Sand Creek Massacre National Historic Site

Restoration Plan 2011

NATIONAL PARK SERVICE

Lady Bird Johnson Wildflower center
THE UNIVERSITY OF TEXAS AT AUSTIN

Table of Contents

List of Tables

List of Figures

Introduction

Initial investigation into the establishment of Sand Creek as a National Historic Site began in 1998 as a result of legislation sponsored by Colorado Senator Ben Nighthorse Campbell. [1] This legislation, the Sand Creek Massacre National Historic Site Study Act, mandated that the National Park Service identify the location and extent of the massacre, as well as the feasibility of creating a National Historic Site (NHS). After many years of research and cooperation among partners such as the State of Colorado, Kiowa County, Representatives of the Cheyenne and Arapaho Tribes from Montana, Oklahoma and Wyoming, private citizens, and the Conservation Fund, the Sand Creek Massacre NHS was officially authorized in 2000 and established as a National Park Service unit in 2007. Its mission is to preserve and protect the cultural landscape of the massacre and to enhance public understanding of this historic event.

Located in the Great Plains on the eastern edge of Colorado in Kiowa County, the 2,400 acre park is a combination of sand hills, wetlands, shortgrass prairie, mixed grass prairie and sage shrub land. Sand Creek, an intermittent stream, crosses the site. Preservation and restoration of the entire Park to a mid-1800s ecological landscape began in 2003, subsequently the Lady Bird Johnson Wildflower Center was hired to conduct a site assessment and assist NPS staff to assemble a restoration plan of Sand Creek Massacre NHS. The goals of restoration efforts at Sand Creek Massacre NHS are twofold: to restore the native prairie ecosystem, and to enhance the human relationship with this landscape through restoration and historic narratives. This Restoration Plan will provide the Sand Creek Massacre NHS with the appropriate tools to demonstrate successful ecological restoration techniques, enhance historical and recreational landscape value, preserve the cultural landscape for Cheyenne and Arapaho communities, reintroduce wildlife such as prairie chickens, and provide opportunities for multicultural research which supports the natural and cultural knowledge. This Restoration Plan also complements the National Park Service's mission to use "scientific study and observation" to further an "understanding of this unique cultural and ecological environment".[2]

Project Site - Historical

On November 29, 1864, roughly 600 volunteers from the 1st and 3rd Colorado Regiments attacked an encampment of Cheyenne and Arapaho along Sand Creek. "The camp's isolation from its approximately 1,000 horses, pastured at a distance because of lack of forage near the creek, hindered escape"[3] and over 150 Cheyenne and Arapaho Indians were killed in the attack, most of whom were women, children, and elderly. The exact location of the

[1] Public Law 105-243. Can be found at: http://www.nps.gov/sand/historyculture/upload/us0610199801pl105-243[1].pdf
[2] http://www.nps.gov/sand/naturescience/index.htm
[3] http://www.nps.gov/sand/historyculture/index.htm

Massacre was obscured over time as the area experienced extensive farming and ranching by early European settlers, as well as other disturbances such as fire, grazing, hunting, erosion, and development. Review of historical documents and gathering of stories from descendents of survivors, however, has helped to identify the location of the massacre site, though the site continues to be studied.

Project Site – Ecological

Sand Creek Massacre NHS is located in Great Plains - Palouse Dry Steppe province eco-region. Currently, Sand Creek receives 13 inches of rain annually, has average minimum and maximum air temperatures of 35 and 66^{o}F respectively, and has an elevation ranging from 3,940-4,085 feet.

"Sand Creek Massacre NHS is roughly bisected by Big Sandy Creek, a sub-irrigated, intermittent stream typical of a sandy Great Plains riparian system. Loamy, level plains of shortgrass prairie and agricultural fields expand away from Big Sandy Creek to the north and east. Sand hills with sand sagebrush shrublands occupy the south and west side of Big Sandy Creek, much of which is in native rangeland. The authorized boundary of Sand Creek Massacre NHS surrounding the established boundary is in private ownership, and it is surrounded by dryland agricultural fields and rangeland with sparse development" (Sovell et al. 2008).

Sand Creek's landscape is a physical record of the narrative of human relationships with the natural environment. Environmental changes due to human influences have contributed to alterations in the landscape throughout history. This was true even when Paleo-Indians entered the area roughly 8,000-10,000 years ago as they transitioned from nomadic hunter-gatherers to sedentary farmers during periods of favorable climatic conditions, for example, consistent rainfall. However, more recent historical narratives describe the changes inflicted on this ecosystem as Native Americans and early European settlers competed for limited resources. Europeans began to explore the area in the 1700s, at the same time that Cheyenne and Arapaho tribes were also expanding into the Plains. The Anglo-European population in the region doubled in the mid-1800s placing ever increasing demands on the landscape for resources.

Beginning in 1830, increased migration and settlement by Europeans increased prairie and riparian degradation through heavy grazing and inadequate farming techniques. "The increased demands on the land, both by native populations and white settlers, coupled with the unpredictable nature of the climate, had taken the plains ecosystem to the very brink of collapse" (Michell 2007).

With the increase of settlement of the southern Great Plains from 1700 onward, there was a transition from grazing and browsing native herbivores (e.g. bison) to free ranging and eventually confined livestock (Smeins 1980). Cattle have marginally different diets from bison which, although slight, can have dramatic difference on vegetation. Increased settlement and higher stocking rates of heavy grazers such as cattle, along with the suppression of fire, decreased herbaceous productivity and allowed an increase in brush species (Smith 1899). The impact of managed cattle was significantly different than that of bison on the local vegetation. Migrating bison produced short duration but very intense grazing events, allowing the land several years to recover between bison grazing events. Conversely, domestic cattle caused continual disturbance of varying intensity. This continuous grazing pattern alters the composition and suppresses productivity of the herbaceous biomass resulting in both the spread of woody and invasive species and the loss of palatable species at a local scale (Walker 1993). This phenomenon can be exacerbated by simultaneous drought (Van Auken 2000).

As introduced livestock species began to replace the bison and pronghorn antelope, and droughts in the mid-1800s intensified, the natural and cultural pressures placed on the landscape were dramatically increased.

Farmland along stream channels was initially irrigated by primitive, privately owned ditches until a large network of corporate canals was developed around 1880. Elevated areas were dry land farmed until drought caused the land to be returned to grazing. The decades-long impact of droughts and increasing pressures on the landscape through human use were major contributors to the dustbowl in the 1930s. These historical and ecological occurrences have led to the need for restoration.

Goals and vision of implementing Restoration Plan

The goal of this project is to restore these ecosystems to their mid-1800s state to serve as a living historical demonstration of the landscape that that existed during the time of the massacre. Due to past agricultural practice, development, and alteration of the historic disturbance regime, very little of these original plant communities remain. The restored site will not only serve as a demonstration of a historic landscape but will also provide a refugium for native species whose populations are in decline. After restoration is complete, the resulting spectrum of plant communities viewed at Sand Creek will represent the region's structural diversity, from shortgrass prairie to prairie wetland to riparian areas.

Furthermore the restoration of Sand Creek Massacre National Historic Park will evoke an inseparable and reciprocal connection between natural resources, cultural resources and people through shared experiences and activity and through the healing of the land. The potential target restoration areas include two small parcels totaling approximately 5 acres that will be restored to the landscape that existed at the time of the Sand Creek Massacre. Equally significant to the site's ecological restoration is the interpretation of the site. The Park will provide the opportunity for visitors to form their own ideas, conclusions and connections, both intellectual and emotional, about the history of the place.

The Park will work to restore the ecological landscape to a sustainable condition and to enhance its value as a cultural resource, not only for the Cheyenne and Arapaho communities, but also for all park visitors. The Park hopes to reintroduce native wildlife such as prairie chickens, preserve the population of culturally significant cottonwood witness trees, and provide multicultural research opportunities.

II. Site Assessment and Planning

Ecological site analysis

Sand Creek Massacre NHS's 2,400 acres lie along a 5.5 mile stretch of the Big Sandy Creek in southeastern Colorado. The landscape contains mixed-grass prairies, wooded riparian areas, and a section of rare wetland prairie. These wetlands areas are vital to the shortgrass prairie ecosystem and contribute significant wildlife habitat. The Creek is currently an intermittent stream with grass, brush and cottonwood stands. The eastern cottonwood trees are "found in even-aged groves close to current or historic seasonal stream traces of Big Sandy Creek" (Perkins et al., 2005: 11).

Figure 1: Cottonwood trees as seen in the riparian areas at Sand Creek in 2008.

The majority of the site is classified as short grass prairie which is characterized by its low stature, primarily due to two factors: low precipitation rates and an adaptation to heavy grazing by bison, elk, and pronghorn sheep. Currently, it is estimated that due to ecological and cultural changes across the Plains, “48% of the short-grass prairie ecosystem has been lost for agricultural purposes, or due to the creation of pastureland by seeding the area with exotic grasses” (Samson et al. 2004).

Soil types that have historically supported similar vegetation communities are grouped into ecological sites within the NRCS soil survey. The ecological sites within Sand Creek are mapped in Figure 2, followed by their description (NRCS 2009).

Ecological Sites at Sand Creek Massacre NHS

Table 1 contains the seven major ecological sites found at Sand Creek Massacre NHS (NRCS, 2009). The table and descriptions below contain information for the entire federally-owned lands within and around Sand Creek Massacre NHS, roughly 12,000 acres. Ecological Site descriptions replace the traditional range site descriptions that focused primarily on forage production in favor of descriptions that include vegetation dynamics and broader resource uses and values as well as forage production, historical plant climax community and historic fire regime. Soils with similar properties that produce and support a similar plant community, and respond similarly to management, are grouped into the same ecological site. Ecological sites are differentiated from one another based on four main factors: significant differences in species or species groups; significant differences in species composition; differences in productivity; and soil factors that influence species composition or productivity (NRCS 2009).

Table 1: The seven principal ecological sites within Sand Creek Massacre National Historic Site.

EcoSite*	# of Acres**	Distinct Soil Types	Map Color
Loamy Plains	4,992	Baca Loam; Baca-Wiley Complex; Colby Silt Loam; Kim-Harvey-Stoneham Loams; Kim-Stoneham-Larimer Loams; Richfield Silt Loam; Singerton-Pultney Complex; Stoneham Loam; Wiley Loam	Orange
Deep Sands	3,314	Bijou Loamy Sand; Bijou-Valent Loamy Sands; Valent Loamy Sand; Valent-Blownout Land Complex	Yellow
Sandy Plains	2,024	Fort Collins Sandy Loam; Olney Loamy Sand; Sundance Loamy Sand	Blue
Sandy Bottomland	872	Bankard-Glenberg Complex	Green
Salt Meadow	787	Fluvaquents	Purple
Sandy Salt Flat	203	Keyner Loamy Sand	Red
Saline Overflow	154	Manzanola Clay Loam	Light Blue

*This list is not exhaustive. Two other Eco-Sites exist on site but their extent is minimal relative to the other Eco-Sites and they are not located near Sand Creek's central 2,400 acres.

**Acreage was rounded to the nearest whole number.

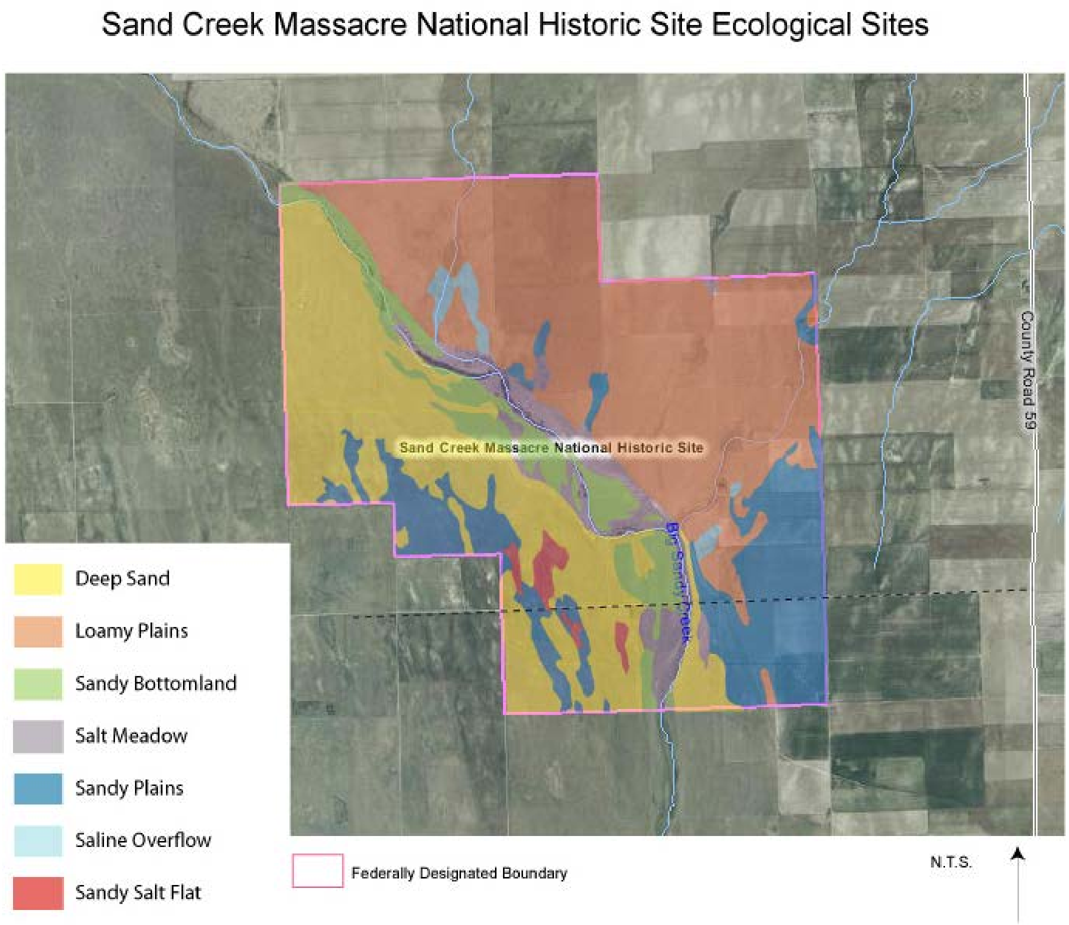


Figure 2: The seven major ecological sites at Sand Creek Massacre NHS.

Deep Sands

The Deep Sands ecological site occurs on the upland plains. Slopes are nearly level to gently undulating, typically less than 5 percent. Low stabilized hummocks or dunes frequently occur and elevations range from 5,000 to 7,000 feet above sea level. The surface textures are loamy fine sand and sand that extends to a depth of 60 inches or more. The soils on this site are deep and excessively drained as the soils are rapidly permeable and have a low water-holding capacity. Thus, surface runoff is very slow and the fast drying characteristic of the soil surface makes soil blowing a hazard.

The vegetative community is a grassland characterized by both warm- and cool-season perennial tall and mid-grasses, low growing shrubs and half-shrubs, and a variety of forbs. Forb production fluctuates greatly from year to year due to the amount of available fall and spring moisture. When moisture levels are high, forbs are an important and productive element of the Deep Sand's vegetative community.

Loamy Plains

The loamy plains ecological site occurs on level to gently sloping fan piedmont, alluvial fans, fan remnants or flood plains. Slopes range from 1 to 15 percent, averaging less than 5 percent, and elevations range from about 3,800 to 5,000 feet. The loamy plains are a grassland community dominated by warm-season mid-grasses, though tall grasses, cool-season grasses and forbs make up an important component of the plant community. Woody plants make up only a minor component though certain species such as honey mesquite (*Prosopis glandulosa*) readily invade this site, perhaps facilitated by bare areas where grass competition and/or fire is diminished. As grasses diminish, the area could transform into a shrubland.

The loamy plains have been called a "tension zone" (Curtis 1959) as the site often lies between sandy upland sites and clayey lowland sites, reflecting the intermediate character of the soil texture. For example, the site intergrades with sandy, clayey, and gravelly or gravelly loam sites and does not often form sharp boundaries with them. Within these tension zones, species diversity is high and differences in environmental conditions can produce large changes in community structure. Thus, plant composition can vary dramatically among the various soil conditions. The presumed historic plant community type of the loamy plains is dominated by black grama (*Bouteloua eriopoda*) while tobosa (*Pleuraphis mutica*) and alkali sacaton (*Sporobolus airoides*) are secondary dominants (NRCS 2009). This type of plant community has not been located anywhere in the Sand Creek Massacre NHS sandy loam ecological site. The loss of black grama, with subsequent dominance by burrograss (*Scleropogon brevifolius*) or threeawns (*Aristida spp.),* as a typical response to grazing (Hunter 1996, NRCS 2009).

Sandy Bottomland

The Sandy Bottomland ecological site is a riparian site in the flood plains along major rivers and streams in the Great Plains. Relative to other sites, the Sandy Bottomland is located at the lowest position on the landscape. The deep soils in this ecological site are composed of sandy alluvium with some silty and loamy layers interspersed in certain locations as a result of flooding and associated overland flow. Periodic flooding occurs on much of the site but is usually of short duration and signs of deposition are usually visible. Deposition of sandy alluvium continues on portions of many Sandy Bottomland sites. Some of the fluvial terraces located further upland from the streambed are no longer regularly flooded and have become more stable. Generally, smaller streams such as Sand Creek have less developed terraces that are narrower in width while major rivers can have stream terraces of several hundred feet in width. The periodic and frequent flooding events have played a major role in the development of the historic natural plant community.

Historically, plains riparian sites produced scattered timber, mainly cottonwoods (*Populus spp.)* and a few willows (*Salix* spp.) along with some shorter shrubs such as plum (*Prunus spp.),* sumac (*Rhus spp.*) and willow baccharis (*Baccharis salicina*). Tallgrasses such as sand bluestem (*Andropogon hallii*), switchgrass (*Panicum virgatum*), Indiangrass (*Sorghastrum nutans*) and little bluestem (*Schizachyrium scoparium*) were the dominant class of herbaceous vegetation in this ecological site. Vegetation would establish and increase between flood events, but major floods left a more sparse plant population, particularly in the region near the channel, as vegetation was directly destroyed by flood waters or impacted by flood related soil erosion and deposition. Stream channels shift over time making different areas subject to flooding over time. Under this cycle of flooding and stable periods, fluvial terraces were formed. Over time, some areas were less frequently flooded and became more stable. With stability, the plant community would increase in both diversity and density.

The development of the plant community depends not only upon the frequency of major flooding, but also soil development and the presence or absence of a high water table. The high water table in the Sandy Bottomland means that the amount of plant available water is comparatively high resulting in a high production potential for plant growth. Although there may be a high water table present under portions of the ecological site, the soil is not saturated to the surface. The upper profile is generally well drained, although water can be found at depths of 3 to 5 feet along major streams in the region, the level fluctuating from seasonally and yearly. Generally, willows and cottonwoods take advantage of the high water table, as do some of the deeper rooted shrubs and tall grasses. Typically, a plant community dominated by a variety of grass species with fewer water loving shrubs indicates a greater depth to ground water. The depth to water will have as much or more influence on the plant community makeup as grazing management or the presence or absence of fire.

Natural fire was also an important factor in shaping and maintaining the historic plant community on the Sandy Bottomland site. The tall grasses, along with some accumulated dead woody material from shrubs and trees, provided a significant fuel load. Cottonwoods have increased dramatically in many areas of this ecological site due to fire suppression (as well as reduced flooding events). If cottonwoods are desired in this zone, which is often the case for aesthetic and wildlife purposes, the use of prescribed fire in this site must be carefully planned and applied. For example, larger cottonwoods could be protected by mowing underneath the canopy. Since this site is adjacent to streams that often have a largely bare sandy stream bed, the movement of fire can sometimes be more easily managed.

The vegetative community in this ecological site is as much a result of non-human influences on environmental flows of these creeks and rivers, such as a high water table and occasional fires, as human actions. There is some speculation as to whether flooding events were influenced by overgrazing of the surrounding watershed, contributing to greater runoff. Though bison often grazed the range closely, their migratory habits allowed for recovery of the native vegetation. In some cases, reservoirs were constructed on major streams which have interrupted the natural frequency of flooding causing a major change in the amount and the nature of the vegetation in the Sandy Bottomland. With suppression of flood events he amount of all types of vegetation usually increases, and in many cases regionally, invasive woody species such as salt cedar (*Tamarix ramosissima*) have invaded and become dominant. Currently no salt cedar exists in the park, but an infestation exists upstream which requires constant monitoring. Over time, with no major flooding, vegetation of all types will usually increase as the site stabilizes. This is a natural process, but is one that is definitely influenced by human activities.

Salt cedar is an introduced shrub-like tree that has invaded bottomlands along many of the western streams in the U.S., and occupies significant portions of many Sandy Bottomland sites in this region. Russian olive (*Elaeagnus angustifolius*) and common bermudagrass (*Cynodon dactylon*) may also invade the site.

Maintaining good vegetative cover on this site has a positive effect on water quality downstream by reducing sedimentation and increasing aquifer recharge.

Salt Meadow

The Salt Meadow is found on nearly level to gently sloping bottoms and fans adjacent to the Sandy Bottomland in the floodplain region of Sand Creek. The soils are composed of a clay loam for the first 0-10 inches and a stratified clay loam to gravelly sand past 10 inches, all somewhat poorly drained soils. The soils have water tables at or near the surface much of the growing season. The slope in this eco-region is low, ranging from 0-4%, with a low depth to the water table, roughly 12-48 inches.

These sites receive water from surrounding areas, either as shallow ground water or surface runoff. The Salt Meadow site is a grassland mixed with shrubs. Since moisture for plant growth is supplied principally by a shallow water table, vegetation is tolerant to saline or alkaline factors, which dominate this site. Grasses such as western wheatgrass and vine-mesquite dominate the site, with shrubs and forbs making up an important part of the vegetative community.

Sandy Plains

The Sand Plains ecological site also occurs on the upland zones, but in the level to gently undulating sloping areas. Elevation ranges from 3,600 to 4,800 feet above sea level and slope ranges from 0 to 9 percent. The soils of this site are deep and well drained; the surface textures are fine sandy or loamy fine sand from 10 to 36 inches thick. The subsoils are sandy clay loam, fine sandy loam or loamy fine sand. In some areas, a calcic horizon occurs at a depth of 20 to 40 inches. These soils types and structures have fairly rapid permeability and a moderate to high water holding capacity.

In this site, the plant-soil-air-water relationship is important. Because of the coarse surface textures, the soils, if unprotected by plant cover and organic residue, can become wind-blown and low hummocks or dunes can form around shrubs. The vegetative community is grassland dominated by warm-season, tall and mid-grasses. Cool-season bunchgrasses, shrubs and half-shrubs, and forbs occupy approximately 40 to 45 percent of the plant community and are evenly distributed. Similar to the Deep Sands, forb composition of the Sandy Plains fluctuates from year to year depending upon moisture conditions.

Sandy Salt Flat

The Sandy Salt Flat consists of very deep, well drained soils. This site is in floodplains, alluvial flats, fan remnants and stream terraces and have.   Slopes range from 0 to 3 percent, and elevations range from 3,700 to 5,000 feet. Surface soil textures are loam, sandy loam and silt loam while subsoil textures are silty clay loam, clay loam, loam and sandy clay loam. Salt flats can be associated with playas that are barren because they are inundated for long periods. Bare areas may persist for decades or longer. Furthermore, the soils contain varying amounts of salt and alkali accumulations which inhibit certain plant species. The soils and vegetation of this site intergrades with that of the loamy sites, depending on the levels of gypsum and sodicity/salinity. Differences in sodicity within the Sandy Salt Flat site have important effects on soil properties while differences in salinity control plant composition directly. The historic plant community type of the Sandy Salt Flat site is dominated by alkali sacaton (*Sporobolus airoides*) and scattered small shrubs. Fluctuations in sacaton cover may occur in response to drought or grazing pressure as either influence can lead to plant mortality. The concentration of sodium and/or salts at the soil surface may also play a role in retarding sacaton establishment in patches and larger areas. Alteration of surface hydrology, such that run-in water is diverted away from grass patches, may also lead to grass loss.

Saline overflow

The Saline Overflow ecological site occurs on overflow lands where salt and/or alkali accumulations are apparent and salt-tolerant species dominate the plant community. It is associated mainly with ephemeral streams yet this ecological site can also occur around pond margins, particularly if the water recedes, for example, in drawdown zones. The elevation in the Saline Overflow ranges from 2,250 to 4,500 feet and slopes are low, ranging from 0 to 4 percent.

The high saline soils are primarily greater than 20 inches deep and surface textures are mainly silty clay loam and loam, but can also be silty clay, silt loam, sandy loam, clay loam and clay. Permeability is variable, depending on surface texture and the amount of salt and/or sodium present. These sites are affected by additional moisture, which is mainly the result of surface run-in.

Vegetation in the Saline Overflow includes tall, medium and short grasses, forbs and shrubs. The historic climax plant community in this ecological site is grassland dominated by cool and warm season grasses with scattered shrub cover. This community's dominant species include grasses such as wildrye and alkali sacaton and shrubs such as winterfat and black greasewood. Medium and short grasses are abundant in this ecological site as a result of disturbances such as grazing. Example of dominant short and medium grasses include western wheatgrass and inland saltgrass.

The diversity in plant species and the presence of tall, deep-rooted perennial grasses allows for moderately high drought tolerance. The tall grass's strong, healthy root systems allow production to increase significantly with favorable precipitation. The healthy tall grass plant community provides for soil stability and a functioning hydrologic cycle. In some areas, the vegetative community is more compromised and consists of short and medium grasses, and weedy forbs. Though the medium and short grasses provide moderate soil stability, these areas emerge as a result of continual adverse disturbance. These areas have reduced native plant production and are regularly invaded by kochia (*Kochia scoparia*) and foxtail barley (*Hordeum jubatum*). The lack of plant litter and the short plant height results in higher soil temperatures, poor water infiltration rates and increased evaporation, which gives short sod grasses and annual invaders a competitive advantage over the cool season tall and medium grasses. Restoration efforts will help move these types of plant communities within the Saline Overflow towards a higher successional stage and a more productive plant community.

Current conditions

An extensive mapping and vegetation survey was conducted in 2007 by the National Park Service to gather baseline data needed to make future land management decisions. A synopsis of the site is found in that report (Neid et al. 2007); what follows is a brief description of the biological community and areas that are best suited for ecological restoration.

The diversity of grassland and riparian areas at Sand Creek Massacre NHS provides a unique and important habitat. However, several historical factors have altered the landscape including the conversion of land for agricultural practices and the suppression of fire. Changes such as these have compromised the existing site ecology. The Great Plains area is a good example of the same climactic area having a number of stable ecological states. Any given site in the Great Plains has probably been, within the last several thousand years, open grassland, savanna and riparian woodland. All three of these conditions are stable states and once present, are often resistant to change under the normal climatic and disturbance regime (Smeins 1980, Smeins 1982, McPherson et al. 1988, Smeins and Merrill 1988, Archer 1989, 1990).

Models of the formation of plant species assemblages at the community- and landscape-scale invoke the association of environment, climate and time (Begon et al. 1986). These, in turn, interact with the changes in population and distribution of floral and faunal species. In North America, however, with the spread of human activity over the last 10,000 years, the growing influence of agriculture, industry and society has had an even more dramatic impact on vegetation change.

As early as the 1850's, as Europeans settlers moved farther west, the native prairie was converted to cultivated agriculture. Converting the prairie for agricultural purposes has led to several detrimental site conditions. Removal of native prairie grass species led to an increased potential for erosion, invasion by nonnative species, loss of habitat for native wildlife and decreased diversity. Across the Sand Creek Massacre NHS, significant potential for erosion exists. Prairie grass's extensive root system binds the soil, protecting it from erosion. The prairie sod is so dense that “settlers once used it like bricks to build houses” (NPS 2005). The physical act of converting prairie to row crop agriculture reduces this native, highly functional, surface cover and destabilizes soil structure. Furthermore, continuous heavy grazing by livestock can compact soils and affect many of their characteristics and functions, such as water infiltration.

Prairie grasses have the unique ability to thrive with major disturbances such as drought, fire and grazing. “Unlike most plants that add new growth to their tips, [these] grasses grow from their base and have an extensive root system” (NPS 2005). Thus, the sensitive growth tissues remain below the soil protected from these types of disturbance. This unique method of growth allows the plant to grow back after grazing or fire disturbances, and their deep root systems (sometimes extending 10-15 feet (4.5-6 m) below the surface) allow them to access water below the surface during times of drought. A second major element of prairie ecosystems are forbs. Forbs are advantageous species in that they often send their roots deeper than some grasses to access more water, and provide an important food source for many species (Bolen & Robinson 2003).

The extensive root systems makes original prairie sod a great conserver of soil and water. Water runoff from prairie is relatively small when compared to row crops or other ecosystems where there is no large network of roots. The early farming practices did very little to capture and retain moisture. The Dust Bowl of the 1930's, centered on the Southern Plains, was a result of removing the protective vegetative layer and exposing vast areas of cultivated prairie soil to wind action and drought.

Currently, the site has low native grass and forb diversity, many nonnative species are present and some riparian woody species are absent. There is an over abundance of sage and annual weeds such as kochia (*Kochia scoparia*) and Russian thistle (*Salsola tragus*).

Biological conditions

Shortgrass prairies support numerous animal and plant species, including endangered and threatened species. Protection of the native biological resources – plant and animal species – also preserves the culture landscape.

Figure 3: Short grass prairie at Sand Creek Massacre NHS. Source: NPS

The site and surrounding area have been affected by hunting, grazing, cultivation, water diversion, development, introduction of non-native species and local extinction of native species such as the pronghorn antelope and bison.

The wetland prairie at Sand Creek is a persistent emergent wetland. Meaning, it is dominated by persistent vegetation for most of the growing season, in most years. Though the Great Plains wetlands only comprise a small portion of the landscape, they are often the areas of highest species diversity.

The wetland, shortgrass prairie and riparian areas of Sand Creek Massacre NHS support numerous species of birds. According to the NPS, at least 59 bird species have been recorded in the site. Only one species of fish, the Plains killifish, has been recorded in Sand Creek. Several small mammals are also present in the site, such as the black-tailed prairie dog. The prairie dog, discussed again later in this report, is a crucial indicator species as to the health of Sand Creek's ecosystem. One of the reasons it is considered a crucial is that numerous other species depend on the habitat provided by the prairie dogs and their burrows. The prairie dog was listed as a special-status species in Sand Creek NHS, one of 11 total. The other species classified were the burrowing owl, mountain plover, Swainson's hawk, scaled quail, northern harrier, loggerhead shrike, bleached skimmer dragonfly, red-headed woodpecker, white-faced ibis and northern leopard frog[4]. As one of the goals of this plan is to restore prairie conditions to the mid 1800s in order the opportunity exists to bring back the native plant and animal diversity historic to the park, including populations of the prairie dog and lesser prairie chickens depending on desirability of these species. Although the lesser prairie chickens historically occupied Sand Creek NHS, it is thought that the species may be locally extinct from the area.

Currently, there is a stand of cottonwood trees lining Sand Creek. It is not clear whether or not these trees were present during the massacre, though some of them may have been present as saplings. It is also unclear how the cottonwoods became established along the creek, though it is believed that they may be associated with historical flooding events.

Table 1 in Appendix A contains the Master Plant List for Sand Creek Massacre NHS. Table 2 in Appendix B contains the list of non-native species found on site.

Ecological Reference Sites

It is important to note that each restoration project presents a unique set of circumstances, and no two ecological areas are identical. Therefore, project approach and management should account for any differences between the reference site and the restoration site. Reference sites are areas that are comparable in structure and function to the restoration site before it was altered. They may be used in several different ways: as models for restoration projects, or as a means for measuring the progress of the restoration project. Historic information on the ecological conditions of Sand Creek Massacre NHS could be used as a reference; however, these conditions may be unknown, and have been altered considerably over the years. Thus, it may be most useful to identify an existing, relatively healthy, similar site as a reference for this project.

The suggested reference site for the Sand Creek Massacre NHS restoration is the area surrounding the monument and upstream of the western boundary in section 24 of the USGS Topographic digital raster for the Sand Creek site. The river bottom in section 30 of the same map also provides a good reference point for vegetation communities of riparian areas.

[4] http://www.nps.gov/sand/naturescience/animals.htm

However, some riparian and prairie species to be re-introduced will need to be obtained off-site, for example, winterfat (*Krascheninnikovia lanata*).

Introduction to restoration process at Sand Creek

The continued protection and restoration of the resources at Sand Creek will contribute to the changing diversity of the ecosystem and biological communities with the aim to restore the park to its mid-1800s condition. Thus, the target vegetative community should be shortgrass prairie across most of the site and the goal along Sand Creek should be a healthy riparian community. The restoration objectives outlined during the 2009 restoration workshops were as follows: "The park will work to restore the ecological landscape to a sustainable condition to enhance its value as a cultural resource not only for the Cheyenne and Arapaho communities but also for all park visitors. The Park hopes to reintroduce prairie chickens, preserve the population of culturally significant cottonwood witness trees, and provide multicultural research opportunities." Scientific study and observation of these resources will add to our understanding of this unique environment.

It is often beneficial for restoration to occur incrementally so that the vagaries of climate do not overwhelm a significant investment or effort. Additionally, the incremental approach will allow for fine tuning the restoration methods to what works best on site with the most effective staff and volunteer effort. Initial efforts should begin in high priority areas. For example, if Sand Creek will contain a trail network, then restoration could be visible from the trail. Combining restoration areas with trail locations will increase accessibility, facilitate monitoring and add to the interpretive and educational experience for park visitors. The intent of this report, however, is not to be overly prescriptive but to allow Sand Creek Massacre NHS staff and volunteers to discern where priority areas are located and where time can be most efficiently directed.

III. Installing the Plan – Restoration and Management Techniques

As mentioned in the Introduction, restoration efforts at Sand Creek began in 2003 when the Natural Resource staff from Sand Creek and Bent's Old Fort National Historic Sites began reseeding a washed out road. Later efforts involved the removal of invasive species along the creek and riparian zones and seeding 25 acres of the park with a native seed mix. In the long term, Sand Creek staff will continue to collect seed and work on small revegetation efforts including the removal of invasive species.

Ecological restoration is a process dependent on a number of key variables: controllable variables (seed addition, prescribed fire, grazing, mowing); partially controllable variables (seed bank, soil conditions); and some variables beyond the control of the restoration manager (climate, immigrant seed). Any one of these uncontrollable variables can effectively trump active management events, or can impede some or all of the aforementioned variables. To increase the chance of success it is important to adopt an integrated management plan that constantly monitors the progress toward the target state and can direct the management accordingly. Therefore, although this plan provides an outline of the expected actions, events may force further input of resources or delay the process.

Restoring historic communities

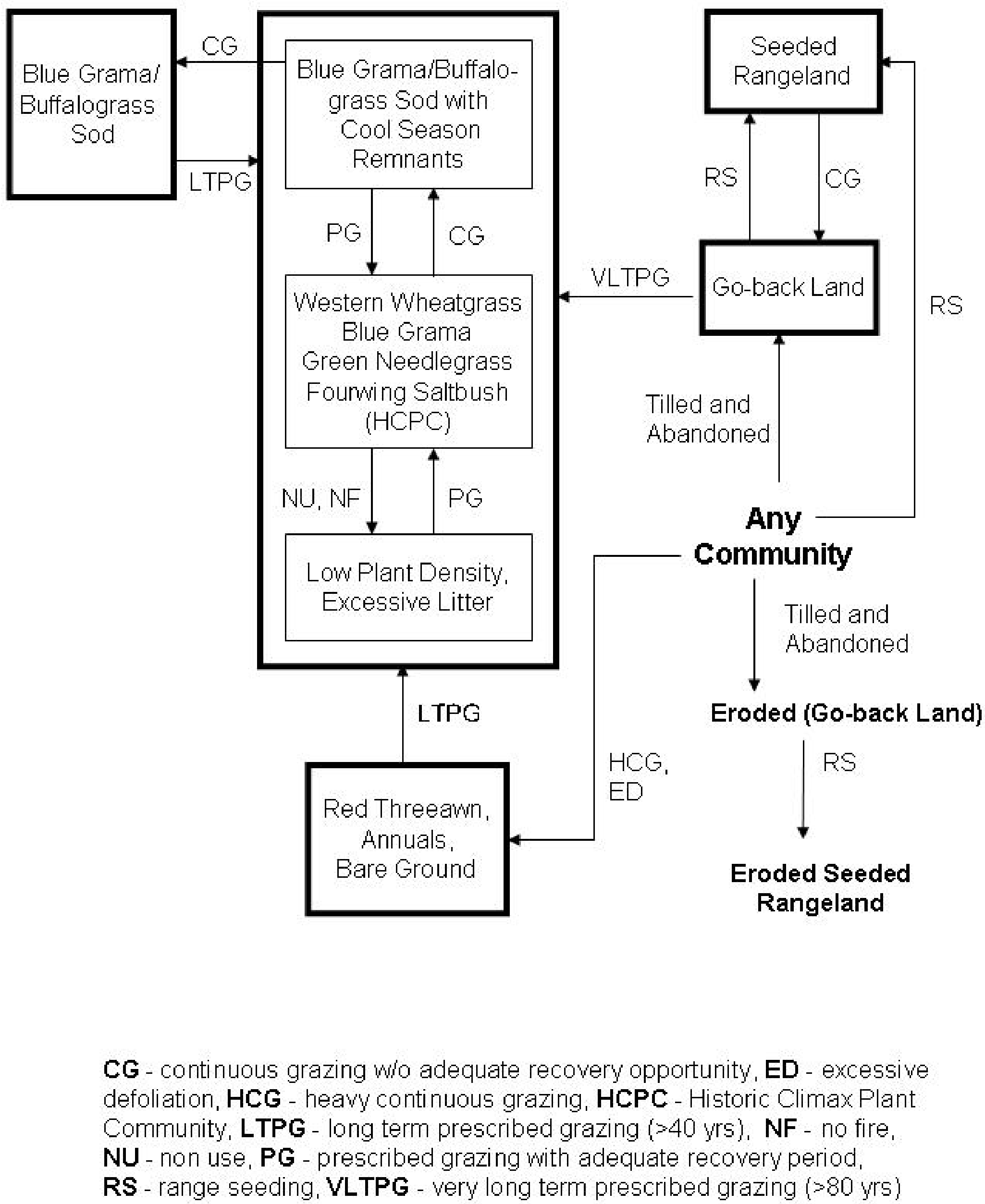
For most climatic zones of the world, there are a number of different stable ecological systems that could exist there, with the current ecosystem a result of historic events such as glaciations, catastrophic fire, normal periodic disturbance, past faunal use (including humans) or similar events. These historical events interact with soil and climatic extremes to result in the current ecological system, but this system is rarely the only one that has or could exist on the site (Egan and Howell 2001). Ecological systems that are self-sustaining within limits and require few inputs are referred to as stable ecological states. These states, resulting from climatic conditions and historical events or recent management, are resistant to change and require a shift in current management or another catastrophic event in order to move from one stable state to another. The energy required for this shift varies between ecological systems (Laycock 1991, McPherson 1997, Peterson et al. 1998, Anonymous 2000).

There are a wide variety of tools and methodologies available to the land manager to help move between the various stable ecological states. As an example, Figure 4 shows the different stable states that are possible for the loamy bottomland ecological site present in the restoration areas of Sand Creek Massacre NHS and the tools and methods that are commonly employed to move between the states. Once achieved, these ecological states (grassland, savanna or riparian), are considered stable in that they do not require significant inputs in order to be maintained, but most will require some form of routine management (Smeins 1982, McPherson et al. 1988, Archer 1989, 1990, Archer and Smeins 1991, Scanlan and Archer 1991, Archer 1996, Fuhlendorf et al. 1997, McPherson 1997, Scholes and Archer 1997). In Figure 4, examples of routine management are shown on the interior boxes, with more intensive management shown by the arrows exterior to the boxes. These intensive management methodologies can be used to move between differing stable or intermediary states but may be impractical to use at Sand Creek Massacre NHS because of the amount of resources needed to undertake them, resulting soil disturbance or conflicting neighboring land use.

In keeping with the stated goal of restoring the site to its 1860s condition, the target vegetative community should be shortgrass prairie across most of the site and the goal along Sand Creek should be a healthy riparian community. Prescribed fire, in combination with selective invasive species control and strategic seeding of native species will be important tools within this restoration effort.

The best management strategy for Sand Creek Massacre NHS is to move toward a mosaic of diverse prairie plant communities across most of the site, and a healthy riparian condition along Sand Creek. A large number of areas on site will require significant energy and expense to return to an 1860s condition. For this reason, priority management will be given to relatively intact sites and high visibility sites and to slowly expanding these areas over time. This methodology will protect existing diversity and function, while allowing enhancement over time. Over time, as high priority sites shift from the more labor and cost intensive restoration phase, to the less intensive maintenance phase, resources can be shifted to lower priority sites.

Figure 4 State Transition Diagram, Loamy Plains ecological site.



Source: NRCS Soil Survey (2009)

Administrative

While restoration of Sand Creek Massacre NHS will address many ecological and biological conditions, this process must address administrative conditions as well. For example, a vegetation plan must comply with NEPA regulations. Under the NEPA guidelines, seeds can be collected directly from the site, but can be sown with only light soil disturbance. Details of this provision are found in Section 106 of the National Historic Preservation Act which outlines a process for allowing federal agencies to fully consider historic preservation issues in planning projects.[5] [6]

Necessary Processes, Permits & Regulations

As mentioned earlier, prescribed burning is a recommended technique for prairie restoration (Bolen & Robinson 2003, Helzer 2010, Holechek et al. 2004, Vallentine 1989). Without fire, the predominant ecological sites found within Sand Creek Massacre NHS will move to a low plant density, excessive litter state (NRCS 2009). Prescribed fire is currently a restoration practice applied at the Lake Meredith National Recreation Area in the panhandle region of Texas. The prescribed fire team from Lake Meredith will help with prescribed burns at Sand Creek Massacre NHS. To get started with prescribed burning, it will be important to have the assistance of knowledgeable and experienced people. Fire management plans at Sand Creek Massacre NHS are already in place and tribal consultation needs to be on-going in this regard. Karl Zimmerman, Chief of Resources and Operations at Sand Creek Massacre NHS, will need a resource technician. Outreach on this fire management plan is recommended to alert the public to the purpose and timing of this project. As a reference, the 2009 prescribed burn press release for Lake Meredith NRA can be found here:

http://www.nps.gov/lamr/parkmgmt/firemanagement.htm.

---

[5] The entire document can be located here: http://www.achp.gov/docs/nhpa%202008-final.pdf

[6] Agencies are responsible for completing the following steps in the process:

- Initiating Review, determining if Section 106 applies to a given project and, if so, initiate review;
- Identifying Historic Properties, determining the area that will be affected by the project and gathering information to decide which properties in the project area are listed in or eligible for the National Register of Historic Places.;
- Assessing Effects on Historic Properties, determining how historic properties might be affected by the project; and
- Resolving Adverse Effects, identifying those effects that alter, directly or indirectly, the characteristics of a historic property that qualify it for inclusion in or eligibility for the National Register.

Other administrative attention might be needed if irrigation is to be used on site. (Irrigation practices are described below). For example, it is necessary to ensure that there is adequate water availability at the site. If not, then water rights will need to be researched if new irrigation is needed.

Physical needs and resources

When conducting restoration activities at Sand Creek it is important to consider the equipment and labor needed to carry out tasks, the level of community involvement and the availability of biological materials. Table 2 below summarizes some of the needs in this regard for the prairie restoration at Sand Creek. Park staff will need to research costs specific to Sand Creek NHS.

Table 2: Physical Needs and Associated Costs of Sand Creek Restoration

Sand Creek Massacre NHS Physical Needs Assessment		
Physical Need		**Cost**
Seed Sorter/Cleaner	Rent or Purchase? Source?	
Seed	Arkansas Valley Seed Pawnee Buttes Seed Sharp Bros. Seed	
Tree Spade(s)	Rent or Purchase?	
Other Tools?	Seeder Herbicide applicators	
Volunteer Labor Volunteer coordination	Who?	
Labor	Temporary, seasonal Who?	
Staff member(s) for labor supervision	Who?	

The most efficient way to begin a large restoration project is by first focusing on the highest priority areas. The lessons learned and skills obtained from the first projects will inform second phase projects and so forth. As the need for the labor and resources utilized on the first projects undertaken begins to wane, they can be reallocated to the next projects. It is critical to account for continuing maintenance and invasive species control of already restored or enhanced projects when reallocating those resources.

Timeline & Methods

Prairie Restoration

Native prairies are highly diverse and productive communities. This diversity cannot be recreated over a short time period. Prairie restoration projects strive to replace the prairie's basic components through seeding, transplanting and modification of soil conditions so that the prairie can begin to heal itself under continual management supervision. In time, the diversity will increase as additional species become established.

Prairie restoration efforts will preserve existing prairie species while adding some native species diversity (see Appendix A), and restoring the native fire regime through the use of prescribed burns. For the intensive restoration to be successful, efforts will need to focus first on removal of the invasive species and restoration of the natural disturbance regime, followed by the establishment of the Great Plains-Palouse Dry Steppe Prairie plant species. Invasive species reduce biodiversity and ecosystem stability and should be managed with an integrated pest management plan. Using this approach, restored prairie can be expanded bit by bit, and the existing remnant prairie can be enhanced with more biodiversity native to this ecoregion.

Invasive species management

Due to alterations in natural fire and grazing cycles, many of the grasslands in the Great Plains region have been invaded by woody oneseed juniper (*Juniperus monosperma*), smooth brome (*Bromus inermis*), cheatgrass (*Bromus tectorum*), Kochia (*Kochia scoparia*) and King Ranch bluestem (*Bothriochloa ischaemum*). Tamarisk (*Tamarix spp.*), scotch thistle (*Onopordum acanthium*) and Russian olive (*Elaeagnus angustifolia*) threaten the riparian areas. Examples of these species are illustrated below.

Figure 5: Examples of Invasive Species at Sand Creek Massacre NHS. From left to right: Cheat grass, Woody oneseed juniper, tamarisk and smooth brome.

Invasive species management is critical to the success of most restoration projects. Invasive species should be managed through a program of chemical and mechanical removal, prescribed fire, and through efforts to increase the general health of the community. This approach, is known as integrated pest management, which the U.S. Environmental Protection Agency defines as follows:

> Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment.
>
> The IPM approach can be applied to both agricultural and non-agricultural settings, such as the home, garden, and workplace. IPM takes advantage of all appropriate pest management options including, but not limited to, the judicious use of pesticides.[7]

An integrated pest management plan should be developed for Sand Creek NHS to complement the restoration plan. During the early phase of a restoration project, the preferred method of invasive species control is often judicious use of chemical herbicide. Species specific herbicide control methods can be found for many species in the Element Stewardship Abstracts originally compiled by the Nature Conservancy[8]. Ideally, over time, reliance on herbicides will be reduced as sound land management encourages a healthy ecosystem, capable of resisting invasion. In all pest management, the least toxic, effective and economically sound choice should be selected. Mechanical removal of invasive species is preferable to chemical control when it can

[7] http://www.epa.gov/opp00001/factsheets/ipm.htm
[8] http://www.invasive.org/gist/esadocs.html

be done effectively and economically. However, mechanical removal is labor intensive and thus may not always be an economically feasible choice. In addition, mechanical removal can cause soil damage. When herbicides are used, they should be applied in the most directed manner possible, and the least toxic, effective, herbicide should be selected. In addition, the potential impacts of inactive ingredients and additives should be evaluated. Prescribed fire is often better suited for use as a long-term management tool, rather than an immediate control method, and will be further discussed below.

Herbicide

Herbicides can be applied in a number of ways: broadcast, spot application, “wicking,” or by cut stump treatment. Broadcast application tends to apply the most herbicide by dispersing a broad mist over the entire area using either suspended sprayer on a tractor, or through aerial application. Spot application uses less herbicide as it selectively sprays herbicide within a field, targeting only a subset of the plants in the area. Wick application uses a saturated media (typically a rope or sponge) to put a small amount of herbicide on the target plant. Cut stump treatment uses mechanical removal of the upper plant material combined with herbicide application to the newly exposed cambium of a woody plant using either a spray wand, a paintbrush, or a chemical wash bottle. The most focused application method that will be effective should be selected in each situation.

Most weed management can be done within the scope of this project with several herbicides such as glyphosate and fluazifop. Glyphosate is the active ingredient found in such products as Round Up® and Eraser®. Glyphosate is a broad spectrum herbicide that can be used for control of a wide range of plants. Therefore, it’s application must be carefully timed and directed to avoid damaging desirable plants. Fluazifop is a grass-specific herbicide, meaning that it does not typically harm shrubs, forbs, or trees. Fusilade® is a common brand name herbicide with fluazifop as the active ingredient. If used correctly the benefits of these two chemicals are significant. Adjuvants, such as methylated seed oil (MSO), should be used with the herbicides, if not already added by the manufacturer. Adjuvants are important because they help the herbicide to stick to the plant surface and thus be absorbed more effectively into the plant. This greatly increases the effectiveness of herbicides. In addition, imazapic has been shown to be effective in controlling annual bromes, such as cheatgrass, though it often harms perennial grasses (Vermeire et al. 2009). As discussed earlier, the least toxic, effective, herbicide should be chosen in each situation, and the most focused application method that will be effective and economical should be chosen.

As discussed below, a portion of the prairie restoration efforts will be done through the interseeding method. Thus, it is important to understand the nature of undesirable species like

Kochia (*Kochia scoparia*) in order to plan invasive species management accordingly. Kochia is a common invasive species found at Sand Creek Massacre NHS. It is a common spring annual weed that invades pastures, rangelands, roadsides and dryland crops. Kochia plants average 12,000 seeds per plant under various conditions but can produce up to 23,000 seeds per plants in optimal conditions (Thompson et al. 1994, Nussbaum et al 1983). Kochia expresses very little dormancy, can germinate without light, and germination can occur with only one day above 10°C (50°F) resulting in early spring germination (Alan & Wiese 1985). In many restoration projects, native species are seeded into the ground to create a diverse and stable plant community. However, weed species such as Kochia that are already in the soil seed reserve interfere with optimal establishment of the desired plant community. The plant's early germination characteristic provide it with a competitive advantage over neighboring dormant perennial species; early germination allows it to use limited resources that could otherwise have been used by desirable species. Using herbicide to control annual weeds can become difficult when forbs are part of the desired seed mix since many annual weeds such as Kochia are forbs themselves. The plants will not resprout, so mechanical removal or mowing can control existing individuals. If herbicide is applied, it must be applied early in the lifecycle as the plants become more resistant with age. A New Mexico extension fact sheet suggests planting grasses first which will allow for methods such as mowing or the spot application of specific herbicides that do not harm grasses[9]. If the kochia are not allowed to set seed (through mowing, physical removal or herbicide application), the seed bank could be exhausted in 2 to 3 years, the length of time kochia seed remains viable in the soil. At that time forbs could be added. A similar method for controlling Kochia may be useful for Sand Creek.

Be cautious with the use of adjuvants however, because they can have environmental toxicity issues greater than the herbicide itself. Be sure to follow the manufacturer's guidelines found on the label whenever using herbicide.

Interseeding Method

Two main approaches to prairie restoration include the agricultural method and the interseeding method. We recommend using the interseeding approach for prairie restoration at Sand Creek Massacre NHS. Interseeding calls for seed to be sown among existing plants; this can be done with a seed drill on a tractor or by spreading seed by hand and raking. The interseeding approach is most appropriate for use when erosion is an issue and when existing natives should be protected. Very little soil preparation is necessary, though spot application of herbicide to existing invasive species prior to seeding is recommended.

[9] http://weeds.nmsu.edu/downloads/Russian_thistle_and_kochia_homeowner.pdf

This approach preserves existing native diversity, requires less work and is less likely to cause significant erosion from the site. For the first several years, competition from weed species will be more intense than it would be with the agricultural approach. More invasive species control will be necessary with this approach, but eventually the plant community will become more resistant to invasion and competition from invasive species.

Seeding

As a general rule, forbs should be sown in the fall/late summer and grasses in the spring. See Table 3 below. However, if only one seeding time is available, all of the seed can be sown in the fall. Processed seed, as is obtained from a commercial seed company, can be very effectively planted with either a no-till drill or a Brillion© seeder. Alternatively, seed can be hand broadcast and raked in by hand or with a tractor-drawn harrow to achieve good soil-seed contact. Several distributors have developed versions of seeding machines adapted for native seed by incorporating three separate seed bins for the three main types of seed: light fluffy seed, small hard seed and large hard seed. By using this type of range seeding equipment, all of the seed can be planted in one pass. Most seed companies will ship seed already mixed and bagged for a 3-bin seeder if requested.

It is recommended that seed be sown across two distinct events: one in the fall to synchronize with fall rains, the second to coincide with spring rainfall the following year. Many grasses will not germinate in the fall and may be lost to predation or rotting over the winter. A fall sowing of forbs and some rapidly establishing grasses will help to fill the ecological niche opened by fire and reduce the chance of invasion by undesirable grasses.

Seeding preferentially into disturbed areas will increase the seed's chance of germination and subsequent survival because of enhanced seed soil contact and the temporary reduction in competition from established plants. For example, seed can be applied after prescribed fire or into areas where the soil has been disturbed following invasive species control efforts.

The source of seed material is an important consideration in restoration projects. Ideally, all introduced seed will be of a local genotype. Introducing nonlocal genotypes can cause outbreeding depression as local and non-local genotypes hybridize (Goto et al. 2009). Outbreeding depression simply means that the local population, which is adapted to local conditions, could lose desirable characteristics or gain undesirable characteristics from the introduced group that is adapted to conditions elsewhere. For this reason, seed should be sourced from as close to the restoration site as possible. The definition of local is subject to debate. We suggest sourcing seed from within the EPA Level III ecoregion, or 200 miles of the site whenever possible. Reputable seed dealers will have records of where their stock originated, and seed collection can be used if appropriate collection sites are located. Seed collection should be done responsibly, as discussed below, and all laws and regulations should be followed.

Seed Collecting

Oftentimes the dominant species of a plant community will be available commercially, while many of the less common species are not. Many grass species that may be unavailable commercially would still be very useful for use in restoration efforts at Sand Creek Massacre NHS. Species included in this category are bushy bluestem (*Andropogon glomeratus*), silver bluestem (*Bothriochloa saccharoides*), hairy grama (*Bouteloua hirsuta*), Texas grama (*Bouteloua rigidiseta*), red grama (*Bouteloua trifida*), curly-mesquite (*Hilaria belangeri*), seep muhly (*Muhlenbergia reverchonii*), big muhly (*Muhlenbergia lindheimeri*), Texas wintergrass (*Nassella leucotricha*) and meadow dropseed (*Sporobolus asper*). Many of these species are annuals or short-lived perennials that are particularly effective at quickly establishing cover on bare ground. All of these species are already present at Sand Creek Massacre NHS Lands and could therefore be harvested at limited expense beyond labor costs.

Hand collected seeds can be used to add diversity to a seed mix for restoration of native plant communities. This is an excellent activity for volunteer groups to undertake. The Lady Bird Johnson Wildflower Center routinely uses volunteers to gather seed of hard- to-find species for either greenhouse production or restoration of natural areas. Furthermore, locally collected seeds ensure that the plants are adapted to that locale. Seeds grown in a different part of the state or country, even if they are the same species found locally, may not be ideally adapted to the new locale's climate, soil, etc. Beyond that, imported plants can cross pollinate with the local stock, changing the genetics of the local population. When collecting seed, it is important to ensure that seeds are ripe before you collect them. Cues to determine if seeds are ripe enough to pick vary from species to species. Therefore, it is valuable to utilize the help of an expert seed collector if possible. Mechanical equipment is also available for the small-scale harvesting of seeds. Since this equipment is expensive, mechanical harvesting is an activity that will probably only be practical undertaken by contract or trade with companies or groups already possessing this equipment.

Seed can be hand broadcast where needed directly into the ash, or drill seeded over the entire field. Invasive species should be controlled by ongoing spot spraying or hand pulling.

Irrigation

Though native plants require significantly less irrigation than nonnative plants, all plants need some water to grow from seed. Irrigation will increase initial seedling germination and survival significantly, and if used, will need to be continued until the new plantings are established—typically one year. The amount of irrigation required varies with species, amount of rainfall received, and water storage capacity in the soil. Water requirements will be highest immediately after plants are installed and will decrease as the plants' root systems develop. Grass seed will not germinate unless it receives at least 0.5 inches, preferably in more than one rain event over several days, to retain sufficient soil moisture. Following germination, survival is enhanced if the top 3 inches of soil are kept moist with a minimum application of 0.5 inch a week for the first month. Thereafter, during the first growing season these areas should receive a minimum of 2 inches a month.

Temporary aboveground PVC pipe irrigation systems can be installed in high visibility areas where rapid success is important. In areas where a slower establishment of prairie is acceptable, irrigation should not be necessary.

Table 3: Seed Harvesting, Sowing & Weed Control Timetable for Sand Creek Massacre NHS

	Fall	Winter	Spring	Summer
2008	Seed harvest S: 2PP	Seed sow S: 1PP Seed testing contract	Seed harvest S:2PP Herbicide: ? Mowing S: 2PP	Seed harvest S:2PP Herbicide: ? Mowing S: 1PP Seed drill instruction
2009	Seed harvest S: 4PP Seed sow S:contract & 2PP Exclosures etc: ?	Seed testing contract	Seed harvest S: 2PP Monitor weed Weed control S: 2PP	Seed harvest S: 2PP
2010				

Prescribed Fire

Spring, summer and fall fires have been shown to reduce annual brome density (Prescribed fire alone, will not reduce (and may encourage) fire-adapted invasive species such as cheatgrass, so chemical herbicides will need to be judiciously and strategically applied.

In many ecosystems, fire represents part of the dynamic equilibrium which maintains the balance between productivity and decomposition (Pyne 1982). Both wild and anthropogenic fire have drastically shaped the North American landscape. Several times during the Pleistocene, the Siberian land bridge between North America and Asia opened up as fluctuating global temperatures caused repeated drops in sea level. This allowed passage of fauna and flora between the two continents (Kreech 1999). Evidence from both North and South America suggests that humans successfully started colonizing the continent as early as 13,000 or 14,000 years ago and have had a direct influence on the landscape (Kreech 1999). Though it is difficult to establish the historic fire regime for Sand Creek area because of a lack of trees to carry fire scars, charcoal layers have been analyzed and show a decreasing frequency of fire with European settlement (Ford XX). Although the early Paleo-Indians may have indirectly influenced landscape through hunting large herbivores, perhaps the greatest impact was the technology of fire.

Most plant communities around the world are to a greater or lesser extent fire-prone. Plants will burn under the right conditions, and many have evolved to survive under pressure of frequently occurring wild (lightning induced) fire. In fact, prior to the arrival of humans, lightning was the primary source of wildland fires in North America. Many plants are fire-adapted, meaning that they are either dependent on fire (e.g. smoke or heat-triggered germination) or tolerant of fire (e.g. fire resistant bark, post-fire resprouting etc.). Because of this proclivity to fire, fire frequency in most ecosystems enhances plant diversity by repeatedly disturbing succession. This disturbance cycle results in a more heterogeneous environment supporting a larger suite of plant species (Wright and Bailey 1982).

The degree to which fire plays a role in a natural system can be assessed from a number of indicators (Bond and van Wilgen 1996, Pyne et al. 1996a, Burrows et al. 1999). These include:

- Historic factors: traditional aboriginal use of fire;
- Climatic indicators: season and amount of rainfall and lightning frequency;
- Floral factors: post-fire regeneration strategies (seeders/resprouters), post-fire floristic changes, fire toleration (bark thickness) presence of fire sensitive taxa

Prescribed burning can be defined as the systematically planned application of burning to meet specific management objectives (Scifres and Hamilton 1993). It can be used for a variety of applications such as brush control, to increase forage (Scifres and Hamilton 1993), reduction of fuel load to reduce wildfire risk (Pyne et al. 1996b), removal of invasive weeds (Britton et al. 1987), or part of a disturbance regime to maintain floral diversity (Bond and van Wilgen 1996). Whatever the objective, a prescribed burn requires thorough planning including statement of objectives, description of burn technique and follow-up assessment and monitoring. Broadly speaking, prescribed fire is used to maintain or manipulate systems that experience, or once experienced, historical or anthropogenic fires.

The Great Plains prairies are fire-controlled ecosystems, meaning they have been shaped by fire. As described previously, when fire is removed from these ecosystems, there is a greater likelihood that species not adapted to fire can increase to the detriment of the native species. Intensity of fire and seasonality of fire episodes are coming to be understood as important factors in the vegetative community's response to a fire. Fire events any time of year will reduce woody species, but the species by species effects of fire are quite variable. These vary based on how wet or dry the year has been, the intensity of the fire, and the season in which the fire occurred. While winter prescribed fires are more common in agricultural practice and often more acceptable to regulatory authorities, summer fires were probably a greater influence in the evolution of these vegetative communities and tend to be most effective for restoring diversity of native species as part of a long term management strategy.

Historical Burn Timing

As mentioned previously, ignition sources for fires in presettlement times are believed to be primarily lightning induced followed by both intentional and unintentional ignition by Native Americans. A study of lightning-ignited fires in the Northern Great Plains over the past five decades indicated that almost 75% of lightning-ignited fires occurred during July and August, though lightning-ignited fires were recorded every month from April to September (NPS, 2002). It is presumed that this pattern has not significantly changed for the last few centuries. Historical documents and accounts of early settlers suggest that there were two seasonal periods for fires ignited by American Indians; one during the spring with a peak in April, and one during the fall with a peak in October (NPS, 2002). Although Sand Creek Massacre NHS is in the Southern Great Plains network, it is safe to say that similar fire patterns existed in this area as well.

Prescribed Fire at Sand Creek Massacre NHS

Fire as a form of disturbance has a marked effect on the ecology of any system. Its primary effect of combustion of living and dead fuels has two consequences: the interference or removal (not necessarily death) of existing plants, and a redistribution of the nutrients as ash or smoke, which once were sequestered in plant material. The compositional rearrangement of sequestered nutrients may stimulate regeneration from seed of existing species, resprouting of those individuals still alive, or the arrival or germination of species which were apparently absent prior to the burn (Bond and van Wilgen 1996, Pyne et al. 1996b). Thus, while fire may help control the spread of kochia at Sand Creek Massacre NHS for example, it may not entirely remove this invasive prairie species.

The fire itself, although a discrete event, possesses variable characteristics in intensity, frequency and season of burn. Manipulation of these variables is available to the land manager and can be used to affect vegetative growth, seed production and seed germination, which in turn drive the function, composition and structure of a plant community (Bond and van Wilgen 1996, Pyne et al. 1996b, McPherson 1997). For example, winter fire will repress spring forb production but will favor spring and summer grass production.

The areas of Sand Creek Massacre NHS with a history of agricultural use that are currently dominated by non-native grasses and forbs such as cheatgrass (*Bromus tectorum*), crested wheatgrass (*Agropyron cristatum*), Russian thistle (*Salsola tragus*), and kochia (*Kochia scoparia*), could be burned in the fall or spring though the more heavily disturbed areas may require repeated treatments. Kochia is one of the targeted species that the prescribed fires will aid in eliminating, along with follow-up treatments. Cheatgrass reduction may be accomplished by either a fall burn shortly after the cheatgrass has germinated or a spring burn before the cheatgrass begins growth for the season. Cheatgrass germination and growth is largely dependent on precipitation, so some flexibility may need to be written into burn plans to account for this. If it is determined that repeated annual burning is required to continue cheatgrass reduction, areas that are dominated by native species should be excluded.

In the process of preparing for prescribed burns, accumulation of decadent vegetation in areas currently kept mowed at a low frequency may be required.

Always exercise caution when using fire as a management tool, and it is highly recommended that small areas <1/4 acre are initially burned to understand general and specific plant responses.

Prescribed fire during the growing season should also help encourage wildflower displays for the following year.

Over time, repeated use of prescribed fire is intended to restore and maintain the grassland/prairie habitat in a healthy condition. However, an important element of success will require careful and consistent monitoring of the site. Ideally, prescribed fire regimes will include a mixture of burn intensities, burn season and return intervals. Since Sand Creek Massacre NHS is a mixed prairie, initial return intervals will be shorter (2 to 3 years) than maintenance return intervals. Maintenance return intervals of 4 to 12 years can be instated at Sand Creek Massacre NHS once the desired vegetative structure and composition is achieved. However, the appropriate return interval and fire intensity for a site will be influenced by many factors. For example, areas dominated by non-native species or areas where resprouting species could emerge need shorter maintenance return intervals (3 to 7 years) than the typical 4 to 12 years. The exact timing as to when subsequent burnings should be conducted is not included in this restoration plan as that is best left to the decision of the park managers who monitor the site and guide the restoration to the desired target state. All areas should be at least annually examined to monitor plant composition, vegetative structure and soil conditions, and the results of these examinations should be used to determine appropriate fire regimes. Monitoring, evaluation, and data gathering for these restoration efforts is discussed in more detail in Section V.

Prairie Mowing

Mowing can be used to mimic some aspects of grazing albeit with obvious differences in impact. Mowing is non-selective with regard to species. Plant material is cut and evenly dispersed across the ground as litter, as opposed to digestion and concentrated defecation by herbivores. These processes suggest that mowing will have a different impact on the plant community dynamic compared to grazing and fire. The two processes have been shown to exhibit some equivalence in effect (Collins and Gibson 1990, Collins et al. 1998) but may in the long term result in thatch accumulation which may have differential effect on species propagation. Collecting the cut material (haying) will reduce thatch accumulation and may be self-supporting if the hay is traded for the mowing services, but may cause nutrient depletion. The advantages, on a small scale, of ease and variety of implementation (e.g. season, cut height, etc.) may render this technique useful in certain circumstances. However, mowing is, in many cases, much more costly over time than maintenance with prescribed burning.

A low frequency mow regime should be implemented pre-restoration for the prairie areas. Low frequency is defined as mowing once or twice a year in winter (December through February) and/or summer (July through August). During the restoration process, burning or mowing treatments should be delayed until newly established vegetation is well established. After restoration, the mowing regime is dependent on the implemented restoration technique. If the prairie area is to be managed by mowing, a low-frequency mowing regime should be used, with mowing occurring in winter, after warm season grasses have gone dormant. It is not necessary to mow every year, but occasional mowing or burning is necessary to maintain this system. If area is to be managed by prescribed burning, the mowing schedule should be suspended to allow herbaceous growth to accumulate for at least one growing season until sufficient fine fuel has accumulated to support the desired fire. Mowing is not recommended if the area is to be managed by fire. There should be an interval of several years between burns.

Example Project:

As recommended earlier, restoration should begin in areas with relatively intact blocks of remnant prairie consisting of a native vegetative community. Management will focus on optimizing and enhancing the health of this area with the use of interseeding and prescribed fire as described above. Below is an example of what a restoration approach could look like for such an area and with stated techniques.

Since the vast majority of the present species are native, spot application of herbicide in the invasive species areas, while augmenting with missing species, should result in the most efficient establishment of a healthy native prairie on site. Suggested treatment is to reduce patches of non-native plants, by targeted herbicide application. Grass specific herbicide, such as fluazifop, should be used during the winter on non-native cool season grasses while the majority of native grass species are dormant. Interseeding method should be done with seed mixes and rates, which are designed to enhance species diversity at the site. Mowing should precede seeding efforts. To replicate the historic fire frequency, prescribed fires should be installed every 4 to 7 years, primarily in the growing season (June to October), however it can be beneficial to initially burn more frequently (every 2 to 3 years) until all invasive species are under control and desired species are established. Seed can often be added immediately following prescribed fire so the seedlings can take advantage of the temporary opening of the canopy.

4. Interpretive Framework

Restoration of Sand Creek Massacre NHS will be most successful in the long-term if efforts are coordinated with interpretive goals. Since Sand Creek Massacre is a National Historic Site, the site receives many visitors annually; this provides an opportunity to showcase how restoration efforts are integral to the study of land/human relations, and connecting visitors with the cultural landscape as well.

Connection between restoration and interpretation

As the National Park Service states, “The landscape of Sand Creek Massacre National Historic Site is a record of human relationships with the natural environment, the contrasting values of American Indians and Euro-Americans, and their competition for limited resources” (NPS 2010). Sand Creek Massacre NHS is a wonderful example of the changes that took place on the Great Plains once settled by Native Americans and then Europeans. But history is not the only mechanism available to us for examining the human-land relationships at Sand Creek Massacre NHS. In fact, “the site continues to reflect human relationships with the environment, including the values of native Plains people, European explorers, Euro-American settlers, and, most recently, the National Park Service” (NPS, 2010). Thus, restoration will be most effective when coupled with a thorough interpretative framework that showcases both past and current human relationships with the landscape at Sand Creek Massacre NHS.

Interpretive Goals

Interpretive goals for the site include the demonstration of restoration techniques with a focus on native plants, showcasing rare native plants, educating users on the value of ecosystem services, creating an environment where prairie dogs can be re-introduced to the site, showcasing ecosystem flux over time highlighting the 1800s period, demonstrating the connection between people, history and place, and lastly, creating a land ethic where place belongs to the people and people belong to the place.

Demonstration of restoration techniques

A demonstration project can be an instrument for supporting restoration goals with the added ability to act as educational and community-engagement tool. All restoration on site will be conducted with public awareness and education in mind. There may even be instances where visitors and the local community can volunteer with restoration efforts.

The demonstration of ecological restoration techniques and issues for Sand Creek Massacre NHS will focus on native plants. Ecologist Aldo Leopold's first rule of intelligent tinkering is to keep all the pieces (Leopold (1939) 1966); this is why it is so important to focus on the value of native plants. Native plants are integral pieces of the larger ecosystem upon which other species and processes depend. Healthy ecosystems value all their component pieces and integrate them into a dynamic whole.

Native North American plants are defined as those that existed here without human introduction. Native plants are best suited to withstand the ecological conditions of Sand Creek Massacre NHS and achieve the goal of maximizing the site's tolerance for the range of environmental conditions found in the Great Plains. Native plants can also help speed vegetation establishment and, once established, provide robust erosion control thanks to the long root systems of many species, which hold soil in place. The loss of native plant communities - to urbanization, introduction of invasive species, or other human activities and events - has reduced wildlife habitat and the genetic diversity necessary for balanced ecosystems. By removing invasive species, it is possible to bring the native plant ecosystem back to a more valuable healthy system. For example, at Sand Creek Massacre NHS the removal of tamarisk will help achieve this goal.

At Sand Creek Massacre NHS it is important to identify which plant communities in the area create wildlife habitat and which plants are used as food for certain animals. Increased diversity of plants within the ecosystem will result in increased habitat provision. Restoration of native plant communities can include demonstration areas where efforts to remove invasive species such as tamarisk are described to the public through the use of signage, or by including the public in volunteer restoration efforts. Other native communities across the site should be labeled to showcase which species were present in the mid-1800s, and other information such as which native plants are used by wildlife or help prevent erosion for example.

Showcasing Rare Native Plants

Sand Creek Massacre NHS also has the unique ability to showcase rare native plants. There are several rare native plants at Sand Creek Massacre NHS. According to the National Park Service, approximately 829 plant species were reported as culturally significant to the associated Sand Creek Massacre NHS tribes. "At Sand Creek Massacre NHS, 62 plant species are known to have ethnobotanical and cultural significance to the associated tribes: 13 are culturally significant to the Arapaho, 26 to the Cheyenne, 12 to the Comanche, 22 to the Kiowa, and 8 to the Southern Ute" (NPS, 2010). Several of the plant species were culturally significant to multiple tribes, such as the soapweed yucca (*Yucca glauca)* and bush morning-glory (*Ipomoea leptophylla).* As plant composition changed over time due to natural or human disturbance, the uses of plants changed as well. Some species were no longer available at Sand Creek Massacre NHS while others, some non-native species, were added.

The use of native plants in this restoration project will be a prime demonstration for visitors to understand the importance of species adaptation and to understand how all of the 'pieces' fit into the larger whole. For example, animals that live in the area have co-evolved with certain plants species and require them in their diets. This demonstration of restoration might also inspire local communities to choose native plants residentially and commercially since native plants also preserve a sense of place and regional identity.

The Importance of Wildlife Communities

Prairie dogs are one example of an animal species deeply tied to the local prairie ecosystem and its native plants. In fact, prairie dogs have many roles in grassland systems. The presence of a prairie dog colony increases the chances that other rare species (such as mountain plovers (*Charadrius montanus*) and swift foxes (*Vulpes velox*) will be present. Their burrowing tunnel systems provide refuge for a variety of species from invertebrates to reptiles. They also play an important role in nutrient and soil cycling since they are prey species for higher trophic levels. The prey species status also provides population control to neighboring ranchers and farmers.

The Great Plains historically supported a wildlife community that was similar in structure, processes, and behavior to grassland wildlife assemblages throughout the world (Knopf and Samson, 1997). In the mid-1800's the numbers of individuals of native mammal species such as bison (*Bison bison*), black-tailed prairie dogs (*Cynomys ludovicianus*), pronghorn (*Antilocapra americana*), elk (*Cervus elaphus*), grizzly bears (*Ursus arctos horribilus*), and gray wolves (*Canus lupus*) occurred in unfathomable numbers. Estimates of bison may have been as high as 60 million (Knopf and Samson 1997) and there were between 40 to 100 million hectare of prairie dog towns in 1900 (Miller et al. 1994).

Migrating bison produced short duration but very intense grazing events, similar in some ways to a fire. Land often had several years to recover between bison grazing events. Domestic cattle, on the other hand, caused continual disturbance, of varying intensity, of rangeland throughout the entire year. When continual or near-continual grazing keep herbaceous biomass suppressed, two things happen: populations of palatable species collapse at a local scale, which in turn aids the spread of woody species by reducing competition between woody and herbaceous species (Walker 1993).

European market demands and sport increased hunting for bison. The local extinction of bison had significant political, cultural, and ecological consequences, including the loss of economic independence and a vital spiritual element, to native Plains people. The last documented bison in the area was killed in 1885, 12 miles south of the massacre site. But due to efforts in the later portion of the 1900s, bison populations have returned and now there are closer to 500,000 in the Plains regions (NPS, 2010).

The decline of bison and prairie dogs from their historic levels are particularly important when understanding current grassland dynamics. Grazing by bison and prairie dogs was a primary driver of the ecology in the Great Plains and the two species are often viewed as mutualistic. Bison and other large herbivores use prairie dog colonies for grazing due to the higher nutritional value of plants within dog towns (Koford 1958, McHugh 1958, Coppock et al 1983a, Krueger 1986). This high intensity, low frequency grazing had a profound impact on major grassland processes. This grazing regime would affect everything from the types of vegetation communities present to the pattern of fire progression. The latter occurred as fires were stopped by the wide swaths of sparsely vegetated ground left in the wake of roaming bison herds.

Ecosystem Flux

Just as animal and plant populations changed over time, so did larger ecosystem systems, particularly in the 1800s. Many grassland systems have undergone significant changes since they were first described by early Europeans. Exotic species invasions, expanding row-crop agriculture, overgrazing, and establishment of woodlots have all contributed to grassland degradation and loss of genetic diversity. Estimates for loss of mixed-grass prairie range from 30-99.9% and for short-grass from 46-82% depending on the region (Samson et al. 1998). Since many grasslands have been converted to other uses, prairie restoration is increasingly important in the Great Plains.

Perhaps the most significant impact to the Great Plains was the Homestead Act of 1862 where nearly 1.5 million people acquired over 300,000 square miles of land. This available land resulted in a huge loss in native prairie as it was converted to row-crop agriculture. However, these losses are not limited to settlement times. Samson et al. (2004) estimated that 36,000 square miles of grassland was converted to agriculture between 1982 and 1997.

In addition to human changes in the landscape, there are also ecological cycles that create landscape change as well. Climate and fire are very significant contributors to the spread and maintenance of grasslands. The Great Plains climate is highly variable with stormy weather patterns and increasing precipitation from west to east across the plains (Risser et al. 1981).

According to the National Park Service,

> "The Great Plains weather is highly influenced by the clashing of air masses from westerly winds that are modified by arctic airstreams from the north and tropical airstreams from the south. Westerly air masses

that become saturated over the Pacific Ocean have been obstructed by the Rocky Mountains which cause precipitation over the mountains and drier conditions on the leeward side of the mountains. These drier conditions result in the short-grass ecosystem of the western plains. Annual precipitation within the Southern Plains Network ranges from 12 inches (31 cm) in the western plains to 39 inches (97 cm) in south central Oklahoma. Approximately 2/3 of this rainfall occurs from April through September. There is a general temperature gradient in the Great Plains increasing from northwest to southeast. Changes in temperature result in a north-south gradient between cool-season (C_3) grasses and warm-season (C_4) grasses. Cool season grasses are most efficient photosynthesizing in cooler temperatures and dominate in the northern or higher elevation plains, where warm-season grasses are more efficient under warmer temperatures (Black 1971) and are more dominant in the grasslands that make up SOPN." [10]

Periodic climatic extremes, like drought, have also affected animal and plant communities. The Great Plains, particularly the short-grass prairie, undergo frequent droughts from reduced precipitation, increased evapotranspiration, and increased water runoff. Sustained droughts, on a cycle that has ranged from 10-20 years over the past few centuries, are a regular event and have killed bison, and severe winters can kill pronghorn. Droughts also have a lag effect on fauna that feed on certain seeds. These climatic fluctuations further support the importance of restoring native plant communities. Native species, such as sideoats grama (*Bouteloua curtipendula*), blue grama, and buffalo grass, have adapted to these drought conditions. They are accustomed to withstanding long periods of drought as well as periodic heavy rain events. The many species native to the Great Plains have adapted to be able to survive these highly variable conditions and in some cases, native plants can take advantage of drought conditions.

Prairies are all about change. Changes in settlement patterns, varied weather patterns, increased European use along riparian corridors, and changes in bison populations are all examples of factors that had a dramatic effect on the historic landscape. Historic efforts were made to mitigate the effect of droughts and floods on the settlement of the Plains region.

Sand Creek could be the only, or the best place, to see short/midgrass prairie. This site can demonstrate how the entire Southern Plains were in a huge state of transition through the 1800's. All Southern Plains Network cultural parks, such as Sand Creek Massacre NHS, have designated periods of significance, and therefore the management goals at these parks are to achieve a landscape reminiscent of the mid-1800s.

Ecosystem services

Ecosystem services are goods and services of direct and indirect benefit to humans that are produced by ecosystem processes involving the interactions of living and nonliving elements. Nature is a provider of resources and health and security. In restoring an ecosystem, we are also restoring the services it provides to humans (see Constanza et al., De Groot et al.) The United Nations' 2004 Millennium Ecosystem Assessment (MEA) grouped these services into

[10] SOPN stands for Southern Plains Network

four broad categories: provisioning (e.g. providing food and water), regulating (e.g. climate control), supporting (e.g. pollination), and cultural (e.g. recreation).[11] Restoration at Sand Creek Massacre NHS will provide many of these services for the immediate Sand Creek area, but also to the larger region as these ecosystem services extend beyond human-designated boundaries.

From a cultural perspective, the two most important services that will be restored at Sand Creek Massacre NHS are the provisioning of food and medicine. As mentioned earlier, many of the native plant communities have cultural significance for the Cheyenne and Arapaho tribes due to their medicinal properties. Furthermore, native animal communities, as well as human, relied on the food provided by these native plant communities for centuries. Nature is both an apothecary and a supermarket.

Other services produced as a result of this Restoration Plan include carbon dioxide sequestration, oxygen production, water quality improvements and reductions in water runoff, clean air, cooler air, habitat, human health, cultural amenities and recreation, and sense of place. Native plants provide a sense of regional identity. Native plants blend with the natural aesthetic of the region, giving the area a unique identity. Carbon dioxide sequestration occurs when carbon dioxide is removed from the atmosphere and stored indefinitely by vegetation such as trees. This same vegetation on site also produces oxygen. Water purification is one of the many services provided by ecosystems. Pollutants and sediment are processed and filtered out as water moves through prairie grasses, wetland areas, forests, or riparian zones. Vegetation traps dust, dirt, and harmful atmospheric gases from the air we breathe providing clean air. Significant habitat is created in the prairie grasses and riparian areas for fish and wildlife. As mentioned earlier, many species use the burrowed areas created by prairie dogs for their own shelter. In many cases, visiting Sand Creek Massacre NHS is the only exposure individuals may have to the local landscape. Thus, the site provides an opportunity to expose volunteers, residents and travelers to the unique landscape characteristics of the Southern Great Plains prairie furthering a sense of place.

Connection between people, history and place

The landscape at Sand Creek Massacre NHS is a record of human relationships with the natural environment, the contrasting values of Indians and Euro-Americans, and their competition for limited resources. An environmental history of Sand Creek describes how the impacts of human actions contributed to environmental changes over time.[12] This environmental history

[11] http://www.millenniumassessment.org/en/index.aspx
[12] For a thorough environmental history of Sand Creek see “Sand Creek Massacre Site: An Environmental History” by Elizabeth Michell, Department of History at Colorado State University, 2007.

describes the difference between the new world (early settlers) and the old world (Native Americans) approaches to land management and land uses. In other words, a competition between people who adapted to the land, and people who adapted the land to themselves.

Water has been a scarce resource in the western and central portions of the Great Plains for centuries. Surface water is important for ecological reasons, but the presence of this water was also important for European settlers. The majority of the Southern Plains Network parks were created due to their cultural significance to Native Americans or early settlers. The main reason for the significance to these groups was the availability of water, principally from flowing rivers and creeks. Streams in the southern plains, as is the case at Sand Creek, are characterized by irregular flow, and a distinct wet-dry cycle.

The deep roots of the grasses and forbs have superb ability to catch and hold rainwater. The extensive root system also binds the soil to the earth, protecting it from erosion. Water runoff from prairie is relatively small when compared to row crops or other ecosystems where there is no large network of roots. As Europeans moved west, native prairie began to be converted to cultivated agriculture as early as the 1850's. When prairie is converted to row crop agriculture, the agricultural processes reduce surface cover, destabilize soil structure, and accelerate organic carbon loss. Furthermore, cultivated crops return little carbon to the soil. The Dust Bowl of the 1930's, centered on the Southern Plains, was a result of removing the protective vegetative layer and exposing vast areas of cultivated prairie soil to wind action and drought. In addition, chronic heavy grazing by livestock can compact soils and affect many of their characteristics and functions (e.g., water infiltration). The varied uses of prairie sod, which required its removal, resulted in a loss of soil and water.

Land Ethic

As mentioned above, past land uses were causing a decline in system health at Sand Creek Massacre NHS which resulted in decreasing environmental and economic value.

Another factor for ecological change in the landscape is the manifestation of human values on the landscape. Native American and early European settlers placed different values on the landscape over time. Climatic fluctuations as those described above had a profound influence on how different land management strategies would impact the overall health of the plains ecosystem. The ecosystem would respond to the climatic fluctuations; when rains were abundant, so too was the vegetation and thus the fauna that consume it. In times of drought, animal populations waned due to food scarcity. The survivors of these types of fluctuation environments were typically migratory, following the food and water. This is especially true of the Native American communities whose nomadic characteristics led them to move around the Plains, following the food and water. But when early European American settlers arrived in the area, they applied a stationary agrarianism to the plains. This put their communities and ways of life in constant conflict with the fluctuating ecosystem. In fact, it was the limited available resources that were at the heart of the Sand Creek Massacre.

These changes not only demonstrate how humans are a part of nature but also how humans need to be stewards of the land and take care of nature so we can take better care of ourselves. Leopold's Land Ethic definition can be used to show this connection between the people and the land: "A land ethic changes the role of homo sapiens from conqueror of the land community to plain members and citizens of it." Our understanding of nature is changing and we are now better equipped to interact with nature on a less intrusive level.

The land ties people to their own history and place. Natural and historical places help us understand who we are. Restoration at Sand Creek Massacre NHS is important because it helps us remember our past (the diversity of our country), experience our present, and see what can happen with the landscape in the future, making life better for future generations. Sand Creek restoration will highlight the integration of nature and culture in the historical processes that communities remember, creating a sense of identity. It will also demonstrate the reciprocity of proprietary interest. Meaning, the place belongs to the people and the people belong to the place.

Land

As the interpretive goals explained above demonstrate, people and land are intimately connected. The Sand Creek Massacre NHS is significant to several native Plains cultures that have historical and cultural associations with the land and its resources, mainly the Cheyenne and Arapaho tribes, but records also indicate that the site was associated with the Comanche, Kiowa, and Ute tribes.

Vegetation is an integral part of the cultural landscape and native plants tie well with the Site's mission. As mentioned earlier, roughly 829 plant species were reported as culturally significant to the associated tribes, having ethno-botanical and cultural significance. According to Michell (2007), "The Cheyenne had abandoned farming when they moved south into the Central Plains, but they still relied on wild plants and herbs for medicine and for carbohydrate in the diet. Among the plants the women and children gathered were lambs quarters (*Chenopodium berlandieri*), American licorice (*Glycyrrhiza lepidota),* groundplum milkvetch (*Astragalus crassicarpus*), chokecherries (*Prunus virginiana*), and the most favored of all, prairie turnip (*Psoralea esculenta*), a protein-rich root that was a diet staple, a medicine, and a commodity the Cheyenne traded for maize" (Michell, 2007: 36). Though the Cheyenne no longer practiced horticulture, they did continue to conduct rough plant management. For example, they transplanted groundnut (*Apios Americana*) and prairie turnips "in strategic locations to help feed war and hunting parties traversing the plains" (Michell, 2007: 36). Continued research in Sand Creek Massacre NHS will expand our knowledge of the resources preserved and protected in this area.

People

Restoration at Sand Creek Massacre NHS provides visitors and the local community with a sense of place, a sense of history, and an opportunity for educations on the area's history, the native species, and the overall Great Plains prairie ecosystem. Equally important to the interpretive framework for restoration at SCMNHS is an understanding of how people influenced the landscape.

The site has been used by humans for the past 10,000 years. Paleo-Indians entered the area 8,000-10,000 years ago. During wet periods, these nomadic hunter-gatherers adjusted to a more sedentary farming lifestyle. In the 1700s Europeans began to explore the Plains, at the same time when American Indians, including the Cheyenne and Arapaho, entered the region. Population increases in the mid-1800s placed increasing demands on the environment and the resulting competition for limited resources, coupled with the different cultural land use philosophies and practices, amplified tensions between these communities. Visitors to the Site will walk away with an understanding of how historical events such as the 1864 Massacre are intimately tied to the landscape.

Some of the important historical interpretive opportunities as they relate to human populations can include the following six main strategies:

1. This is sacred ground to the Cheyenne and Arapaho cultures.

   - First, the area was a strategic resource for all populations inhabiting the area which resulted in conflict between cultures. Bison and other natural resources, though spiritually significant to the Native Americans, were like "oil" to the pioneers migrating westward. The extirpation of bison from the area by the early settlers decimated an important resource for the Native American communities.
   - Second, the site serves to remind us of the consequences of irrational fears of other cultures. The pressure from settlers in the western regions (i.e. Denver and other cities) for the government to solve their "fear" of the Indian tribes lead to the decision of the massacre by Chivington. Interpretation of this 'fear' concept could perhaps be demonstrated through a parallel event in our current society, that fear of terrorism leads to extreme actions.

- Lastly, the cottonwood trees have a deep cultural significance to the Native American tribes of the area. These trees provided shelter, timber, firewood, forage, and wildlife habitat. In addition, certain trees were associated with the encampment and the massacre along the river.

2. In relating historical significance to the restoration of the prairie, several interpretive points can be used:

   - There is a great benefit to conduct restoration of ecological systems that are essentially a thing of the past since the historic prairies are an integral part of current human life, our history, and our sense of place. When Euro-American settlers first entered the Plains, they encountered areas in which forest gave away to grassland. These largely treeless areas existed in a variety of community types depending upon degree of soil wetness, depth to bedrock, and frequency of fire. The early settlers avoided the prairie areas thinking that few trees meant few soil nutrients for their crops, but in this they were wrong. To understand and manage the valuable ecosystems at Sand Creek Massacre NHS, it is also important to understand the pre-settlement communities that formed these landscapes.
   - The prairie has great historical importance for native peoples, particularly as important food-gathering sites.
   - A healthy prairie will spur the return of native species, a goal that is also compatible with park goals for the cultural landscape at Sand Creek Massacre NHS. Native plants that provided high-quality food and cover to native wildlife, and if degraded areas are restored, the native habitat will naturally support more food plants, and thus, more wildlife.
   - A healthy prairie system will also help visitors relate back to a sense of place as the Native Americans experienced it. This park serves as a sanctuary of that human spirit.
   - The prairie restoration can be used as a museum piece. To preserve the landscape, we also preserve the memory of the massacre.
   - Restoration can provide answer to “How could the Native Americans have survived here?” The restored site will allow the visitor to experience what the historic communities had and how they lived.
   - Restoration can serve as a metaphor for healing cultural wounds. Working together to heal the land helps to heal our lives and relationships. Though the prairie was changed, it was not destroyed. While the Massacre was an effort to completely destroy the culture, it too was unsuccessful. Though there was a

huge cultural loss due to the loss of so many elders, the culture -- like the land -- was altered, but not destroyed.

3. Interpretation efforts can help people relate to nature and plants in different ways than they did before their visit.
    - By preserving a vista and view, one is allowed to feel the “sanctity” of the space and appreciate what has occurred.
    - Restoration speaks about who we are; the history lessons are in the landscape.
    - A healthy ecological community has the power to provide peace and reflection.
    - Interpretation can use the regenerative landscape that has healed as a symbol of rebound and endurance --- parallel to the Native American cultures.
    - Interpretation should emphasize plants that are edible to people (and specific cultures) and how these plants were used in the past and can still be used today.
    - Interpretation can demonstrate how to help preserve the prairie by following good farming practices – a polyculture rather than a monoculture. This can be a good method to reach out to the agricultural neighbors.
    - The demonstration of native plants can also focus on the difference between Eastern and Western medicine. Plants provide an alternative healing practice, homeopathy of the planet.

4. As the land heals, economic value also improves. Even farm animals and wildlife have “improved living conditions”. For example, better vegetative health means better grazing for cows and other livestock.
5. This restoration project can serve as a demonstration for others to copy. This allows the park to go beyond just a passive resource. It may also serve as a restoration plan for healing cultures. Essentially, the park can become of a model of national significance whereby the park and local tribes working together to restore and heal the land, and interpret the landscape, could become a model that similar sites across the nation adopt.
6. And lastly, the Park can serve as a conduit for native culture and making a connection to traditional values. If bison can be moved across state lines, then park can use a tribal bison herd to graze the park, when appropriate resources have been acquired to managed these activities.

Native American Involvement

None of the restoration goals or interpretative framework will be successful without the involvement of the Native American communities. According to Dr. Henrietta Mann, a full-blood Cheyenne, it is very important for Native peoples to maintain their connection to the land. While access to and protection of sacred sites are constant struggles, she said, places such as Sand Creek Massacre NHS provide an opportunity for native peoples to connect with their historical landscape. The Cheyenne stewardship with restoration and community will lead the way in saving the world; responsibility was to heal the earth.

The main interpretative goals for the Native American involvement should include the following:

- The massacre was a horrific event that needs to be remembered. But this remembrance also provides a positive healing opportunity, a chance to make amends.
- The natural resource, the landscape at Sand Creek Massacre NHS ***is*** the cultural resource.
- Restoration and interpretation provide a physical area to remember and contribute to the healing of the land.
- There are also regenerative opportunities, finding ways to belong to the place and culture. The use of tribal interpreters allows visitors to become immersed in the first person experience.
- And finally, there are opportunities to go from audience to action. By sharing work, people are sharing experiences.

V. Monitoring and Evaluation of Success

Success of the restoration project will depend in large part on monitoring the site for changing conditions – improvements or areas that need continued attention. "The agrarian-dominated landscape, the small size of the parks, and the scale at which ecological processes naturally occurred in the region, all affect park management. None of the Southern Plains Network parks are large enough to restore and maintain complete assemblages of native species, natural conditions on a pre-European scale, nor the ecological processes that sustained them. However, due to the rarity of high-quality short-grass and mixed-grass prairie, it is essential that prairie in NPS ownership be maintained in optimal condition to provide habitat for rare species, facilitate important nutrient cycling, and serve as an example of grassland fragment management. The development of a long-term monitoring plan must consider these aspects in design and implementation. Adequate assessment and monitoring of the effects of grazing, climate, and fire on grasslands, must be multi-scaled, include spatial and temporal patterns, and match management inferences and applications" (NPS, 2010).

The unique weather patterns of the Great Plains present some challenges when designing a long-term monitoring program. The inter-year variability can increase the noise to signal ratio in monitoring projects. This can confound efforts to analyze and interpret temporal and spatial trends and to identify causative factors in changes in natural resources. In addition, there can be large local variation in precipitation, necessitating site-specific weather monitoring stations to obtain accurate information.

Use belt/line intercept transect for sage, and quadrate for grass and forbs. The Southern Plains Network protocol is to place a quad every 10 meters for a total of 5 plots per transect (15 nested quads).

The site should also be photo monitored – especially pre- and post-treatments. To help with field identification of planted species, these seed will also be grown in pots and photographed at various stages of growth for easy reference in the field.

Photographic Monitoring is a quick and effective means of documenting changes in soil and vegetation over time. Evidence taken from these photographs provides investigators with invaluable spatial data that may be utilized in the assessment of a site's health and development. Photographic documentation of soil and vegetation topics of interest is an essential first step in photo monitoring. Monitoring implies the need to determine change. This determination has two components:

- Photographic technique
- Grid Analysis

Camera locations and photo points must be marked by permanent features such as t-bar posts or stamped metal fence posts. Camera locations and photo points shall not be placed near stream edges or any other dynamic environments because the camera locations and photo points will not be discernable if there are any events such as erosion or floods (USDA & Hall, 2001).

Photographic monitoring should occur in areas where documentation of change is most needed, such as areas of potential erosion or vegetation establishment. Several steps are needed to begin photographic monitoring:

- Define the topics of interest such as erosion, vegetation establishment, or riparian bioengineering;
- Define the monitoring area and its limits;
- Based on the above objectives, locate photo points to best document change. These points will be the locations of meter boards. Meter boards, or size control boards, identify the item being monitored, establish a camera orientation reference point for subsequent photography, set up a constant size-reference by which change can be documented, and provide a point on which to focus the camera (USDA & Hall, 2001);
- Establish camera locations for optimum coverage of the subject. Coverage might require multiple photo points from the same location or multiple camera locations focusing on the same point (USDA & Hall 2001). The camera locations must be properly documented so that subsequent photography provides consistent analysis.

An example of how a photographic monitoring station was set up is presented in the images below.

Figure 5: Example of Photographic Monitoring Station. Photograph by Frederick C. Hall, USDA.

To determine changes in soil, vegetation, or stream banks for example, outline the selected topic on a clear plastic sheet. Then place a grid under the sheet. Count grid intersects falling on and within the outline, and record. Compare these counts from previous photographs of the same topic to estimate change. Each plastic sheet with its outlines and associated counts is a set of data and must be identified clearly and then archived. Grid analysis is based on standard geometric relations between photograph, camera, and meter board. A set distance between camera and meter board for the initial and all subsequent photographs of a specific topic is a

must (USDA & Hall, 2001). Examples of using plastic sheets to outline changes in vegetation are presented in the images below.

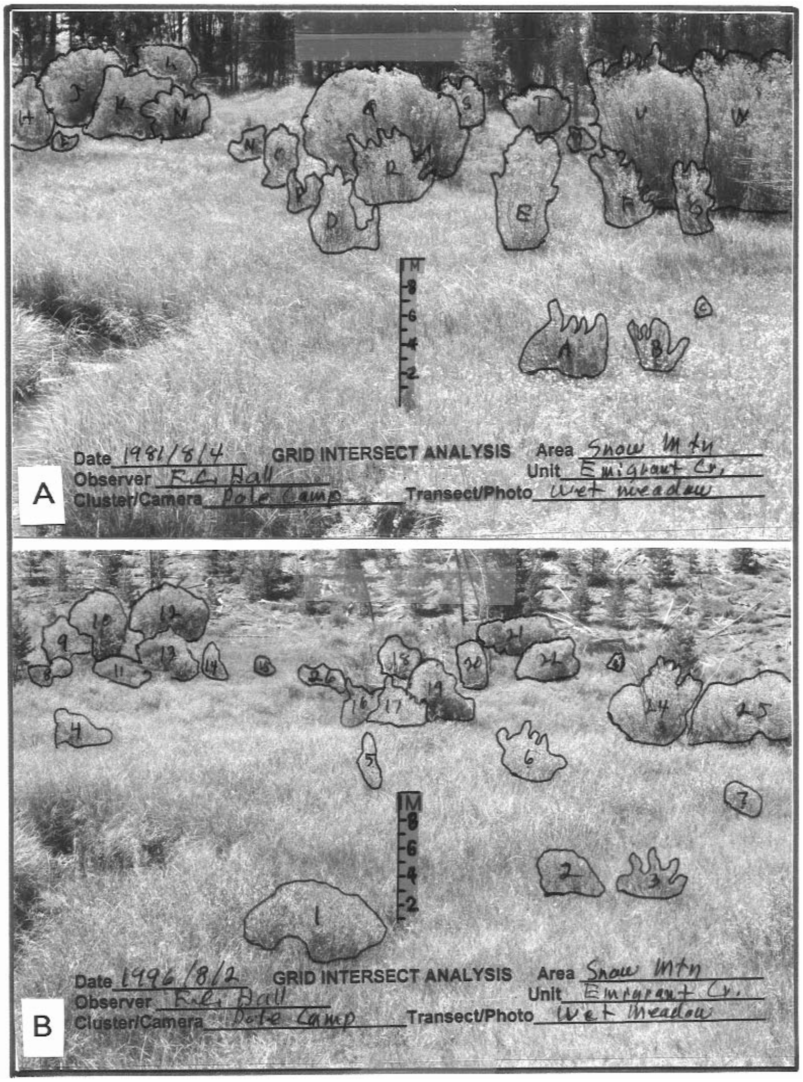


Figure 6: Example of photographic monitoring station with tools and analysis. Photograph by Frederick C. Hall, USDA.

Several materials will be needed to conduct photographic monitoring. These include:

- A fixed lens digital camera that is 2.4 mega pixels or higher; the DPI (digital pixels per inch) shall be set to the same value for each photograph. Preferably at no less than 150 DPI;
- A meter board;
- Forms for site identification and photo points;

- T-posts or stamped metal fence posts to mark camera positions;
- Compass and 100 foot tape for measurements;
- Clear plastic sheet.

The sequencing of photographic monitoring is based upon the desired goals. For instance, if the goal is to determine erosion patterns along Sand Creek, then photographs would need to be taken during or after rainfall events. If the goal is to monitor vegetation establishment in prairie restoration area, then the photographs might occur with each season. If any of the photographic observation areas are to be mowed, care should be taken so that T-post, stamped metal fence post, and meter board locations are visible to maintenance crews. Failure to do so may result in the damage or loss of important data markers.

As mentioned earlier in this section, the unique weather patterns of the Great Plains present some challenges when restoring the prairie ecosystem and designing a long-term monitoring program. For example, cottonwood trees may have been largely absent at the time of the massacre but these populations will be maintained as they related to culturally significant "witness" trees. Thus, it is important to be clear about how we can know that the site has recovered. Revegetation success criteria were developed for the Rocky Mountain Arsenal National Wildlife Refuge shortgrass restoration (found in Appendix C). Success of restoration at Sand Creek Massacre NHS will follow those guidelines. Indicators for success are as follows:

- survival of at least 5 grass species that are planted
- propagation of at least 10 forbs species
- live cover of native species is 30% and live plus thatch coverage of same is 70%
- there should not be any one species that accounts for more than 40% of cover
- at least 50% of species planted are present

According to the NPS, "knowing the condition of natural resources in national parks is fundamental to the Service's ability to manage park resources 'unimpaired for the enjoyment of future generations' (Organic Act of 1916, 16 U.S.C. 1 § 1). For years, managers and scientists have sought a way to characterize and determine trends in the condition of parks and other protected areas in order to assess the efficacy of management practices and restoration efforts and to provide early warning of impending threats" (NPS 2005).

In other words, monitoring allows us to detect changes or trends in a resource. Monitoring is important because it provides site-specific information needed to identify changes "in complex, variable, and imperfectly understood natural systems" (NPS 2005). Monitoring also determines whether the observed changes are indicators of unwanted influences, such as human disturbance, or demonstrate natural levels of variability within the target ecosystem. Through repeated observations over a given period of time, management staff is able to assess the progress of meeting restoration goals. By understanding changes that may occur at Sand Creek Massacre NHS, staff are better equipped to make future restoration and management decisions.

An ecosystem approach to monitoring and management is needed because most parks are open systems, and threats such as air and water pollution, or invasive species originating outside of the park's boundaries may intrude upon restoration efforts. National parks must be managed in ways that recognize the constraints and limitations imposed by the landscape in which the unit is nested.

Success at Sand Creek Massacre NHS can also be met by measuring how the ecological restoration meets the interpretative goals.

VI. Closing

In the 10,000 years since humans arrived in the Sand Creek area, environmental changes have contributed to the lifestyles of the people that lived in the area just as human activities have altered the environment. The site is an example of these changes that took place on the Plains since the arrival of humans. Sand Creek Massacre NHS is undergoing restoration at the bequest of the National Park System whose authorizing legislation directs NPS to manage the site as close as practicable to the 1864 cultural landscape. The goal of this restoration is to evoke an inseparable (reciprocal) connection between the natural resource, the cultural resource, and the people through shared experiences and activity, and the restoration and healing of the site. The result will be a sustainable landscape compatible with conditions found at the time of the massacre in 1864.

References

Alan, L.R. and A.F. Wiese. 1985. Effect of degree days on seed emergence. Proc. South Wed. Sci. Soc. 38:488.

Anonymous. 2000. Deep Redland ecological site description. Page 25 *in* Defining the Texas landscape through ecological site descriptions. USDA Natural Resource Conservation Service, Lady Bird Johnson Wildflower Center, Austin. TX.

Archer, S. 1989. Have southern Texas savannas been converted to woodlands in recent history? American Naturalist 134: 545-563.

Archer, S. 1990. Development and stability of grass/woody mosaics in a subtropical savanna parkland, Texas, U.S.A. Journal of Biogeography 17: 453-462.

Archer, S. 1996. Assessing and interpreting grass-woody plant dynamics. Pages 101-134 *in* J. Hodgson and A. Illius, editors. The ecology and management of grazing systems. CAB International, Wallingford, Oxon, United Kingdom.

Archer, S. and F.E. Smeins. 1991. Ecosystem-level processes. Pages 109-134 *in* R.K. Heitschmidt and J. W. Stuth, editors. Grazing management: an ecological perspective. Timberline Press, Portland, OR.

Begon, M., J.L. Harper, and C.R. Townsend. 1986. Ecology. Blackwell, Oxford.

Bolen, E. G. and W. L. Robinson. 2003. Wildlife ecology and management. 5th edition. Pearson Education, Inc., Upper Saddle River, New Jersey.

Bond, W.J. and B. Van Wilgen. 1996. Fire and plants. Chapman and Hall, New York, NY, U.S.A.

Britton, C.M., H.A. Wright, B.E. Dahl, and D.N. Ueckert. 1987. Management of tobosagrass rangeland with prescribed fire. Range and Wildlife Management Note 12, Texas Tech University.

Burrows, N.D., B. Ward, and A.D. Robinson. 1999. The role of indicators in developing appropriate fire regimes *in* Australian Bushfire Conference Albury, Australia.

Collins, S.L. and D.J. Gibson. 1990. Effects of fire on community structure in tallgrass and mixed-grass prairie. Pages 81-98 *in* S.L. Collins and L. Wallace, editors. Fire in North American Tallgrass Prairie. University of Oklahoma Press, Norman, OK.

Collins, S.L., A.K. Knapp, J.M. Briggs, J.M. Blair, and E.M. Steinauer. 1998. Modulation of diversity by grazing and mowing in native tallgrass prairie. Science 280: 745-747.

Coppock, D.L., J.K. Detling, J.E. Ellis, and M.I. Dyer. 1983. Plant-herbivore interactions in a North American mixed grass prairie. I. Effects of black-tailed prairie dogs on intraseasonal plant biomass and nutrient dynamics and plant species diversity. Oecologia (Berlin) 56:1-9.

Costanza, R., R. d'Arge, R.de Groot, S. Faber, M. Grasson, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, and M.V.D. Belt. 1997. The value of the world's ecosystem services and natural capital. Nature. 387L: 256.

Costanza, R. and H.E. Daly. 1992. Natural capital and sustainable development. Conservation Biology 6:37-46.

Costanza, R. D. Duplisea, and U. Kautsky. 1998. Introduction. Ecological Modeling 110:1-4.

Costanza, R., L. Wainger, C. Folke, and K.G. Maler. 1993. Modeling complex ecological economic systems – toward an evolutionary, dynamic understanding of people and nature. Bioscience 43:545-555.

Curtis, J.T. 1959. The vegetation of Wisconsin. University of Wisconsin Press, Madison.

De Groot, R.S. 1987. Environmental functions as a unifying concept for ecology and economics. Environmentalist 7:105-109.

Egan, D. and E.A. Howell, editors. 2001. The historical ecology handbook. Island Press, Washington, D.C.

Finch, D.M. 1996. Ecosystem disturbance and wildlife conservation in western grasslands - A symposium proceedings. General Technical Report RM-GTR-285. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 82 p.

Finch, Deborah M. 2004. Assessment of grassland ecosystem conditions in the Southwestern United States. Vol. 1. Assessment of grassland ecosystem conditions in the Southwestern United States. Volume 1. Gen. Tech. Rep. RMRS-GTR-135-vol. 1. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 167 p..

Ford, P.L., Potter, D.U., Pendleton, R., Pendleton, B., Robbie, W.A., Gottfried, G.J., 2004. Southwestern grassland ecology. In: Finch, D.M. (Ed.), Assessment of Grassland Ecosystem Conditions in the Southwestern United States, vol. 1. General Technical Report RMRS-GTR-135-vol. 1. US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO, pp. 18–48.

Ford, Paulette L. and G.V. Johnson. 2006. Effects of dormant- vs. growing-season fire in shortgrass steppe: Biological soil crust and perennial grass responses. Journal of Arid Environments. 67: 1-14.

Ford and G.R. McPherson. 1996. Ecology of fire in shortgrass prairie of the southern Great Plains. *Ecosystem Disturbance and Wildlife Conservation in Western Grasslands*, USDA Forest Service Rocky Mountain Forest and Range Experiment Station General Technical Report RM-285., Fort Collins (1996) p. 20–39 .

Fuhlendorf, S.D., F.E. Smeins, and C.A. Taylor. 1997. Browsing and tree size influences on Ashe juniper understory. Journal of Range management 50:507-512.

Goto, S., H. Iijima, H. Ogawa, and K. Ohya. 2009. Outbreeding depression caused by intraspecific hybridization between local and nonlocal genotypes *Abies sachalinensis*. Restoration Ecology. 19(2): 243-250.

Hall, Frederick C. 2001. Ground-based photographic monitoring. Gen. Tech. Rep. PNW-GTR-503. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 340 p. Accessed at: http://www.fs.fed.us/pnw/pubs/gtr503/

Hall, Frederick C. March 2002. General Technical Report PNW – GTR – 526 Photo Point Monitoring Handbook: Part A – Field Procedures. United States Department of Agriculture, Forest Service. Portland, Oregon.

Hall, Frederick C. March 2002. General Technical Report PNW – GTR – 526 Photo Point Monitoring Handbook: Part B – Concepts and Analysis. United States Department of Agriculture, Forest Service. Portland, Oregon.

Helzer, C. 2010. The Ecology and Management of Prairies in the central United States. University of Iowa Press, Iowa City.

Holechek, J.L., R.D. Pieper and C.H. Herbel. 2004. Range Management Principles and Practices. 5th edition. Pearson Education, Inc., Upper Saddle River, New Jersey. 607

Hunter, M.L. 1996. Fundamentals of Conservation Biology. Blackwell Science. Cambridge, Massachusetts. 482.

Koford, C.B. 1958. Prairie dogs, whitefaces and blue grama. Wildl. Monogr. 2:1-78.

Kreech, S. 1999. The Ecological Indian. W W Norton and Co., New York, New York.

Krueger, K. 1986. Feeding relationships among bison, pronghorn and prairie dogs: an experimental analysis. Ecology 67:760-770.

Lady Bird Johnson Wildflower Center, TBG Partners & Pate Engineering. (2010). "Protocol for Sustainable Roadsides, Williamson County". DRAFT. Chapter 5, Section 2, Item #43: Photographic Monitoring.

Laycock, W.A. 1991. Stable states and thresholds of range condition on North American rangelands: A viewpoint. Journal of Range Management 44:427-433.

Leopold, A. (1939) 1966. A sand county almanac: with essays on conservation from Round River. Ballantine Books, New York.

Malin, James. 1967. *The Grassland of North America: Prolegomena to its History*. Gloucester, MA: Peter Smith, p. 115.

Malin, James C. 1984. *History and Ecology: Studies of the Grassland*, ed. Robert P. Swierenga (Lincoln and London: University of Nebraska Press, 1984), 6.

McHugh, T. 1958. Social Behavior of the American buffalo (*Bison bison*). Zoologica (N.Y.) 43:1-40.

McPherson, G. R. 1997. Ecology and management of North American savannas. 1st edition. University of Arizona Press, Tucson.

McPherson, G. R., H. A. Wright, and D. B. Wester. 1988. Patterns of shrub invasion in semiarid Texas grasslands. The American Midland Naturalist 120:391-397.

Michell, Elizabeth, Mark Fiege, and Julia Langfield. 2007. *Sand Creek Massacre Site: An Environmental History*. Colorado State University, Department of History. (Thesis)

Miller, B., G. Ceballos, and R. Reading. 1994. The prairie dog and biotic diversity. Conservation Biol. 8:677-681.

Neid, S., J. E. Stevens, K. Forest, and M. Fink. 2007. Sand Creek Massacre National Historic Site: Vegetation Classification and Mapping. Natural Resource Technical Report NPS/SOPN/NRTR--2007/050. National Park Service, Fort Collins, Colorado.

Nussbaum, E.; Wiese, A.; Crutchfield, D.; Chenault, E.; Lavake, D.; Green, J. 1983. Production and Water Use Efficiency of Weed. Proc. South Weed Sci. Soc. 36:146.

NPS 2005—see Perkins et al. 2005.

NPS (The National Park Service). 2010. Sand Creek Massacre National Historic Site website, accessed at: http://www.nps.gov/sand/index.htm

NRCS. 2009. Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov .

Perkins, D. W., H. Sosinski, K. Cherwin', and T. F. Zettner. 2005. Southern Plains Network Vital Signs Monitoring Plan: Phase I. National Park Service, Southern Plains Network, Johnson City, TX, USA.

Peterson, G., C. R. Allen, and C. S. Holling. 1998. Ecological resilience, biodiversity, and scale. Ecosystems 1:6-18.

Pyne, S. J. 1982. Fire in America: a cultural history of wildland and natural fire. Princeton University Press, Princeton, NJ, USA.

Pyne, S. J., P. L. Andrews, and R. D. Laven. 1996. Introduction to wildland fire. 2nd edition. John Wiley and Sons, Inc., New York, New York.

Risser, P. G., E. C. Birney, and H. D. Blocker. 1981. The true prairie ecosystem. Hutchinson Ross Publishing, Stroudsburg, PA.

Samson, F. B. and F. L. Knopf, editors. 1996. Prairie conservation: preserving North America's most endangered ecosystem. Island Press, Washington, D.C.

Scanlan, J. C. and S. Archer. 1991. Simulated dynamics of succession in a North American subtropical *Prosopis* savanna. Journal of Vegetation Science 2:625-634.

Scholes, R. J. and S. R. Archer. 1997. Tree-grass interactions in savannas. Annual Review of Ecology and Systematics 28:517-544.

Scifres, C. J. and W. T. Hamilton. 1993. Prescribed burning for brushland management: the South Texas example. Texas A&M Press, College Station, TX.

Sebastian, Jim. 2005. Kochia Control to Aid in the Establishment of Perennial Grasses and Forbs. Boulder County Parks and Open Space Small Grants Report for 2005 Research Project. Accessed at:
http://www.bouldercounty.org/openspace/resources/res_funding/res_fund_pdfs/SGR/2005/2005Beck.pdf

Sherow, James E., 1992. "Workings of the Geodialectic: High Plains Indians and Their Horses in the Region of the Arkansas River Valley, 1800-1870," *Environmental History Review* (Summer 1992): 62-84. 58 Ibid., 71.

Smeins, F. E. 1980. Natural role of fire on the Edwards Plateau. Pages 4-16 *in* Prescribed Range Burning in the Edwards Plateau. Texas Agricultural Extension Service, Junction, Texas.

Smeins, F. E. 1982. The natural role of fire in central Texas. Pages 3-15 *in* T. G. Welch, editor. Prescribed range burning in central Texas. Texas Agricultural Experiment Service, Texas A&M University, College Station, TX.

Smeins, F. E. and L. B. Merrill. 1988. Long-term change in semi-arid grassland. Pages 101-114 *in* B. B. Amos and F. R. Gehlback, editors. Edwards Plateau Vegetation. Baylor Univ. Press, Waco, TX.

Sovell J, J Bell and S Neid. 2008 San Creek Massacre National Historic Site Natural Resources Report NPS Southern Plains region

Thompson, C.; Thill, D.; Shafii, B. 1994. Germination Characteristics of Sulfonylurea-Resistant and Susceptible Kochia (*Kochia Scoparia*). *Weed Science* 42 (1): 50-56.

Vallentine, J.F. 1989. *Range development and improvement*. 3rd ed. Academic Press, New York.

Vermeire, L., M. Rinella, and J. Muscha. 2009. Managing annual bromes in the northern Great Plains. *in* The Range Beef Cow Symposium XXI. University of Nebraska - Lincoln, Casper WY.
This paper is posted at DigitalCommons@University of Nebraska - Lincoln.
http://digitalcommons.unl.edu/rangebeefcowsymp/272

Walker, B. H. 1993. Rangeland ecology: Understanding and managing change. Ambio 22:80-87.

West, Elliott. 2000. *The Contested Plains: Indians, Goldseekers, and the Rush to Colorado*. University Press of Kansas; pp.73-74.

Wright, H. A. and A. W. Bailey. 1982. Fire ecology: United States and southern Canada. John Wiley, New York, New York, USA.

Van Auken, O.W. 2000. Shrub Invasions of North American Semiarid Grasslands. Annual Review of Ecology and Systematics 31: 197-215.

Appendix A: Sand Creek Massacre National Historic Site Master Plant List

Sand Creek Massacre National Historic Site Master Plant List				
Scientific Name	**Synonym**	**Common Name**	**Abundance**	**Nativity**
Abronia fragrans		sand verbena	Common	Native
Achnatherum hymenoides		Indian ricegrass	Rare	Native
Agropyron cristatum		crested wheatgrass	Rare	Non-Native
Amaranthus retroflexus		redroot pigweed	Rare	Native
Ambrosia psilostachya		western ragweed	Abundant	Native
Andropogon hallii		sand bluestem	Uncommon	Native
Apocynum cannabinum		Indianhemp dogbane	Uncommon	Native
Argemone polyanthemos		prickly poppy	Rare	Native
Aristida oligantha		prairie three-awn	Uncommon	Native
Aristida purpurea Nutt. var. longiseta (Steud.) Vasey		Fendler threeawn	Abundant	Native
Artemisia filifolia		sand sagebrush	Abundant	Native
Artemisia ludoviciana		Louisiana sagewort	Common	Native
Asclepias engelmanniana		Engelmann's milkweed	Rare	Native
Asclepias latifolia		broadleaf milkweed	Rare	Native
Asclepias speciosa		showy milkweed	Uncommon	Native
Asclepias subverticillata		poison milkweed	Abundant	Native
Asclepias viridiflora		green milkweed	Rare	Native
Aster sp.		Aster sp.	Common	Unknown
Astragalus bodinii		Bodin's milkvech	Rare	Native
Astragalus ceramicus var. filifolius		painted milkvetch	Rare	Native
Astragalus crassicarpus		groundplum milkvetch	Uncommon	Native
Astragalus miser		timber milkvetch	Rare	Native
Astragalus missouriensis		Missouri milkvetch	Common	Native
Astragalus mollissimus		woolly milkvetch	Uncommon	Native
Astragalus pectinatus		tine-leaved milkvetch	Uncommon	Native
Astragalus praelongus var. ellisiae		stinking milkvetch	Rare	Native
Astragalus purshii		woollypod milkvetch	Rare	Native
Astragalus sp.		Astragalus sp.	Uncommon	Unknown
Astragalus sp. #2		Astragalus sp. #2	Uncommon	Unknown
Astragalus sp. #3		Astragalus sp. #3	Uncommon	Unknown
Astragalus sp. #4		Astragalus sp. #4	Rare	Unknown
Astragalus sp. #5		Astragalus sp. #5	Rare	Unknown
Astragalus sp. #6		Astragalus sp. #6	Rare	Unknown

Bouteloua curtipendula		sideoats grama	Abundant	Native
Bouteloua gracilis		blue grama	Abundant	Native
Bouteloua hirsuta		hairy grama	Common	Native
Brassicaceae		UF99	Uncommon	Unknown
Buchloe dactyloides		buffalograss	Abundant	Native
Caesalpinia jamesii		James rushpea	Rare	Native
Calamovilfa longifolia		prairie sandreed	Common	Native
Callirhoe involucrata		winecup	Common	Native
Calylophus serrulatus		plains yellow primrose	Rare	Native
Carex filifolia		threadleaf sedge	Rare	Native
Carex foenea		silvertop sedge	Common	Native
Carex inops ssp. heliophila		sun sedge	Rare	Native
Carex nebrascensis		Nebraska sedge	Rare	Native
Carex parryana		Parry sedge	Rare	Native
Carex praegracilis		silver sedge	Rare	Native
Chamaesyce serpyllifolia ssp. serpyllifolia		thyme-leaved spurge	Common	Native
Chenopodiaceae		UF10	Common	Unknown
Chenopodium album		lambsquarters	Common	Native
Chenopodium sp. #1		Chenopodium sp. #1	Abundant	Unknown
Chenopodium sp. #2		Chenopodium sp. #2	Common	Unknown
Chenopodium watsonii		Chenopodium watsonii	Common	Native
Chenopodiun sp.		Chenopodiun sp.	Common	Unknown
Chloris verticillata		windmill grass	Rare	Native
Chrysothamnus viscidiflorus		green rabbitbrush	Uncommon	Native
Cirsium undulatum		wavyleaf thistle	Common	Native
Convolvulus arvensis		field bindweed	Abundant	Non-Native
Conyza canadensis		conyza	Abundant	Native
Croton texensis		Texas croton	Uncommon	Native
Cryptantha circumscissa		beggars tick	Abundant	Native
Cucurbita foetidissima		buffalo-gourd	Rare	Native
Cyperus schweinitzii Torr.		Schweinitz's flatsedge	Rare	Native
Dalea aurea		Golden prairie clover	Rare	Native
Dalea candida		white prairie clover	Rare	Native
Dalea cylindriceps Barneby		Andean prairie clover	Unknown	Native
Dalea enneandra		bigtop dalea	Rare	Native
Dalea nana Torr. ex Gray var. nana		dwarf prairie clover	Unknown	Native
Dalea purpurea		purple prairie clover	Rare	Native
Dalea sp. #1		Dalea sp. #1	Rare	Native
Dalea villosa		silky prairie clover	Rare	Native
Delphinium virescens		Plains larkspur	Rare	Native

Descurainia pinnata (Walt.) Britt.		western tansymustard	Unknown	Native
Distichlis spicata		inland saltgrass	Abundant	Native
Dracopis sp.		coneflower	Rare	Unknown
Dyssodia papposa		fetid marigold	Common	Native
Eleocharis sp.		spike rush	Abundant	Unknown
Elymus canadensis		Canada wildrye	Abundant	Native
Elymus elymoides (Raf.) Swezey ssp. brevifolius		squirreltail	Abundant	Native
Elymus repens		quackgrass	Uncommon	Non-Native
Elymus trachycaulus		slender wheatgrass	Rare	Native
Engelmannia pinnatifida	Engelmannia peristenia	Engelmanns daisy	Abundant	Native
Equisetum hyemale		horsetail	Common	Native
Eragrostis trichodes		sand lovegrass	Uncommon	Native
Ericameria nauseosa ssp. nauseosa		rubber rabbitbrush	Rare	Native
Erigeron bellidiastrum		western fleabane	Abundant	Native
Erigeron compositus		cutleaf daisy	Uncommon	Native
Erigeron glabellus subsp. pubescens		streamside fleabane	Common	Native
Erigeron modestus		plains fleabane	Rare	Native
Eriogonum annuum		annual buckwheat	Abundant	Native
Erysimum asperum		wallflower	Abundant	Native
Escobaria vivipara var. vivipara		purple pincushion	Rare	Native
Euphorbia marginata		snow on the mountain	Uncommon	Native
Evolvulus nuttallianus		Nuttalls evolvulus	Uncommon	Native
Fabaceae		UF12	Rare	Unknown
Gaillardia pulchella		blanket flower	Uncommon	Native
Gaura coccinea		scarlet gaura	Abundant	Native
Gaura parviflora	Gaura mollis	velvet gaura	Uncommon	Native
Glycyrrhiza lepidota		American licorice	Common	Native
Grindelia squarrosa		curlycup gumweed	Uncommon	Native
Gutierrezia sarothrae		broom snakeweed	Common	Native
Haplopappus spinulosus		cutleaf ironweed	Common	Native
Helianthus annuus		common sunflower	Common	Native
Helianthus petiolaris Nutt.		prairie sunflower	Unknown	Native
Hesperostipa comata (Trin. & Rupr.) Barkworth ssp. comata		needle and thread	Common	Native
Heterotheca villosa		hairy goldenaster	Rare	Native
Hilaria jamesii	Pleuraphis jamesii	galleta	Rare	Native
Hordeum jubatum		foxtail barley	Abundant	Native
Hordeum pusillum		little annual barley	Common	Native

Hymenopappus tenuifolius Pursh		Chalk Hill hymenopappus	Common	Native
Ipomoea leptophylla		bush morning glory	Uncommon	Native
Ipomopsis laxiflora (Coult.) V. Grant		iron ipomopsis	Unknown	Native
Ipomopsis longiflora		flaxflowered ipomopsis	Abundant	Native
Iva axillaris		povertyweed	Abundant	Native
Juncus arcticus Willd. ssp. littoralis (Engelm.) Hultén		Baltic rush	Abundant	Native
Juncus effusus		common rush	Rare	Native
Juncus marginatus		grassleaf rush	Rare	Native
Kochia scoparia		kochia	Abundant	Non-Native
Koeleria macrantha		prairie junegrass	Rare	Native
Lactuca serriola		prickly lettuce	Uncommon	Non-Native
Lappula echinata var. occidentalis	Lappula occidentalis var. occidentalis	flatspine stickseed	Common	Native
Lappula occidentalis (S. Wats.) Greene var. cupulata (Gray) Higgins		flatspine stickseed	Unknown	Native
Lepidium densiflorum		pepperpod mustard	Abundant	Native
Liatris punctata		dotted gayfeather	Rare	Native
Linaria dalmatica (L.) P. Mill.	Linaria dalmatica	Dalmatian toadflax	Rare	Non-native
Linum rigidum		stiff flax	Abundant	Native
Linum sp.		Linum sp.	Uncommon	Unknown
Lippia cuneifolia	Phyla cuneifolia	frog fruit	Uncommon	Native
Lithospermum incisum		narrowleaf stoneseed	Uncommon	Native
Lupinus pusillus		small lupine	Rare	Native
Lygodesmia juncea		rush skeletonweed	Abundant	Native
Machaeranthera tanacetifolia		tanseyleaf tansyaster	Unknown	Native
Melilotus alba		white sweetclover	Uncommon	Non-Native
Melilotus officinalis		yellow sweetclover	Abundant	Non-Native
Mentzelia decapetala		tenpetal blazingstar	Common	Native
Mirabilis hirsuta		hairy fouroclock	Common	Native
Mirabilis linearis		narrowleaf fouroclock	Uncommon	Native
Muhlenbergia asperifolia		scratchgrass	Abundant	Native
Muhlenbergia pungens		sandhill muhly	Rare	Native
Muhlenbergia torreyi		ring muhly	Uncommon	Native
Oenothera albicaulis		pale evening-primrose	Rare	Native

Oenothera coronopifolia		cutleaf evening-primrose	Rare	Native
Oenothera harringtonii		Colorado Springs evening-primrose	Rare	Native
Oenothera spp.		evening-primrose	Common	Native
Oonopsis engelmannii (Gray) Greene		Engelmann's false goldenweed	Unknown	Native
Opuntia fragilis		brittle cactus	Uncommon	Native
Opuntia polyacantha		plains pricklypear	Uncommon	Native
Oxytropis campestris		field locoweed	Rare	Native
Oxytropis sericea		white locoweed	Abundant	Native
Oxytropis sp.		Oxytropis sp.	Common	Unknown
Packera neomexicana var. mutabilis		variable senecio	Rare	Native
Packera tridenticulata (Rydb.) W.A. Weber & A. Löve		lobeleaf groundsel	Rare	Native
Palafoxia sphacelata		othake	Rare	Native
Panicum capillare		witchgrass	Common	Native
Panicum obtusum		vine mesquite	Common	Native
Panicum sp.		Panicum sp.	Uncommon	Unknown
Panicum virgatum		switchgrass	Common	Native
Pascopyrum smithii		western wheatgrass	Abundant	Native
Paspalum setaceum		sand paspalum	Uncommon	Native
Penstemon albidus		white beardtongue	Rare	Native
Penstemon spp.		penstemons	Rare	Native
Physalis heterophylla		clammy groundcherry	Uncommon	Native
Physalis hispida (Waterfall) Cronq.		prairie groundcherry	Unknown	Native
Physalis longifolia		common groundcherry	Common	Native
Physalis pumila		prairie groundcherry	Uncommon	Native
Plantago patagonica		woolly plantain	Abundant	Native
Poa glaucifolia	Poa arida	Glaucous bluegrass	Rare	Native
Poa pratensis		Kentucky bluegrass	Common	Native (Introduced)
Polanisia dodecandra ssp. trachysperma		clammy weed	Rare	Native
Polypogon monspeliensis		annual rabbitsfoot grass	Uncommon	Non-Native
Populus deltoides		eastern cottonwood	Rare	Native
Portulaca oleracea		purselane	Rare	Non-Native
Psoralea argophylla	Pediomelum argophyllum	silverleaf scurfpea	Rare	Native
Psoralea digitata	Pediomelum digitatum	palmleaf scurfpea	Rare	Native
Psoralidium lanceolatum		lemon scurfpea	Uncommon	Native
Psoralidium		slimflower scurfpea	Abundant	Native

tenuiflorum				
Quincula lobata		purple ground cherry	Rare	Native
Ratibida columnifera		prairie coneflower	Common	Native
Ratibida tagetes		short-ray prairie coneflower	Abundant	Native
Redfieldia flexuosa		blowout grass	Rare	Native
Rosa arkansana		prairie rose	Rare	Native
Rumex altissimus		pale dock	Common	Native
Rumex crispus		curly dock	Uncommon	Non-Native
Salix sp.		willow	Uncommon	Native
Salsola iberica	Salsola tragus	Russian thistle	Abundant	Non-Native
Schedonnardus paniculatus		tumblegrass	Abundant	Native
Schizachyrium scoparium		little bluestem	Rare	Native
Schoenoplectus maritimus (L.) Lye		cosmopolitan bulrush	Rare	Native
Schoenoplectus tabernaemontani (K.C. Gmel.) Palla		softstem bulrush	Unknown	Native
Scirpus americanus		chairmaker's bulrush	Abundant	Native
Scirpus maritimus var. paludosus		cosmopolitan bulrush	Rare	Native
Senecio integerrimus		groundsel	Rare	Native
Solanum rostratum		buffalo bur	Uncommon	Native
Solidago gigantea		late goldenrod	Rare	Native
Sophora nuttalliana		silky sophora	Rare	Native
Sorghastrum nutans		yellow indiangrass	Rare	Native
Spartina pectinata		prairie cordgrass	Common	Native
Sphaeralcea coccinea		scarlet globemallow	Abundant	Native
Sporabolus airoides		alkali sacaton	Abundant	Native
Sporobolus compositus		tall dropseed	Rare	Native
Sporobolus cryptandrus		sand dropseed	Abundant	Native
Symphyotrichum ericoides		heath aster	Common	Native
Talinum parviflorum		fame flower	Common	Native
Thelesperma megapotamicum		Hopi tea greenthread	Uncommon	Native
Toxicodendron rydbergii		poison ivy	Uncommon	Native
Tradescantia occidentalis		prairie spiderwort	Rare	Native
Tragopogon dubius		salsify	Uncommon	Non-Native
Tripterocalyx micranthus (Torr.) Hook.		smallflower sandverbena	Unknown	Native
Typha angustifolia L.		narrowleaf cattail	Unknown	Native
Typha latifolia		cattail	Abundant	Native
Verbena bracteata		prostrate vervain	Common	Native

Veronica officinalis		common speedwell	Rare	Native
Vulpia octoflora		six-weeks fescue	Abundant	Native
Yucca glauca		yucca	Rare	Native

Appendix B: Sand Creek Massacre National Historic Site Non-Native Plant List

Sand Creek Massacre National Historic Site Non-Native Plant List				
Scientific Name	**Synonym**	**Common Name**	**Abundance**	**Nativity**
Convolvulus arvensis		field bindweed	Abundant	Non-Native
Kochia scoparia		kochia	Abundant	Non-Native
Melilotus officinalis		yellow sweetclover	Abundant	Non-Native
Salsola iberica	Salsola tragus	Russian thistle	Abundant	Non-Native
Chenopodium sp. #1		Chenopodium sp. #1	Abundant	Unknown
Eleocharis sp.		spike rush	Abundant	Unknown
Poa pratensis		Kentucky bluegrass	Common	Native (Introduced)
Aster sp.		Aster sp.	Common	Unknown
Chenopodiaceae		UF10	Common	Unknown
Chenopodium sp. #2		Chenopodium sp. #2	Common	Unknown
Chenopodiun sp.		Chenopodiun sp.	Common	Unknown
Oxytropis sp.		Oxytropis sp.	Common	Unknown
Agropyron cristatum		crested wheatgrass	Rare	Non-Native
Linaria dalmatica (L.) P. Mill.	Linaria dalmatica	Dalmatian toadflax	Rare	Non-native
Portulaca oleracea		purselane	Rare	Non-Native
Astragalus sp. #4		Astragalus sp. #4	Rare	Unknown
Astragalus sp. #5		Astragalus sp. #5	Rare	Unknown
Astragalus sp. #6		Astragalus sp. #6	Rare	Unknown
Dracopis sp.		coneflower	Rare	Unknown
Fabaceae		UF12	Rare	Unknown
Elymus repens		quackgrass	Uncommon	Non-Native
Lactuca serriola		prickly lettuce	Uncommon	Non-Native
Melilotus alba		white sweetclover	Uncommon	Non-Native
Polypogon monspeliensis		annual rabbitsfoot grass	Uncommon	Non-Native
Rumex crispus		curly dock	Uncommon	Non-Native
Tragopogon dubius		salsify	Uncommon	Non-Native
Astragalus sp.		Astragalus sp.	Uncommon	Unknown
Astragalus sp. #2		Astragalus sp. #2	Uncommon	Unknown
Astragalus sp. #3		Astragalus sp. #3	Uncommon	Unknown
Brassicaceae		UF99	Uncommon	Unknown
Linum sp.		Linum sp.	Uncommon	Unknown
Panicum sp.		Panicum sp.	Uncommon	Unknown

Appendix: Rocky Mountain Arsenalhttp://www.fws.gov/rockymountainarsenal/habitat/habitat.htm

Refuge Habitat in Restoration

Wildlife Habitat
The wildlife habitat at Rocky Mountain Arsenal National Wildlife Refuge ranges from small patches of relatively undisturbed native prairie, to woodlots and wetlands brought by settlers and farmers.

Shortgrass Prairie Restoration
The Arsenal is home to one of the most intense and successful shortgrass prairie restoration programs in the nation. Refuge biologists are working hard to put the prairie back on this landscape. Within the next 10 years, nearly 8,000 acres of former cropfields will be re-seeded with buffalo grass, blue grama and many other species of grasses, wild flowers, and shrubs that are native to Colorado's high plains.

Arsenal Land History
Most of the Arsenal evolved to farm land between 1880 and 1920. After the Army acquired the land during World War II, they converted abandoned crop fields to grasslands using mostly exotic grasses from Europe and Asia. While some wildlife, such as prairie dogs seem to thrive in unnatural habitats of weeds and exotic grasses, many native songbirds cannot thrive without the diversity of the native prairie.

Invasive Vegetation
Invasive weeds are perhaps the greatest threat to native habitats throughout the West. Some of the most important habitat work at the refuge involves efforts to control the spread of weeds, and to eradicate new infestations before they can spread and destroy habitat values. Refuge biologists intensively monitor the habitat to detect weed infestations. An aggressive "integrated pest management" program involving the use of mowing, cultivating, biological control agents, and approved herbicides is implemented to keep the weeds at bay.

Man-Made Habitat Features
The refuge will also maintain some of the man-made features, such as lakes, wetlands, and some woodlands that wildlife such as the bald eagle have come to depend on over the last fifty years. Trees on this landscape present a conundrum. They provide roosting sites and potential nesting sites for the bald eagle, and for many colorful and popular songbirds that have invaded Colorado from the East. They also provide perches and nest sites for predators such as the magpie and great-horned owl that are probably much more abundant now than they were before settlement - predators that may impact the native prairie species.

Future Refuge Habitat
When the prairie restoration program is complete, the northern "half" of the refuge will be a rolling native grassland, with very few trees. In the south, where there are more water features and old homesteads, visitors will see a more manipulated landscape of lakes, marshes, and woodlots interspersed with the grasslands.