ground water, and that hexazinone reached peaks of less than 0.024 ppm. Applied at typical rates, picloram concentrations in shallow ground water should be less than 0.002 ppm.

FISH AND WILDLIFE

Wildlife species depend directly on vegetation for habitat, so any change in the vegetation of a particular plant community is likely to affect the wildlife species associated with that community. Any change in community vegetation structure or composition is likely to be favorable to certain animal species and unfavorable to others (Maser and Thomas 1983). The key to understanding the effects of vegetation manipulation on wildlife involves an understanding of the vegetation structure, production, flowering, and fruiting of the community; these characteristics relate to seasonal cover and food requirements for particular animal species and predators dependent on them. These characteristics also respond to a particular vegetation manipulation.

Plant communities on many western rangelands are no longer pristine and therefore do not support pristine populations of wildlife species. Many rangeland plant communities have alien herbaceous weeds or a higher ratio of woody to herbaceous perennial vegetation than under pristine conditions. These vegetation conditions may favor certain wildlife species, such as the chukar partridge, which depends on the alien annual grass, cheatgrass, for food (Weaver and Haskell 1967), or they may disfavor other species, such as the pronghorn antelope, which require mixed-plant communities, rather than those plant communities dominated by a few woody or herbaceous species (Yoakum 1975). In general, the greater the diversity of the plant community, the greater the diversity of the associated animal community (Gysel and Lyon 1980).

Therefore, any change in vegetation community structure or composition affects resident fish and wildlife populations. The effects of vegetation manipulation on wildlife depend on vegetation structure, production, and phenology of the community. Because these characteristics relate to seasonal cover and food requirements for particular animal species—and the predators that depend on them—and because these characteristics respond differently to different vegetation manipulations, effects on fish and wildlife from vegetation management would be both positive and negative, depending on the species affected and the type of treatment used. Treatments that reduce runoff and sedimentation would have positive benefits for fish and aquatic wildlife, and there would be shifts or changes in forage and habitat for wildlife, depending on the species. For example, an improvement in deer winter range could result. Vegetation treatments can negatively affect aquatic habitats by causing changes in food supply, water temperature, water chemistry, and bottom composition. Elimination of multistoried vegetation along streambanks would increase water temperature and reduce the supply of invertebrates used as a food source for fish. However, no treatments will eliminate this streamside vegetation to any significant degree, and in general an improvement in riparian vegetation is expected as a result of upland treatments improving watershed conditions. Expected results are an increase in streamside vegetation, a cooling of water temperatures, and an improvement in the depth and quality of fish habitat, including invertebrate populations and other food sources.

Studies determining the effects of vegetation manipulations on wildlife in riparian areas were not found in the literature, but impacts on wildlife species will be identified in individual environmental analyses, when site-specific proposals are selected.

There are data gaps in the understanding of the effects of specific land treatments on the multitude of wildlife species. Therefore, it is very important to monitor the specific impacts of a particular treatment on the wildlife community being impacted. These monitoring studies should be accomplished in cooperation with the state wildlife management agency and the results made available to other interested agencies and personnel.

Manual Methods

Manual methods have the advantage of being highly selective, thus avoiding the potential loss of valuable habitats (Vallentine 1971). Manual methods, however, could negatively affect those wildlife species that depend on the target plants for food or cover. Although this method of vegetation control may open a young forest canopy, it may not benefit larger mammals because the unremoved material can impede movement. These obstacles may restrict deer and elk from using any increases in available forage. Smaller animals also may be affected, particularly birds or small mammals nesting in or at the base of individual target plants. Conversely, accumulated material resulting from manual control could provide cover for smaller mammals and birds, therefore increasing their use of an area. The impacts created by manual treatments should be relatively insignificant. The vegetation communities are generally so expansive, and manual labor so expensive, that the potential for significant changes is not likely.

Sagebrush, Desert Shrub, Southwestern Shrubsteppe, Plains Grasslands, and Mountain/Plateau Grasslands

These vegetation communities are generally very expansive. Any impacts of manual treatments would be very site-specific and insignificant on a programwide evaluation. There would be no significant overall impact to wildlife from manual vegetation treatments in these communities, any site-specific impacts will be evaluated in the site-specific environmental analysis. Larger scale treatments would generally have the same wildlife impacts as mechanical methods.

Chaparral-Mountain Shrub, Pinyon-Juniper, and Coniferous/Deciduous Forests

These vegetation communities are often densely vegetated and may be more practically and economically treated by manual methods. If areas treated by manual methods are limited to small areas, most impacts would be beneficial through increase in habitat diversity in a densely vegetated environment. Size, shape, and spacing of the openings will determine the degree of benefits to wildlife. Excessive or poorly planned thinning of coniferous forests can be detrimental to elk, mule deer, black bear, and other wildlife through loss of thermal and escape cover. Conversely, a well-planned thinning that considers size, spacing, and topography can be beneficial by improving the food-cover relationship. Larger sized treatments would have impacts similar to mechanical treatments.

Mechanical Methods

Mechanical treatments have traditionally been applied most frequently to decrease woody plant cover and increase production of grasses (see discussions of effects of treatments on vegetation). Some species are favored by these conversions, and some are disfavored. Conversion of sagebrush-dominated rangelands in Oregon to more open grasslands is associated with a substantial increase in the pronghorn antelope population (Yoakum 1975), but has been detrimental to sage grouse populations (Call and Maser 1985). Much of the literature on the effects of range vegetation manipulations on wildlife considers treatments designed to increase grass production.

Fish are also in a unique situation. Improperly applied treatment could result in increased siltation from mechanical treatments which could result in loss or degradation of spawning substrate. However, once mitigation is applied, the treatment would be beneficial to the condition of the watershed and ultimately improve habitat for fish.

Mechanical methods can result in soil compaction, damaging the subterranean habitat used by certain burrowing animals. As with manual methods, accumulated material can hinder movement of the larger mammals, but removal of this material would reduce potential habitat niches for many small mammals and birds. Habitat shifts or changes as a result of downed material could last for as long as two decades, assuming normal decomposition rates. It is important to note that mechanical treatments can be selected and structured to increase and decrease other vegetation components and thus favor or disfavor different wildlife species. These treatments can be considered tools for wildlife habitat management when vegetation responses and habitat requirements are understood. Accordingly, determinations on whether particular vegetation treatments will increase or decrease wildlife populations must be made on a site-specific basis, taking into account specific vegetation and animal information. In general, mechanical treatments can be beneficial for wildlife if the treatment areas are arranged in strips and patches and if methods are selected that increase browse and forage availability. Also, negative impacts can be lessened if the period of treatment avoids the bird nesting season and other critical seasons when loss of cover would be critical to wildlife, for example, during critical reproductive periods and prior to severe winter weather conditions. The following discussion presents examples of the relatively limited research on wildlife responses to vegetation manipulations through mechanical treatments.

Sagebrush

Although few wild vertebrates require sagebrush habitats, sagebrush is so widespread that it is a major habitat type in the West (McEwen and DeWeese 1987). The quality of sagebrush habitat for wildlife can vary tremendously and can be a complex situation for analysis. Sagebrush habitat may be critical in certain situations for sage grouse and for wintering big game species. In areas of limited rainfall and forage production the thermal cover provided by sagebrush may be critical to deer and other wildlife survival (W. A. Molini, pers. comm. 1990). Any treatments on critical habitat must receive careful site-specific analysis to avoid significant negative impacts. The sagebrush situation also is complicated by the apparent increase in density and the expanded acreage resulting from human-caused disturbances, creating an "unnatural" existing situation before treatment. Conflicts may arise between maintaining the existing wildlife community and recreating a "natural" wildlife community. As a general rule, negative impacts will be minimized if sagebrush is not removed in large, expansive blocks and if treatment areas are composites of small 40- to 60-acre units with irregular outlines and configurations. In sage grouse habitat, the width of removal areas should not exceed 100 feet.

The design of control units in the sagebrush region is critical to the consequences of the action. The cumulative effect of past control activities must be considered in assessing current and future actions. These two considerations are extremely critical in manipulations of sage brush in sage grouse habitats. The size of control units, the juxtaposition of remaining sagebrush stands, the comparative densities and height of the sagebrush, and the juxtaposition of other habitat components (drinking water and wet meadows) are all significant to the potential impacts. Site-specific analysis and project design are crucial to the success of sagebrush treatment for wildlife. If sagebrush is properly controlled and the end result is an increased diversity and production of a variety of perennial grasses, and a variety of forbs and shrubs, wildlife diversity and abundance also should increase. However, sagebrush control in Nevada by root plowing generally has resulted in the loss of all brush species, including desirable browse species (W. A. Molini, pers. comm. 1990). This would result in a significant adverse impact to big game and other brush-related species and should be considered for mitigation where loss of brush species creates significant adverse impacts. This points out the critical value of the site-specific analysis and in-depth consideration of all ecological values before implementing a proposed treatment.

Desert Shrub

Plant control by mechanical means in desert shrubland must usually be followed by revegetation, which is normally unsuccessful because of low and erratic precipitation. Plant control treatments run the risk of reducing perennial plant cover and increasing weedy annual cover. These possible vegetation changes are expected to also negatively affect indigenous wildlife species. Vegetation manipulation of desert shrubland is generally not recommended.

Southwestern Shrubsteppe

Mechanical treatments have most frequently been applied to reduce the cover of woody species, such as mesquite, that have invaded the semidesert grassland. Increasing structural diversity of vegetation by controlling shrubs and increasing understory species in strips and patches should increase bird diversity and density. Mesquite control that selectively leaves areas important for browse and cover will be much more beneficial for deer than extensive control projects (Severson and Medina 1983).

Rootplowing woody species and seeding perennial grasses increased cotton rat populations in Texas (Guthery et al. 1979). However, sites converted to African lovegrasses in Arizona had much lower diversity and abundance of grasshoppers, rodents, and birds than native grassland sites (Bock et al. 1986). Only sites that lack native grass cover will be considered as candidates for lovegrass seeding after woody plant control, and only if lovegrass already occurs within the watershed.

Smith (1984) compared bird use of undisturbed, crushed, and tebuthiuron-treated creosotebush in Arizona. Black-throated and Brewer's sparrows foraged opportunistically, while verdins avoided crushed plots and vesper sparrows avoided control plots. Mechanical treatments opened up small areas in the creosotebush community, which were used as nesting sites for Cassin's sparrows and feeding sites for grass-eating flocks. Large-scale conversion to grasslands may be detrimental to Gambel's quail, but beneficial to scaled quail, and improve the potential for reintroduction of aplomado falcon.

McCormick (1975) compared small game use of areas invaded by mesquite with areas where mesquite had been controlled to 16 to 100 trees per acre. Both areas supported a native perennial grass and forb understory. Use by doves, quail, and cottontail rabbits was less on the mesquite-controlled areas, while jackrabbit use was similar on controlled and uncontrolled areas. McCormick recommended that mesquite be controlled only where density exceeds 100 trees per acre and advised limited control of small, dense mesquite stands in the drainage areas (100 to 324 trees per acre) to maintain a habitat for these small game species. Germano (1978) compared use by various animals on mesquite-dominated areas, mesquite-free areas, and mesquite woodland with clearings. Mesquite with clearings produced more observations of jackrabbits, antelope, quail, and lizards than the mesquite-free areas. Mesquite-dominated areas had more use by jackrabbits and lizards than did the mesquite-free areas. Total clearing of mesquite may reduce vegetation structural diversity and use by wildlife.

Chaparral-Mountain Shrub

Deer is the only species from the chaparral type of plant community that has been studied extensively (Cable 1975). Deer populations are low in dense brush stands with little understory. Opening up dense stands would generally be beneficial for wildlife; however, some brush should be left uncleared to provide escape cover for deer. In Arizona, deer spent much less time on chaparral cleared by rootplowing and herbicide spraying than in untreated areas (Urness 1974). However, in this study, deer used the cleared areas mainly for feeding. Foraging efficiency was probably high because of high herbaceous plant production compared to uncleared areas. Shrub control treatments resulted in a loss of cover but also brought about a compensating increase in forage production for deer in chaparral. Urness (1974) recommended leaving some brush, clearing less than 50 percent of the area, and clearing in strips no wider than 437 yards. Where brush is so dense that understory forage is lacking, deer and elk use can be increased by brush control.

Mechanical treatments have been used to induce sprouting of brush species and to increase forage availability for deer and elk. However, shrubs intolerant of these treatments may produce less forage after treatment. When chaparral species are controlled by mechanical means, wildlife use should increase as understory production increases and suitable areas are left intact to provide cover.

Pinyon-Juniper

Pinyon-juniper areas with limited understory diversity are usually treated by mechanical means to increase grasses, shrubs, and forbs. Estimating wildlife populations response to these treatments—compared with their behavior in undisturbed areas—is difficult and usually depends on the vegetation diversity before and after treatment in relation to that of undisturbed stands. As in sagebrush removal, negative impacts from pinyon-juniper removal would be minimized by treating patches, resulting in a mosaic of thermal and hiding cover and open foraging areas. For example, chaining pinyon-juniper in Colorado greatly reduced tree cover and did not change shrub cover, but it increased cover of grasses and forbs (Sedwick and Ryder 1987). However, only one of the most common species of breeding birds (chipping sparrow) used the chained plots, while seven other common species used the undisturbed plots. Chaining reduced bird use and species diversity. Foliage- and timber-searching, aerial-foraging, foliage-nesting, and cavity-nesting birds infrequently used the chained plots, while ground-searching and ground-nesting species regularly used them. Evans (1988) suggested that negative effects of chaining on cavity-nesting birds can be minimized by leaving cavity trees near the edge of the treatment zone. Old growth pinyon and/or juniper stands may offer unique and valuable wildlife habitats, adding to the variety within pinyon and juniper stands. When planning site-specific treatments, these old growth communities should be recommended to be left standing as islands and edge communities to the chained or treated areas.

Chaining pinyon-juniper has generally increased small mammal use (Baker and Frischknecht 1973, Sedwick and Ryder 1987). The increased populations of species such as deer mice and chipmunks are thought to be a result of increased grass and forb cover and associated abundance of seeds and arthropods (Sedwick and Ryder 1987). Although black-tailed jackrabbits and desert cottontail may prefer cabled pinyon-juniper over untreated areas (Howard et al. 1987), cottontail rabbits may benefit by leaving a density of 68 to 80 downed trees or living shrubs per acre (Kundaeli and Reynolds 1972). Smith and Urness (1984) also emphasized the importance of leaving downed trees onsite for cover for small mammals. Conversion of juniper woodland-shrubland to wheatgrasses may have negative effects on hawks by reducing cover and the abundance of jackrabbits as well as nesting sites (Howard and Wolfe 1976).

Removal of pinyon and ponderosa pine, as well as juniper and oak, decreased sightings of Merriam's turkey in Arizona (Scott and Boeker 1977). This study recommended strip clearing of trees and retention of mature ponderosa pine for roosting sites to minimize effects on turkey populations.

Mechanical control of pinyon and juniper may increase its use by mule deer for a number of years (Tueller 1976). However, deer use of treated areas is encouraged by the proximity of undisturbed areas for cover (Tausch 1973). Terrel (1973) observed increased deer use in undisturbed areas adjacent to chained areas. Short et al. (1977) found that extensive tree clearing decreased elk and mule deer use, while patch cutting increased use. Evans (1988) suggested irregular chainings to create more edge and patch clearing as ways to increase habitat diversity and wildlife use of pinyon-juniper control projects.

Plains Grasslands

Mechanical treatments most frequently have been applied to reduce cover of woody species, such as mesquite. Increasing structural diversity of vegetation by controlling shrubs and increasing understory species in strips and patches should increase bird diversity and density. Mesquite-dominated rangelands are considered important habitat for mule deer and white-tailed deer. Deer will use these cleared areas less frequently because of reduced food and cover.

Mountain/Plateau Grasslands

The few studies that consider effects of plant control on wildlife on mountain/plateau grasslands are concerned with sage grouse, gophers, or prairie dogs. Mechanical treatments most likely would affect animal density in these areas because of reduced cover and forage.

Coniferous/Deciduous Forests

The literature on effects to wildlife species in this area is sparse; mechanical control will lower the seral stage of the undergrowth in the treatment area, and may affect the biodiversity in the vicinity. When used in these forest-habitat types, this method can improve seed germination, thereby increasing available forage. Pretreatment analysis should include the effects of the proposed treatment on old growth forest habitats and spotted owl habitat.

Biological Methods

BLM may consider using grazing animals, insects, and pathogens as biological methods of vegetation treatment. Typical grazing, as discussed in much of the available literature, generates many impacts on wildlife populations. These impacts may be direct, when wildlife and livestock share food preferences, or indirect, when livestock cause some modification, such as vegetation changes, to the ecosystem. These possible negative effects can be avoided by using grazing systems for biological control that help to increase or maintain wildlife diversity.

Grazing animals may have many effects on wildlife. In riparian areas, grazing can affect songbirds by changing the vegetation composition of the community, thus changing the songbird community because of different habitat requirements. Waterfowl may be similarly affected, especially during breeding and nesting periods. Fish populations may be affected because of changes in stream shading and resulting changes in water temperature. In non-riparian areas, larger game animals may compete directly with livestock for forage. Elk and cattle tend to show the same forage preferences, as do sheep, pronghorn antelope, and deer. Deer use browse, which may be an important forage for cattle in some areas. Biological control using livestock should take these factors into consideration when planning a grazing system (Humphrey 1962).

There also are many positive effects on wildlife from biological control by grazing animals. Small mammal diversity will increase up to a point with the use of grazing as a biological treatment method (Dwyer et al. 1984). Rotation grazing systems have been cited as beneficial for certain wildlife species. The sandhill crane (Grus canadensis) prefers the larger insect population found in grazed areas, and deer (Odocileus) are attracted to the grass regrowth in a recently grazed pasture. In sagebrush regions, cattle grazing can increase the production of bitterbush, a shrub that is palatable to deer. Grazing cattle or sheep in the spring or early summer can increase winter browse for elk (Vallentine 1980). These effects may become noticeable on larger areas being treated by grazing animals.

The impacts of biological treatment by insects and pathogens on wildlife will generally be slight. In most cases, the target plants will remain standing, although weakened or unable to reproduce, thus reducing noticeable and immediate effects. Over time, the composition of the plant community may change, as the native plants regain their competitive edge, possibly improving wildlife habitat. Any insects or pathogens used for general vegetation treatment should be carefully tested for host specificity, thus reducing or eliminating possible negative effects on native vegetation that may be important in wildlife habitats.

Prescribed Burning

Many prescribed fires are staged with the principal objective of modifying some aspect of the vegetation for wildlife. Yet, changes in forage quality and quantity, interspersion of new feeding areas with areas providing cover, and rejuvenation of decadent browse plants are all reasons for burning for wildlife. Changes in vegetation structure and dispersion of burned areas are key factors when planning prescribed fires for wildlife purposes.

Many different wildlife (vertebrate) responses to fires have been reported. Fire effects on wildlife vary with: (1) animal species complex, (2) mosaic of habitat types, (3) size and shape of fire-created mosaic, (4) fire intensity, (5) fire duration, (6) fire frequency, (7) fire location, (8) fire shape, (9) fire extent, (10) season of burn, (11) rate of vegetation recovery, (12) species that recover, (13) change in vegetation structure, (14) fuels, (15) sites, and (16) soils. In addition, all the other factors that alter fire effects on vegetation and soils will influence wildlife responses to burning.

In general, fire affects wildlife by direct killing, alteration of immediate postfire environments, and postfire successional influences on habitat (Lyon et al. 1978). Direct killing of vertebrates by prescribed burning is rare (Lyon et al. 1978). For those species that cannot flee a burn, the most exposed habitat sites are dry, exposed slopes, hollow logs with a lot of exposed wood, burrows less than 5 inches deep, lower branches of trees and shrubs, and poorly insulated underground/ground nesting areas (Lawrence 1966, as cited by Peek 1986). Effects of prescribed burning on ground cover depends on fire severity: low severity fires on wet sites would remove less cover than high severity fires on dry sites. Escaped prescribed burns may accidentally destroy riparian habitats and impact aquatic resources, causing losses of wildlife through exposure, total loss of habitat, and through increased sedimentation of the aquatic habitat caused by unchecked overland flow and destabilized stream channels.

Fire mainly affects wildlife through habitat alteration (Wright 1974a). Fire may have a positive effect on wildlife habitats by creating habitat diversity, by recreating lost or degraded habitats for indigenous species, and by allowing for the reintroduction of extirpated species when habitat degradation was significant to their extinction. Immediate postfire conditions raise light penetration and temperatures on and immediately above and below soil surfaces and can reduce soil moisture (Lyon et al. 1978). Burning of cover and destruction of trees, shrubs, and forage modify habitat structure (Lyon et al. 1978, Peek 1986). The loss of small ground cover and charring of larger branches and logs (with diameters greater than 3 inches) can negatively affect small animals and birds. Early, vigorous vegetation growth immediately after a fire alters feeding and nesting behaviors (Lyon et al. 1978). Postfire plant and animal succession effects creating seral and climax mosaics in habitat cannot be generalized in their effects on wildlife (Lyon et al. 1978, Peek 1986). Negative impacts can be lessened if the period of treatment avoids the bird nesting season and other critical seasons when loss of cover would be critical to wildlife; for example, during critical reproductive periods and prior to severe winter weather conditions.

Sagebrush

No significant changes in small mammal species were observed for 1-year postburn in sagebrush-grassland (Frenzel 1979, as cited by Starkey 1985), but shrews and other species with narrow niches require patches of unburned vegetation to sustain populations, although total small mammal numbers may not be altered (McGee 1982). Habitat changes induced by fire may temporarily decrease the number and diversity of small mammals in sagebrush vegetation (Klebenow and Beall 1977). By increasing habitat diversity, associated bird communities may be increased by burning (Starkey 1985). Low fire frequencies may be useful in maintaining productive habitat for sage grouse (Peek 1986). Large intense fires affect other bird species, such as yellowthroat, yellow-breasted chat, Traill's flycatcher, and yellow-billed cuckoo, because they require dense shrub cover (McAdoo and Klebenow 1978). Conversely, sparrow species require relatively less shrub cover (McAdoo and Klebenow 1978). Because chucker partridge rely heavily on cheatgrass, fire could conceivably be used to improve the habitat for this species (Wright and Bailey 1982). Prescribed burning in these types also may improve the habitat for higher numbers of sheep, pronghorn antelope, and mule deer (Klebenow 1985). Fire suppression has favored the expansion of mule deer populations in some sagebrush areas because of the increased forage or cover (Crouch 1974). In areas of limited rainfall and forage production the thermal cover provided by sagebrush may be critical to deer and other wildlife survival (W. A. Molini, pers. comm. 1990).

Desert Shrub

Plant control by prescribed burning in desert shrubland usually must be followed by revegetation, which is normally unsuccessful because of low and erratic precipitation (Jordan 1981, Blaisdell and Holmgren 1984). Plant control treatments run the risk of reducing perennial plant cover and increasing the cover of weedy annuals. These possible vegetation changes also are expected to negatively affect indigenous wildlife species. Vegetation manipulation of desert shrubland is generally not recommended.

Southwestern Shrubsteppe

Fire can play a role in changing wildlife habitat in southwestern shrubsteppe (Wagle 1981). More black-tailed jackrabbits and bird calls were observed in undisturbed and partially cleared mesquite stands than on adjacent cleared areas (Germano et al. 1983). Wright and Bailey (1982) indicated that fire in desert grasslands is harmful to Gambel's quail but beneficial to scaled quail. Renwald et al. (1978) reported that some honey mesquite trees and lotebushes should be protected during controlled burning to ensure adequate cover. However, Bock and Bock (1978) found more raptors and game birds on 1-year-old burns in sacaton grasslands. Total small mammal populations were reduced. Their study suggested that fire would benefit the wildlife of sacaton communities if mixed-age stands were maintained. In southwestern mesquite-tobosa communities, Renwald (1977) found the highest lark sparrow nesting densities in recently burned areas, and Sontiere and Bolen (1976) reported similar findings with mourning doves.

Fire suppression in desert grasslands has probably allowed mule deer and white-tailed deer to expand their range and increase numbers (Wright and Bailey 1982). Controlled burning can favor some deer food plants and maintain the mesquite-grassland edge (Severson and Medina 1983).

Chaparral-Mountain Shrub

Even though chaparral brush fires burn fast and hot, most studies indicate that little direct mortality of wildlife occurs (Howard et al. 1959, Lillywhite 1977). Controlled burning that maintains diversity and productivity of chaparral can benefit wildlife, while grass conversions reduce vertebrate fauna (Lillywhite 1977). Burning chaparral can shift rodent species from chaparral- to grassland-dominant areas (Wright and Bailey 1982). Rotational burning can greatly improve deer browse and increase deer densities in chaparral communities (Bissell 1955, Wright and Bailey 1982).

Pinyon-Juniper

While complete type conversion of pinyon-juniper sites to grassland may reduce wildlife diversity, creating a mosaic of successional stages with prescribed burning can be beneficial to wildlife (Severson and Medina 1984). Spotty burning probably would favor the greatest diversity of rodent and bird species (Wright and Bailey 1982). Fire suppression has also favored expansion of mule deer populations in some pinyon-juniper areas because of the increased forage or cover. Deer and elk use of burned pinyon-juniper areas depends on postfire successional stages (Stager and Klebenow 1987), because burning can eliminate some important deer browse species (McCulloch 1969). An important factor in the degree of use of burned pinyon-juniper habitats by deer and elk is the interspersion of burned habitats, which provide food, and unburned sites, which provide thermal and hiding cover. Old growth pinyon and/or juniper stands may offer unique and valuable wildlife habitats, adding to the variety within pinyon and juniper stands. When planning site-specific treatments, these old growth communities should be recommended to be left standing as islands and edge communities to the prescribed burning areas.

Plains Grasslands

Fire can be used to benefit some species of prairie wildlife. Dabbling ducks and sharp-tailed grouse production increased on burned grassland as compared to undisturbed grassland in North Dakota (Kirsch and Kruse 1972). Prescribed burning also improved upland plover production. Fires can be destructive to songbirds, which require shrubs for nesting (Renwald 1977). Periodic burning is desirable to maintain ideal prairie chicken habitat in tallgrass prairie, but burned areas may not be preferred habitat for sharp-tailed grouse for several years postfire (Wright and Bailey 1982).

Coniferous/Deciduous Forests

Fire effects on wildlife in coniferous forests depend on ecological relationships and animal habitat needs. Ground fires have little direct influence on tree squirrels and may even be favorable by perpetuating ponderosa pine communities (Wright and Bailey 1982). Ground squirrels initially decreased in burned ponderosa pine communities but increased later as early successional advances were made (Lowe et al. 1978). Fire would probably adversely affect chipmunks in those communities where drier conditions prevail, but they may increase postburn on more moist sites (Lowe et al. 1978, Wright and Bailey 1982). Total bird numbers increased initially after burning in ponderosa pine communities in Arizona but fell to below prefire levels later, although some individual species responded in an opposite manner (Lowe et al. 1978).

In one study, both deer and elk decreased their use of areas immediately following a burn but quickly increased levels of use as compared to control plots. Benefits to deer and elk from fires in these types are generally related to increases in understory vegetation (Leege and Hickey 1971, Severson and Medina 1983). Burns in Douglas-fir and ponderosa pine communities improved forage palatability to mule deer (Keay and Peek 1980). Prescribed fire also can improve winter forage for mountain sheep (Hobbs and Sporwart 1984). Prescribed fire can be used to rejuvenate old aspen stands, increasing habitat for moose, elk, deer, ruffed grouse, and snowshoe hare, all of which depend on the forage or cover produced in a young aspen community (DeByle 1985).

Chemical Methods

Chemical treatments, like mechanical methods, traditionally have been applied most frequently to decrease woody plant cover and increase the production of grasses. Herbicidal control of sagebrush decreases use by sage grouse, which require high sagebrush cover for breeding and nesting (Peek 1986). The control of broadleafed woody plants, especially by selective herbicides, often results in the control of associated broadleaf forbs, both categories on plants contain species which may be important food for many different wildlife species. Near riparian areas, using chemicals to control vegetation can increase sedimentation, which can reduce or eliminate suitable spawning habitat, however, if the appropriate buffer width of existing vegetation is retained and sufficient uneffected vegetation exists within the treated area, there should be no significant erosion sedimentation occurring.

Although most documented cases consider the effects on wildlife of vegetation treatments designed to increase grass production, chemical treatments can be selected and structured to increase and decrease other vegetation components for the benefit or exclusion of different wildlife species. These treatments can be considered tools for wildlife habitat management when vegetation responses and habitat requirements are understood. Accordingly, determinations about whether particular vegetation treatments will increase or decrease wildlife populations must be made on a site-specific basis, taking into account specific information about vegetation and animals. All treatments will affect some change in the existing wildlife communities, including amphibians, reptiles, and invertebrates. These changes in the wildlife community will be analyzed in the pretreatment evaluation, and the project would not be recommended if the effects are unacceptable. The end result of the treatment should be more beneficial to wildlife in general than the community and/or populations foregone by the treatment. Special status wildlife species must receive full and detailed consideration. It is also assumed that the herbicide evaluation techniques and requirements, as approved by the regulatory and academic communities, are adequate for evaluating the impacts of herbicides to the environment, and as a land management agency we are operating within the labelling restrictions and regulations.

Aerial herbicide applications have the most significant potential for affecting wildlife. When determining the timing of herbicide applications, consideration should be given to the potential for humans to consume wildlife that have fed on herbicide-contaminated forage. The treated area could be posted to notify the public of the possible contamination, if herbicides pose any risk. Also, the effect of herbicide consumption on lactating mammals or the feeding of contaminated foods to offspring must be considered. Some negative impacts can be lessened if the period of treatment avoids the bird nesting season and other critical seasons when loss of cover would be critical to wildlife; for example, during critical reproductive periods and prior to severe winter weather conditions. Application of 2,4-D, or diesel fuel as a carrier of herbicides, will have a significant adverse impact to bird eggs, and young of any wildlife species, and should be especially avoided.

Most riparian areas are crucial habitat for wildlife and no major treatments are proposed. The primary practice will be for riparian areas to be buffered and protected from any impacts. The most significant proposed treatment is to remove exotic saltcedar through treatment of individual plants by cutting and brush painting the stump with picloram or triclopyr (Garlon 3A). This treatment should have minimal impact on non-target vegetation, although picloram can affect adjacent vegetation through root transfer. The use of diesel fuel as a carrier for triclopyr could have a significant affect on adjacent aquatic habitats if accidental spills occur.

The BLM Pest Control Handbook, H-9011-1, requires buffering of domestic waters, perennial marsh areas, important fishing and recreational waters, and/or significant fish spawning, rearing, and migration streams. Recommended buffers are the larger of the herbicide label recommendation or 25 horizontal feet for vehicle spraying and 100 horizontal feet for aerial spraying. Additional mitigation is proposed by recommending use of helicopters for spraying adjacent to critical areas and requiring a maximum drift control nozzle (microfoil boom type) for the greatest possible control of the herbicide being applied, and avoiding applications during critical seasons for the fisheries resources. Even with these mitigations it is still possible for impacts to occur through accidental spills or other accidental unplanned events, such as major run-off events after herbicide application. To minimize impacts to fish and other aquatic wildlife, the use of amitrole, atrazine, clopyralid, dalapon, diuron, simazine, triclopyr (butoxyethyl ester only), 2,4-D, or diesel oil carriers should be very carefully regulated and applied when the treatment area is adjacent to aquatic habitats. With these mitigations, and barring accidents, no negative impacts are anticipated to the riparian, fisheries, or other aquatic resources.

Because of this short exposure and the proposed application rates, herbicides are not expected to significantly affect fish or their habitat under any alternative. However, due to the highly significant and sensitive nature of this resource, it is important to consider suggested mitigation and design features (see Chapter 1) to ensure protection of these resources from all potential impacts of vegetation treatment.

For a detailed discussion of herbicide risks to aquatic organisms, see Appendix E, which relates possible doses to documented toxic effects on aquatic organisms. The following sections contain examples illustrating how relatively limited the research is on wildlife responses to vegetation manipulations by herbicidal treatments.

Sagebrush

Although few wild vertebrates depend solely on the sagebrush analysis region, sagebrush is so widespread that it is a principal habitat type in the West (McEwen and DeWeese 1987). Herbicidal control of sagebrush reduces populations of some breeding birds, especially shrub nesters, such as Brewer's sparrow (Best 1972, Schroeder and Sturges 1975, Castrale 1982). A reduction in floral diversity associated with herbicide treatments reduces seeds for insects, which are, in turn, important food for nestlings (Best 1972). The greater the reduction of sagebrush, the greater the negative effect on shrub-nesting birds (Castrale 1982). For this reason, mechanical methods, such as chaining or railing, which only partially control sagebrush and do minimal damage to understory species, may be less detrimental to these birds than chemical treatments (McEwen and DeWeese 1987).

A mixed sagebrush ecosystem provides essential habitat for a variety of wildlife. McAdoo et al. (1986) found the greatest perching and song bird diversity in mixed sagebrush-wheatgrass communities as compared to communities dominated by either sagebrush or wheatgrass. A balanced mixture of shrub- and ground-nesting species of birds occurred in the mixed grass-shrub community, while ground and shrub nesters, respectively, were dominant in grass- and brush-only communities.

Similarly, Smith and Urness (1984) compared small mammals on sites dominated by sagebrush and those where sagebrush was cleared and wheatgrasses were dominant. Total rodent numbers and biomass were greatest where sagebrush and grass occurred together. Deer mice were more abundant in woody plant habitats, while pocket mice were equally abundant in sagebrush and grass-dominated sites.

Sagebrush also is a potential food source for some species. Although wheatgrass established after sagebrush control may furnish important winter and spring forage for mule deer (Austin and Urness 1983), sagebrush, which is more accessible when the snow is deep, is critical winter food in many areas (McAdoo and Klebenow 1979). In areas of limited rainfall and forage production the thermal cover provided by sagebrush may be critical to deer and other wildlife survival (W. A. Molini, pers. comm. 1990). Sagebrush also is important in winter for antelope (Bayless 1969). Yoakum (1975) emphasized that sagebrush conversion treatments that reduce vegetation diversity, such as spraying with herbicides, plowing, or disking, are less desirable for antelope than chaining and revegetation with a mixture of species. Yoakum noted that antelope do best on rangelands with an abundance of grass, forbs, and shrubs. Sagebrush control programs that greatly reduce sagebrush and associated forbs on critical summer and winter ranges may be detrimental to sage grouse, mule deer, white-tailed deer, and moose (Quimby 1966, Kufeld 1968).

In addition, chemical treatment of sagebrush may alter important habitat requirements. Peek (1986) reviewed the possible negative effects on sage grouse of herbicidal control of sagebrush. These upland game birds require sagebrush cover for nesting and breeding, as well as associated forbs for food, and substantial decreases in sage grouse density occur after sagebrush control. Consequently, sagebrush should not be controlled within 1.5 miles or more of sage grouse breeding complexes or along nearby riparian areas (Braun et al. 1977a).

Despite these negative impacts, chemical treatment may be beneficial for wildlife. For example, herbicidal control of sagebrush leaves the dead brush standing to serve as nesting sites for some years after treatment (Castrale 1982). Also, herbicidal control of sagebrush and the resulting increase in grass production may result in increased use by elk (Wilbert 1963). However, elk response to sagebrush control may depend on the availability of forage before and after spraying on treated and adjacent areas. Ward (1973) observed no difference in the grazing habits of elk on scattered sprayed and unsprayed areas.

Most research indicates that vegetation treatment programs should maintain a diversity of vegetation types, including sagebrush. McEwen and DeWeese (1987) emphasized the importance of vegetation diversity to wildlife in the sagebrush region. When sagebrush conversions result in increased diversity and production of grasses, forbs, and shrubs, wildlife abundance and diversity should increase. Although it is difficult to maintain mixed communities of sagebrush and other plants on some sites because of the strong competitive nature of sagebrush, vegetation diversity can be increased by expanding the edge areas of the shrub control treatment zone and by seeding mixtures of species in controlled areas. Neither sagebrush- nor grass-dominated areas are as favorable to wildlife as mixed communities. Future sagebrush conversion projects should provide for vegetation diversity to benefit wildlife.

Desert Shrub

Plant control by chemical means in desert shrubland must usually be followed by revegetation. Revegetation efforts are normally unsuccessful because of low and erratic precipitation. Plant control treatments in desert shrubland risk reducing perennial plant cover and increasing the cover of weedy annuals. Also, because these vegetation changes are expected to negatively affect indigenous wildlife species, vegetation manipulation of desert shrubland is generally not recommended.

Southwestern Shrubsteppe

Chemical treatments have most frequently been applied to reduce the cover of woody species, such as mesquite (Martin 1975). Although research has described the life history and habitat requirements of many wildlife species (for example, see literature citations in Martin and Reynolds 1973), only limited research has addressed the effects of vegetation manipulations on wildlife in southern Arizona and New Mexico. The effects of vegetation treatments on wildlife from research in Arizona and Texas is discussed here.

Expanding the structural diversity of vegetation by controlling shrubs and increasing understory species in strips and patches should increase bird diversity and density. However, such control could decrease deer use by reducing food and cover. Smith (1984) compared bird use of undisturbed, crushed, and tebuthiuron-treated creosotebush in Arizona. Black-throated and Brewer's sparrows foraged opportunistically, while verdins avoided crushed plots and vesper sparrows avoided control plots. In the creosotebush community, chemical treatments opened up small areas, which were used as nesting sites for Cassin's sparrows and feeding sites for grass-eating flocks.

McCormick (1975) compared small game use of areas invaded by mesquite with areas where mesquite had been controlled to 40 to 101 trees per acre. Both areas supported a native perennial grass and forb understory. Doves, quail, and cottontail rabbit use was less on the mesquite-controlled areas, while jackrabbit use was similar on controlled and uncontrolled areas. To maintain a habitat for these small game species, McCormick (1975) recommended controlling mesquite only where density exceeds 101 trees per acre and advised limited control of small, dense mesquite stands in the drainage areas (101 to 323 trees per acre). Germano (1978) compared use by various animals on mesquite-dominated areas, mesquite-free areas, and mesquite woodland with clearings. More jackrabbits, antelope, quail, and lizards were observed in mesquite areas with clearings than in mesquite-free areas. Jackrabbits and lizards used the mesquite-dominated areas more than mesquite-free areas. Totally clearing mesquite may reduce vegetation structural diversity and wildlife use.

As long as cover was maintained, white-tailed deer in Texas adapted to reductions in preferred browse species associated with chemical shrub control (Quinton et al. 1979). In this study, deer populations declined when cover was greatly reduced. The importance of overstory cover and understory forage for deer has led to the use of partial brush control techniques in Texas (Scifres and Koerth 1986). Woody plant regrowth on strip-treated areas increased deer use during the first winter after treatment (Tanner et al. 1978). Habitat patterning of using herbicidal strip treatments or variable herbicide rates to create areas of different wood plant mortality may benefit wildlife (Scifres and Koerth 1986). Mesquite control that selectively leaves areas important for browse and cover are likely to be much more beneficial for deer than extensive control projects (Severson and Medina 1983).

Chaparral-Mountain Shrub

The limited research on wildlife in the chaparral type of plant community has focused on deer (Cable 1975). Because deer populations are low in dense brush stands with little understory, opening these stands is generally considered beneficial for wildlife (Cable 1975). However, leaving some brush intact is recommended to provide escape cover for deer. In Arizona, deer spent much less time on chaparral cleared by rootplowing and herbicide spraying than on untreated areas (Urness 1974). However, in this study, deer used the cleared areas mainly for feeding. Foraging efficiency was probably high because of high herbaceous plant production as compared to uncleared areas. Shrub control treatments resulted in a cover loss, but they also brought about a compensating increase in forage production for deer in chaparral. Urness (1974) recommended leaving some brush on all aspects of range management, clearing less than 50 percent of the area, and clearing in strips no wider than 437 yards. Where brush is so dense that understory forage is lacking, brush control can increase deer and elk use.

Gambel oak areas in Colorado sprayed with phenoxy herbicides had a tremendous increase in elk density as compared to unsprayed areas 2 years after treatment (Kufeld 1977). After 5 years, Gambel oak had regrown, and elk use declined to near pretreatment levels. Kufeld recommended that such areas be treated every 3 years to suppress oak and increase understory production and, consequently, elk use.

Herbicide treatments have been used to induce sprouting of brush species and to increase forage availability for deer and elk. However, shrubs intolerant of these treatments may produce less forage after treatment. Mountain shrub species in Idaho, including maple, willow, ceanothus, rockspirea, and ninebark, had limited basal sprouting after applications of phenoxy herbicides (Lyon and Mueggler 1968). Herbicidal treatments of these species to improve forage availability for deer or elk are not recommended. When chaparral species are controlled by chemical means, wildlife use should increase as understory production increases and suitable areas are left intact to provide cover.

Pinyon-Juniper

The competitive ability of pinyon and juniper trees gradually reduces shrubs, grasses, and forbs on many sites that are left undisturbed (Tausch and Tueller 1977). Using chemicals to control the trees generally increases understory production (Skousen et al. 1986, see the discussion on vegetation) and thereby may increase mule deer use. At the same time, tree control reduces cover and may decrease deer use in some cases. Severson and Medina (1983) have summarized various authors' recommendations to minimize the loss of pinyon-juniper cover for mule deer when conducting control treatments. Suggested sizes of treated areas average no more than 1/3 mile across, and no more than 20 - 50 percent of the total area, depending on the significance of the type of habitat, should be treated.

Of special concern are the effects of vegetation manipulation on bitterbrush associated with pinyon-juniper and sagebrush rangelands. On some rangelands, bitterbrush provides the bulk of mule deer forage in the fall (Austin and Urness 1983). Bitterbrush generally tolerates 2,4-D applications better than it does burning; when sagebrush is controlled by 2,4-D, its forage production may increase (Blaisdell and Mueggler 1956, Murray 1983).

Chemical control of pinyon-juniper areas is expected to have more of a negative effect on associated understory species and potentially a greater negative effect on wildlife use than mechanical methods such as chaining and cabling. Except for breeding birds, which prefer tree habitats, wildlife diversity and use can generally be maintained or increased by pinyon-juniper treatments that expand understory diversity, production, and ecotonal edges.

Plains Grasslands

Chemical treatments have most frequently been applied to reduce the cover of woody species, such as mesquite, that have invaded the plains grasslands. Increasing the structural diversity of vegetation by controlling shrubs and increasing understory species in strips and patches should expand bird diversity and density. Plains grasslands provide important habitat for the mule deer and the white-tailed deer, and clearing large areas can decrease deer use by reducing food and cover.

Meadows supporting sage grouse populations should not be treated with herbicides that control broadleafed plants because sage grouse depend on the seeds and buds for food. Applications of 2,4-D that control meadow forbs would also reduce gopher populations dependent on these forbs. However, prairie dogs on plains grasslands are able to switch their diets from forbs to grasses and maintain their populations after 2,4-D applications.

Mountain/Plateau Grasslands

The few studies that consider the effects of plant control on wildlife on mountain meadows or plains grasslands address sage grouse, gophers, or prairie dogs. Spraying 2,4-D to control iris on mountain meadows in Nevada greatly reduced dandelion and yarrow, which are important spring food for sage grouse (Eckert et al. 1973a). Total forb and dandelion production was minimal to deficient the first year of spraying but increased to adequate for existing sage grouse populations 2 years after 2,4-D applications (Eckert et al. 1973b). Meadows supporting sage grouse populations should not be treated with herbicides that control broadleafed plants.

Chemical Treatment Risk Analysis

A risk analysis was conducted to determine the potential for adverse effects to terrestrial wildlife and aquatic organisms from using 19 herbicides and the carriers diesel oil and kerosene in BLM's vegetation treatment program. Details can be found in sections 6 to 8 of Appendix E. The risks identified are summarized here.

Risks to Terrestrial Wildlife

Risks were calculated for typical exposures to a group of representative wildlife species from rangeland and rights-of-way treatments and for worst case exposures from rights-of-way treatments. These scenarios represent the realistic and extreme exposures that might be encountered. Herbicide applications to public domain forest, recreation sites, and oil or gas drill sites would result in exposures equal to or less than those evaluated.

In general, based on the available toxicity data and on the proposed application rates, risks to wildlife are low from most of the herbicides. Estimated doses for typical rangeland and typical rights-of-way exposures result in a negligible risk from all herbicides considered, as well as diesel oil and kerosene. The application rates for several of the herbicides used on rights-of-way, coupled with extreme exposure estimates, present moderate risks to some species. However, the estimated exposures exceed the LD_{50} only under extreme assumptions for songbirds during the use of atrazine. The typical dose estimates are below the EPA risk criterion of 1/5 LD_{50} and are far below the laboratory species LD_{50} in most cases.

Even using worst case assumptions, the use of amitrole, chlorsulfuron, dalapon, glyphosate, hexazinone, imazapyr, mefluidide, metsulfuron methyl, picloram, sulfometuron methyl, diesel oil, or kerosene is not expected to pose unacceptable risks to terrestrial wildlife. The use of atrazine on rights-of-way presents a moderate risk of adverse effects to large birds, small mammals, and terrestrial amphibians for extreme exposures. Extreme exposures to songbirds result in a significant risk. Bromacil, clopyralid, and dicamba result in moderate risks to songbirds under extreme rights-of-way assumptions.

2,4-D presents moderate risks for the extreme rights-of-way scenario to songbirds, larger birds, small mammals, and terrestrial amphibians. Extreme rights-of-way exposures of diuron present moderate risks for songbirds, small mammals, and terrestrial amphibians. Extreme rights-of-way exposures to simazine result in moderate risks for songbirds and small mammals. Extreme rights-of-way exposures to tebuthiuron and triclopyr result in moderate risks to small mammals.

Risks to Aquatic Organisms

Risks were evaluated for representative aquatic species from exposure to herbicides that drift offsite from typical aerial rangeland and right-of-way applications. Risks were also estimated for an accidental direct spray of a pond and an accidental helicopter jettison of its entire load of herbicide mix into a pond. Risks were calculated for four aquatic species on which toxicity data were generally available for the herbicides. Trout were chosen to represent cold water fish, bluegills to represent warm water fish, and Daphnia (a water flea) to represent aquatic invertebrates. Risks to fathead minnows also were evaluated because toxicity information was generally available on that species.

According to risk calculations for realistic (typical) exposures, risks to aquatic species are low for all herbicides proposed for use. The only risk identified in typical cases is a moderate risk posed by the use of kerosene as an herbicide carrier. Use of appropriate buffer strips along bodies of water and avoidance of spraying on windy days would reduce this risk. No adverse effects are expected on the aquatic ecosystem as a whole. Risks from accidental direct spray of a water body or an accidental jettison of herbicide mixture into a water body are significant, but the probability of either event is low.

Drift Onto a Pond at Typical Rangeland Application Rates

In this scenario, the only risk identified is a moderate risk to trout from the use of kerosene as a carrier for 2,4-D.

Drift Onto a Pond at Typical Rights-of-Way Application Rates

In this scenario, kerosene presents a moderate risk to trout.

Accidental Direct Spray of Pond at the Highest Application Rate

This accident scenario presents risks to aquatic species from several herbicides. There would be moderate risks to bluegills from diuron and simazine, to Daphnia from dalapon, to trout and fathead minnows from atrazine, and to fathead minnows and Daphnia from 2,4-D. Significant risks were identified for Daphnia from amitrole, atrazine, and clopyralid;

for bluegills from 2,4-D; for trout and Daphnia from diuron; for trout, fathead minnows, and Daphnia from simazine; and for trout, bluegills, and pink shrimp from diesel oil.

Helicopter Jettison of 80 Gallons of Mix Into Pond

There are either moderate or significant risks to all species from most of the herbicides from a helicopter jettison into a pond. However, the probability of this type of accident occurring is extremely low.

To summarize, no direct toxic effects to either wildlife or aquatic species are expected from the use of any of the proposed herbicides. Risks to terrestrial and aquatic wildlife species from herbicides will be greater when higher application rates are used, as is generally the case on utility rights-of-way and oil and gas drill sites. Effects by analysis region depend on the extent to which this method is used in the region and the presence or absence of species that may be affected. For example, the treatment of a coniferous forest may affect forest-dwelling mammals and birds, which are likely to be present in relatively large numbers, while the treatment of a sagebrush region would have an almost insignificant potential for risk to aquatic species. Nonetheless, the risk assessment performed for this program found that the chemical risks to wildlife and aquatic species would be low to negligible, with no likely effect to larger animals. The complete assessment is included as a table in Appendix E.

CULTURAL RESOURCES

Before authorizing vegetation treatment actions that could affect cultural resources, cultural properties eligible for inclusion in the National Register of Historic Places will be identified and considered through the process outlined in the National Historic Preservation Act of 1966 and implemented in 36 CFR 800 and the BLM 8100 Manual series. In many States, specific procedures for considering cultural resources have been adapted to local needs by Programmatic Agreements among BLM, the State Historic Preservation Officer, and the Advisory Council on Historic Preservation. These agreements will control how possible effects on cultural resources will be assessed and mitigated.

Historically, there have been direct conflicts between vegetation treatment and traditional lifeway values. For example, mechanical removal of pinyon-juniper woodlands decreases the availability of pinyon nuts for traditional gathering. The list of Target Plant Species (Appendix I) does contain plants such as amaranth, sunflower, cholla, and pinyon pine that were significant to traditional peoples in prehistoric times and either remain significant (i.e. pinyon) or could remain significant in maintaining contemporary traditional lifeways. To the extent that traditional lifeway values are associated with or embodied in properties or other definite locations (BLM 1988e), possible impacts to them can be considered in the same consultation process as used for other cultural resources.

Specific impacts to known and undiscovered cultural resources are similar. Surface-disturbing activities also affect cultural resources and may destroy spatial context as well as individual artifacts features and structures. Cultural properties consisting only of surface manifestations would be destroyed or severely affected during surface-disturbing activities. Organic chemical contamination can make radiometric dating samples unusable and can affect other chemical analyses.

Manual Methods

In addition to general surface disturbance that could disrupt spatial context, mulching with organic materials would complicate radiometric dating, and the use of hard-edged tools may physically damage artifacts. Workers may illegally collect projectile points and other significant artifacts or vandalize cultural resources in other ways.

It is difficult to predict the impacts of manual treatment methods on traditional lifeway values. Given that manual methods are highly selective in their application, it will be possible to avoid specific plants that are associated with traditional lifeways. However, given that these methods may be applied several times a year and/or at specific times to be effective, there may be a direct conflict between the methods and traditional religious practices and/or plant gathering. Also, the specific plants targeted for treatment may be the same as those identified as essential to maintaining traditional lifeways.

Mechanical Methods

Tilling, roller chopping, and blading could damage both surface and subsurface artifacts and disrupt the relative positions of cultural materials. Exposing these sites may also increase the possibility of artifact theft.

Historically, mechanical methods for vegetation treatment have posed significant threats to traditional lifeway values that involve maintaining traditional food sources or access to medicinal and sacred plants. For example, removal of pinyon-juniper woodlands significantly reduces the availability of pinyon nuts for traditional harvest. Thus, as with other methods, the impact of mechanical methods will vary directly with the extent to which plants important to maintaining traditional lifeways are the target plants for treatment or are associated with treatment plants.

Biological Methods

Biological control using grazing animals may damage surface artifacts and disrupt the relative positions of cultural materials; however, site-specific investigations would decrease this possibility. Because of the agents' small size and host-specific action, biological control using insects or pathogens is not likely to affect cultural resources.

Biological control methods will impact traditional lifeway values to the extent that targeted treatment species are essential to maintaining a traditional lifeway and that the specific method involves ground disturbance and/or landscape alteration. Increased grazing will have a greater potential to impact traditional lifeways than will the use of insects and pathogens. Plant specific biological methods, such as insects or pathogens, that are not directed toward traditional lifeway plants are highly selective and will not be likely to impact traditional lifeway values.

Prescribed Burning

The effect of prescribed burning on cultural resources depends on the location of the resource with respect to the ground surface, the proximity to fuels that could provide a source of heat, the material from which artifacts are made, and the temperature to which artifacts are exposed. Threshold temperatures for damage to cultural artifacts manufactured from different materials, such as ceramic or stone, vary significantly.

Surface or near-surface cultural materials may be damaged, destroyed, or remain essentially unaffected by prescribed burning, depending on the temperatures reached and the duration of exposure to that temperature. Wooden structures or wooden parts of stone or adobe structures are susceptible to fire. Combustible artifacts lying directly on the ground surface could be destroyed. The ability to date noncombustible surface artifacts may be adversely affected if exposed to specific high temperatures. Subsurface materials are usually affected by fire only where significant amounts of soil heating occur (where dry accumulations of dead woody fuel or duff layers are consumed). Prescribed fires in areas of cultural significance would not be ignited under conditions dry enough to cause significant subsurface heating. Subsurface cultural resources are generally more subject to harm from construction of firelines around planned fire boundaries than from the fire itself.

The heat, smoke, and soot from prescribed burning can also damage cultural resources, especially prehistoric rock art, by causing spalling which physically destroys the resource or by obscuring the surface of the resource with smoke and soot. Smoke and soot can damage cultural resources, by either increasing chemical deterioration or obscuring carvings and painted motifs.

As with other methods, the impact of prescribed burning will vary directly with the extent to which plants important to maintaining traditional lifeways are the target plants for treatment or are associated with treatment plants.

Chemical Methods

It is unlikely that cultural artifacts protected by soil or plant cover would be adversely affected by chemical treatments. The effect of herbicide treatments on cultural resources depends on the method of herbicide application and the herbicide type used.

Standing wall masonry structures, rock art panels, organic materials, and other types of cultural resources can be impacted by chemical treatments to the extent that the chemical used alters the chemistry of the application site and/or obscures or alters the surface of the application site. Impacts can also occur depending on the amount of surface disturbance created in developing and maintaining landing facilities for aerial applications and the extent of ground vehicle use.

Chemicals may affect the surface of exposed artifacts, but they can be removed. Organic solvents used to remove herbicide formulations with diesel oil or kerosene as carriers (2,4-D and triclopyr) may contaminate the soil in a site and seep into the subsurface portions of artifacts. These organic substances could interfere with the Carbon 14 dating of the sites.

As with other methods, the impact of chemical treatment will vary directly with the extent to which plants important to maintaining traditional lifeways are the target plants for treatment or are associated with treatment plants. Chemical treatment could also impact traditional lifeways, and pose a possible health threat, through residues left on plants used as traditional foods or for ceremonial purposes.

RECREATIONAL AND VISUAL RESOURCES

Recreation is described in BLM's Public Land Statistics (BLM 1987f) as being land based, water based, or snow and ice based. BLM's recreation inventory focuses on resource-dependent activities, such as hunting, fishing, sightseeing, water sports, winter sports, off-road vehicle use, and other specialized activities that are dependent on natural and cultural features found on public lands (BLM 1987h). Less than 1 percent of the total acreage considered in this EIS consists of intensively managed, developed recreation areas. In those areas the goals of vegetation treatments include maintaining the appearance of the area and protecting visitors from adverse effects from contact with noxious weeds and target species; therefore, the adverse effects on recreation areas are not likely to be significant. However, recreation on BLM lands in areas other than intensively managed, developed recreation areas and sites is likely to be affected. For example, chaining of pinyon-juniper or a prescribed burn over a large area would adversely affect recreation activities such as hunting or birdwatching because of displacement of game and nongame wildlife species.

In addition to suppressing the growth of noxious weeds, such as thistles, ragweed, and poison ivy, which in turn decreases the exposure of recreation visitors to thorns, burrs, pollen, poisons, and other plant irritants, vegetation treatment projects provide opportunities for ecologic study and research, and environmental education and interpretation. These opportunities are especially increased in or near high-use areas.

Impacts to recreational resources would vary by treatment method. Some treatment methods would be much less objectionable to the recreationist than others. A hiker or backpacker, for example, would likely bypass a prescribed burn area altogether while continuing to use a trail passing through a mowed or mulched area.

Public lands have many different visual values. Visual values are identified through the Visual Resource Management (VRM) inventory and are grouped into four visual resource inventory classes, which represent the relative value of the visual resources. Classes I & II are the most valued, Class III is moderately valued, and Class IV is least valued. The criteria for determining the classes are scenic quality, sensitivity level, and distance zone. Landform, vegetation, water, color, adjacent scenery, scarcity, and cultural modifications are used in determining an area's scenic quality (BLM 1986).

An adverse visual impact is any modification in land forms, water bodies, or vegetation, or any introduction of structures that disrupt negatively the visual character of the landscape and the harmony of the basic elements (that is, form, line, color, and texture) (BLM 1984e).

Where areas are treated by methods that could significantly change visual contrast (quality), short-term adverse impacts on visual resources would occur. However, based on standard operating procedures and long range plans, the long-term impacts would be beneficial. The intensity of the impact would depend on the treatment method and the area where it was implemented. Most of the land considered for the vegetation treatment program is Class IV; therefore, the impacts that might occur from any of the treatment methods would not be as distinct as in a Class I or II area. Factors that effect the degree of visual contrast are: distance, angle of observation, length of time in view, relative size or scale, season of use, light conditions, recovery time, atmosphere conditions and motion.

Manual Methods

Manual treatment methods of cutting, clearing, and pruning plants would have no adverse impact on recreational areas because these methods are used in areas that are difficult to reach by vehicle or in sensitive areas in which care would be taken to avoid disrupting the habitat. Manual treatment methods are species selective, so undesirable plants may be removed without killing desirable ones.

Of all the treatment methods, manual treatment methods would have the least adverse effect on visual resources because they would be used to treat small areas and to control specific species without disturbing surrounding vegetation. Because these methods are used on a small scale, the visual effects would likely be apparent only at close range.

Mechanical Methods

Mechanical methods could have adverse and beneficial effects. Heavy machinery could disrupt the area, breaking limbs and exposing soil, but mowing might improve the appearance of some sites and make them more pleasurable to visit. Mechanical treatments could make some areas more desirable for recreation activities; for example, clearing brush around a lake could make it more accessible for fishing.

Mechanical methods such as chaining and tilling disrupt the land surface and expose the soil to view. Using these methods on flat terrain, for example, in the sagebrush region, would cause less visual impact than using the methods on steeper areas, such as the pinyon-juniper region, because more area is visible as the land becomes steeper. In the long term, the regrowth of more aesthetically desirable vegetation may prove to be a beneficial impact. Mowing could have a beneficial effect when used to control unsightly vegetation along rights-of-way and in recreation areas.

Biological Methods

The use of biological treatment methods is not expected to have a great effect on recreation resources. The benefit of using insects or pathogens would be the control of very specific undesirable plant species without disturbing desirable vegetation or disrupting the land. Backpackers and campers using rangeland where livestock graze may experience some negative impacts where the livestock have grazed.

Biological treatment methods should have only minimal visual impacts. The sight of animals on rangeland is common and expected; however, an overgrazed area could be visually undesirable. The visual impacts of biological treatments with insects and pathogens should be negligible because they are very target specific and not widely used.

Prescribed Burning

Prescribed burning affects air quality and could be a problem for developed recreation sites and dispersed recreation. The effects of prescribed burning on human health is discussed in Impacts on Human Health. It is likely that visitation to a prescribed burn area would decline drastically or cease altogether in the short term. In the long term, however, visitation could increase because prescribed burning has the highest potential for habitat improvement. The use of fire to create more of the "edge effect" is unparalleled by any other treatment method. The edge effect refers to the richness of flora and fauna occurring in a transition zone where two plant communities or successional stages meet and mix (USDA 1988).

Prescribed burning creates contrasting blackened areas and releases smoke into the air that temporarily impairs visibility. Burning does lessen the amount of logging debris that is seen and darkens the color of stumps and snags that, if not burned, would become more noticeable as they bleached over time. In the long term, prescribed burning might allow the regrowth of more aesthetically desirable vegetation.

Chemical Methods

Herbicide sprays have been a preferred treatment for poison oak and other toxic plants. In the past, herbicides have been applied in "spot" applications rather than broadcast spraying (USDA 1988). The use of herbicides may affect the availability of recreational opportunities because of site closures, wildlife habitat changes, loss of edible fruits, and a temporary loss of berry picking opportunities in the treated site (USDA 1988). Designated BLM recreation sites that are treated with herbicides will have signs posted stating the chemical used, date of application, and a contact number for more information. Signs will remain in place for at least 2 weeks after spraying.

Herbicide use reduces the variety of vegetation and may prevent the manifestation of seasonal changes such as spring flowers and fall color in a treated area. Areas treated with herbicides turn brown and contrast with surrounding vegetation for a short period of time. However, applying herbicides could have the positive visual impact of allowing regrowth of more aesthetically desirable vegetation, such as clovers or wildflowers.

LIVESTOCK

The goals of rangeland treatment methods for livestock include suppressing plant species that are toxic and improving forage production by controlling competing vegetation. Livestock could be affected directly by ingesting poisonous weeds and indirectly by changes in forage supply and herbicide exposure.

Manual Methods

Manual treatment methods are labor and cost intensive and therefore may not be effective in controlling competing vegetation on a large scale. However, these methods are species-specific and could be effective in controlling small, localized areas of weeds.

Mechanical Methods

Mechanical treatment methods, such as bulldozing or chaining, may temporarily reduce livestock forage. Sprouting brush or undesirable herbaceous plants may not be controlled effectively with these methods. However, palatability of certain sprouting brush species may be improved.

Biological Methods

When sheep and goats are used for biological control, their performance may decline because they are confined to particular areas that may contain less palatable forage. An effective mix of sheep, goats, and cattle may increase forage overall because each animal has different dietary preferences. Biological treatments using insects and microbes have little potential for affecting livestock because these treatments are slow acting and highly specific for the target species. However, in some situations it is possible that these agents may prohibit animals from using a pasture during relatively short periods.

Prescribed Burning

The burning of rangeland may temporarily reduce grass and forb production, thus reducing available forage for livestock. However, in most cases, policy requires that livestock not be allowed on a burned area for two growing seasons after a prescribed fire so that forage has an opportunity to recover. The burning of rangeland generally results in greater perennial grass production and grazing capacity, as well as increased forage availability from the removal of physical obstructions to plants posed by dense stands of sagebrush or other brush species. Using prescribed burning in concert with herbicide treatments would effect the greatest positive response in situations involving brush land.

Chemical Methods

Chemical treatments are generally applied in a form or at such low rates that they do not affect livestock. Most significant treatments would be applied when livestock are not in the treated pasture, but spot treatments could be applied any time, regardless of the presence of livestock. Animals consuming forage treated with certain herbicides (picloram, 2,4-D, and dicamba) cannot be slaughtered for food within the time specified on the herbicide label. Dairy animals should not be allowed to graze on areas treated with certain herbicides (picloram, 2,4-D, and dicamba) for the time specified on the label. The potential for livestock exposure to herbicides can be reduced by not allowing grazing within the sprayed areas for one grazing season.

Based on the risk analysis in Appendix E-8, the estimated doses for livestock would be well below the EPA risk criterion of 1/5 LD_{50} for all of the program herbicides. Therefore, the risk of direct toxic effects to these animals is negligible, even assuming exposure immediately after herbicide treatment.

Using herbicides is the most efficient and effective way to control some competing vegetation and noxious weeds. However, some aerially applied herbicides also may eliminate some shrubs and trees that livestock need for shelter.

WILD HORSES AND BURROS

Approximately 36,000 wild horses and 3,300 burros roam the sagebrush and desert shrub regions of the program area. Because most of these animals are on public lands in Arizona, Colorado, New Mexico, Nevada, Montana, Oregon, Utah, and Wyoming, BLM must consider the effects on wild horses and burros when proposing land management strategies. As a result of BLM's herd management efforts, herd populations have increased at an annual rate, which is currently 16 percent overall, since 1971 (BLM 1985). Unfortunately, the increased numbers of wild horses and burros, in combination with other resource demand (for example, livestock grazing and outdoor recreation), are exerting greater ecological pressure on their habitats, threatening the balance of these fragile lands (BLM 1985). Therefore, the effects, both positive and negative, on these wild animals as a result of vegetation treatment methods will essentially be the result of habitat alteration in the sagebrush and desert shrub regions.

Manual Methods

Impacts of manual treatment methods on wild horses and burros would, in most cases, be the same as for livestock. Vegetation conversions using manual treatment methods in the habitat areas of wild horses and burros result in an increased diversity and production of grasses, forbs, and shrubs, which should be beneficial for herd populations.

Mechanical Methods

Mechanical vegetation treatment methods may temporarily reduce forage available to wild horses and burros. However, long-term effects would prove beneficial. Mechanical treatments may temporarily displace wild horse herds.

Biological Methods

Biological treatment methods should not significantly affect herd populations in either sagebrush or desert shrub analysis regions. Grazing, as a biological control method, may compete in a minor way with wild horses and burros, but this would be short term and highly localized. Biological treatments using insects and pathogens have little potential for affecting wild horses and burros because these treatments are host-specific and slow-acting.

Prescribed Burning

Prescribed burning would temporarily reduce available forage for wild horses and burros, but ultimately it could result in increased plant production in treated areas. Using prescribed burning with chemical control could effectively control the tar-