National Park Service
U.S. Department of the Interior

Status and History of Prairie Dogs in Colorado and at Sand Creek NHS

ON THE COVER
A black-tailed prairie dog stands guard at its burrow.
Photograph by: John Sovell, CNHP

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Introduction

Sand Creek Massacre National Historic Site (SAND) was authorized by the U. S. Congress in November of 2000 with an area of 12,500 ac (5,559 ha) for inclusion within the park boundary (Figure 1). Current land acquisitions have resulted in an established boundary that encompasses approximately 2,400 ac (971 ha) (referred to as SAND in this plan) (Figure 1), which is managed by the National Park Service (NPS). The remaining land within the authorized boundary, totaling approximately 10,100 ac, is held by the State of Colorado (6%) and 10 different private landowners (94%). The NPS will act to procure additional private land within the authorized boundary as that land becomes available. According to the Sand Creek Massacre National Historic Site Establishment Act of 2000, SAND was established for the following reasons:

- To protect and preserve the site, including the topographic features that the Secretary determines are important to the site; artifacts and other physical remains of the Sand Creek Massacre; and the cultural landscape of the site, in a manner that preserves, as closely as practicable, the cultural landscape of the site as it appeared at the time of the Sand Creek Massacre;

- To interpret the natural and cultural resource values associated with the site and to provide for public understanding and appreciation of, and preserve for future generations, those values; and

- To memorialize, commemorate, and provide information to visitors to the site to enhance cultural understanding about the site; and to assist in minimizing the chances of similar incidents in the future.

SAND is on the high plains of southeastern Colorado. It is in north-central Kiowa County near the border with Cheyenne County and is located 14 miles NNE of Eads, Colorado (Figure 1). Kiowa County borders Kansas and SAND is approximately 25 miles from the Kansas state-line. SAND is surrounded by dryland agricultural fields and rangeland. The objective of the NPS is to preserve, protect, interpret, commemorate and memorialize the site for future generations. This includes preservation of the native biological resources of the site.

Vegetation

The primary habitat at SAND is shortgrass prairie and sandsage (*Artemisia filifolia*) shrubland with the intermittent Big Sandy Creek bisecting SAND (Figure 2). Shortgrass prairie occurs on the loamier north side of the Big Sandy. There is an estimated 347 ac (140 ha) of this grassland type within the current established boundary of SAND, and 3,245 ac (1,313 ha) within the area authorized for SAND (CNHP 2008, Neid et al. 2007). The shortgrass prairie is excellent habitat for the black-tailed prairie dog (*Cynomys ludovicianus).*

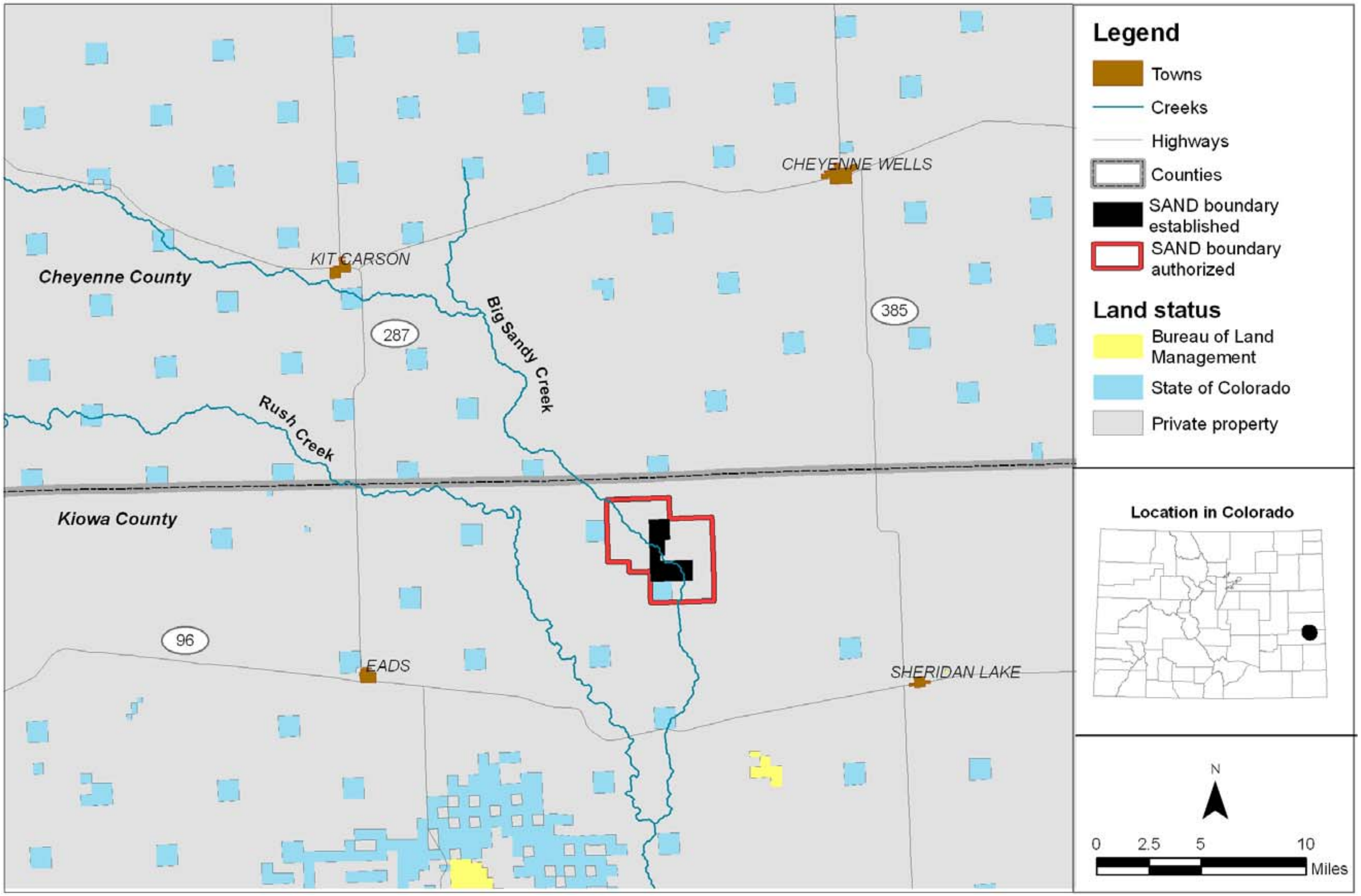

Figure 1. The location of Sand Creek Massacre National Historic Site in Colorado.

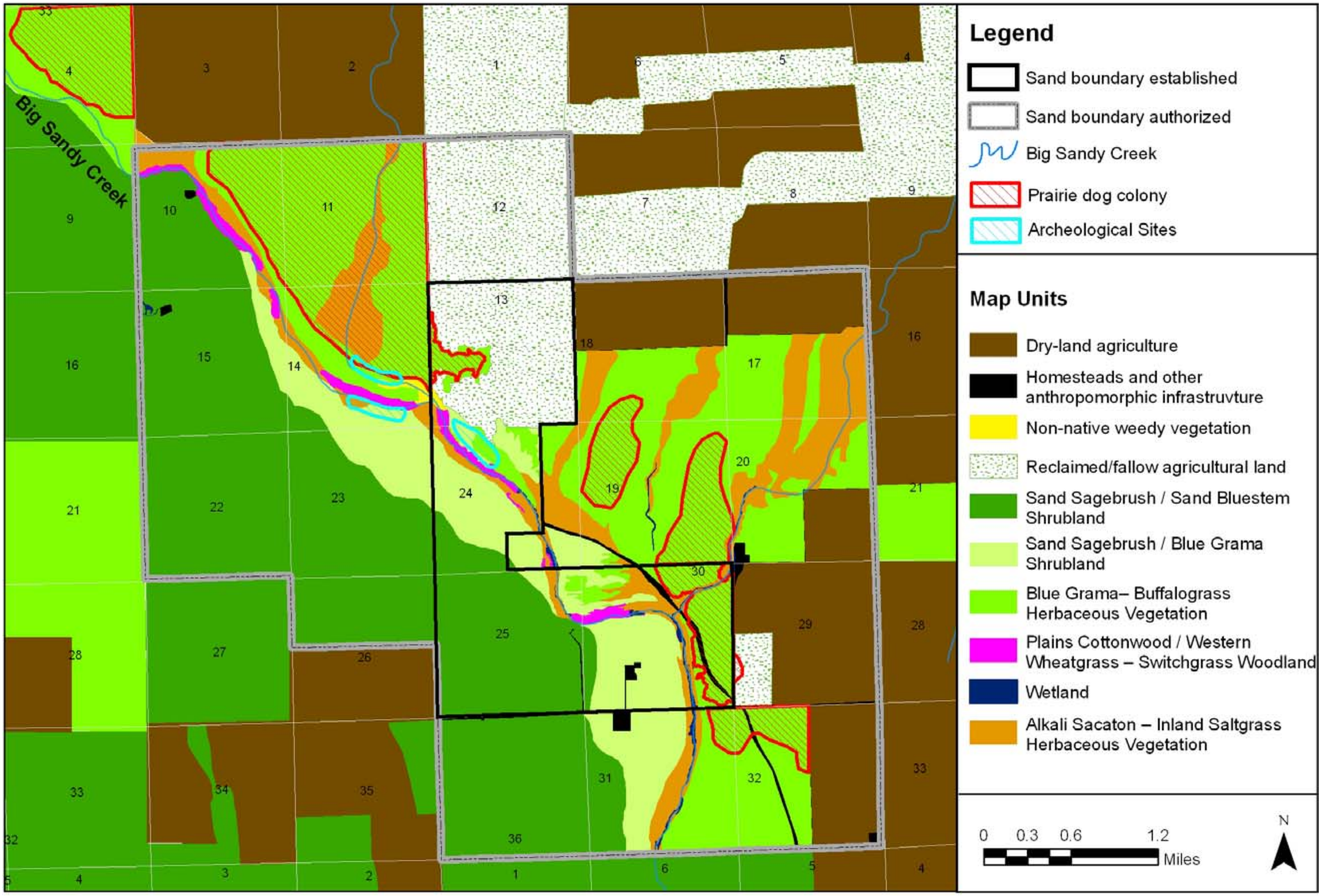

Figure 2. Vegetation map of Sand Creek Massacre National Historic Site showing the location of the black-tailed prairie dog colonies and the archeological sites (after Neid et al. 2007).

Sandsage occupies the sandhills to the south and west of Big Sandy Creek, while the riparian corridor is a mosaic of cottonwood woodland, mesic grassland, and wet meadow surrounding a narrow, braided stream channel (Figure 2) (Neid et al. 2007). There are agricultural fields and reclaimed agricultural fields in the immediate vicinity, especially to the north and east. Soils are well-drained and generally loamy with variable areas of sandy loam, silt loam, and silty or sandy clay loam. On the ancient, alluvial terraces, there are more alkaline indicators.

The following descriptions of the vegetation associations found at SAND are adapted from Neid et al. (2007).

Sand Sagebrush / Sand Bluestem Shrubland — *Artemisia filifolia / Andropogon hallii* Shrubland: This shrubland occurs on the undulating sand hills above the stream terrace on the south side of Big Sandy Creek. This sand sage shrubland is characterized by Sandsage. Soapweed yucca (*Yucca glauca*) is a common subshrub in many areas, especially knolls and bluffs. The understory is characterized by diverse graminoids and forbs. Graminoids are generally dominant and include sand bluestem (*Andropogon hallii*), sideoats grama (*Bouteloua curtipendula*), prairie sandreed *Calamovilfa longifolia*, poverty threeawn (*Aristida divaricata*), and purple threeawn (*Aristida purpurea*) as well as blue gramma, which is ubiquitously present. The tallgrass species are characteristic of this association. Forbs are often diverse and commonly include Cuman ragweed (*Ambrosia psilostachya*), slimflower scurfpea (*Psoralidium tenuiflorum*), lemon scurfpea (*Psoralidium lanceolatum*), western daisy fleabane (*Erigeron bellidiastrum*), dotted blazing star (*Liatris punctata*), Andean prairie clover (*Dalea cylindriceps*), tanseyleaf tansyaster (*Machaeranthera pinnatifida*), bractless blazingstar (*Mentzelia nuda*), prairie sunflower (*Helianthus petiolaris*), annual buckwheat (*Eriogonum annuum*), Canadian horseweed (*Conyza Canadensis*), and other occasional species.

Sand Sagebrush / Blue Gramma Shrubland —*Artemisia filifolia / Bouteloua gracilis* Shrubland: This shrubland occurs on flat terraces and benches immediately adjacent to and above the riparian channel of Big Sandy Creek as well as in limited areas on the level bench above the Chivington Ditch east of the creek. The shrubland occurs at toeslopes and low level areas on the property. This sand sagebrush shrubland is characterized by sandsage. The herbaceous layer is strongly dominated by blue grama, which ranges from 25-55% cover. Sand dropseed (*Sporobolus cryptandrus*) is a common associate and needle and thread grass (*Hesperostipa comat*a) is occasionally present. Forbs are less diverse than in the sand hills but include tanseyleaf tansyaster, shaggy dwarf morning-glory (*Evolvulus nuttallianus*), yellowspine thistle (*Cirsium ochrocentrum*), dotted blazing star, Canadian horseweed, and scarlet globemallow (*Sphaeralcea coccinea*). Occasionally alkali sacaton (*Sporobolus airoides*) and inland saltgrass (*Distichlis spicata*) occur, especially where this association grades into Alkali Sacaton and Inland Saltgrass Herbaceous Vegetation in the riparian corridor.

Blue grama / Buffalograss Herbaceous Vegetation — *Buteloua gracilis / Buchloe dactyloides Herbaceous* Vegetation*:* Shortgrass prairie occurs on the loamier north side of Big Sandy Creek. This shortgrass prairie association is characterized by buffalograss (*Buchloe dactyloides*) and sod-forming blue gramma. Occasional graminoid associates include alkali sacaton, false buffalograss (*Monroa squarrosa*), ring muhly (*Muhlenbergia torreyi*), and/or sand muhly

(*Muhlenbergia arenicola*). Forbs are common but have sparse cover; they include purple poppymallow (*Callirhoe involucrate*), scarlet globemallow, white locoweed (*Oxytropis sericea*), slimflower scurfpea, smooth four o'clock (*Mirabilis glabra*), plains pricklypear (*Opuntia polyacantha*), and tanseyleaf tansyaster. The expression of this association on the lower terraces within the riparian corridor is more alkaline with green prairie coneflower (*Ratibida tagetes*), giant sumpweed (*Iva xanthifolia*), and variable amounts of alkali sacaton and inland saltgrass.

Cottonwood / Western Wheatgrass -Switchgrass Woodland — *Populus deltoides / Pascopyrum smithii - Panicum virgatum* Woodland: The cottonwood woodland occurs along the modern riparian channel of Big Sandy Creek and immediately adjacent alluvial terrace. This cottonwood woodland is characterized by eastern cottonwood (*Populus deltoids*), which generally forms even-aged stands in disconnected patches along the length of Big Sandy Creek. Additionally there are several older and larger individuals or small groups of eastern cottonwood near the older alluvial terraces. The herbaceous layer is dominated by grasses, especially western wheatgrass (*Pascopyrum smithii*) and switchgrass (*Panicum virgatum*). Common associates include Canada wildrye (*Elymus Canadensis*), buffalograss, and alkali sacaton. Inland saltgrass, scratchgrass (*Muhlenbergia asperifolia*), and prairie cordgrass (*Spartina pectinata*) occur infrequently. Forbs are common and can be locally abundant. Species include Cuman ragweed, horsetail milkweed (*Asclepias subverticillata*), upright prairie coneflower (*Ratibida columnifera*), camphor daisy (*Rayjacksonia phyllocephala*), and white prairie aster (*Symphyotrichum falcatum* var. *falcatum*).

Common Threesquare Herbaceous Vegetation — *Schoenoplectus pugens Herbaceous* Vegetation*:* This emergent wetland occurs within the channel of Big Sandy Creek. In the upstream portions of the channel it occurs as small, isolated, ephemeral ponds and in local areas where the channel is deeper. Downstream, near County Road W, the wetland is more extensive. This emergent wetland is characterized by common threesquare (*Schoenoplectus pungens*), which is generally dominant and exhibits 65-80% cover. Common associated species include scratchgrass. Where the wetlands have greater surface water, hardstem bulrush (*Schoenoplectus acutus*) and/or narrowleaf cattail (*Typha angustifolia*) are present. Additional species that occur incidentally and sporadically within the wetlands include Baltic rush (*Juncus balticus*), giant sumpweed, and common spikerush (*Eleocharis palustris*). In several areas eastern cottonwood regeneration is occurring.

Alkali Sacaton – Saltgrass Herbaceous Vegetation — *Sporobolus airoides – Disstichlis spicata* Herbaceous Vegetation: This grassland occurs on older alluvial terraces within the Big Sandy Creek riparian corridor. It occurs in wide swaths on the inside bends of the creek where the alluvial bench is more extensive. The grassland is characterized by alkali sacaton and inland saltgrass. These two species form a patchy mosaic of monotypic as well as mixed swards. Vine mesquite (*Panicum obtusum*) and scratchgrass are frequent. Horsetail milkweed is frequent and can form dense patches within this grassland. Additional associated species include green prairie coneflower, smooth four o'clock, Cuman ragweed, purple poppymallow, pitseed goosefoot (*Chenopodium berlandieri*), smooth goosefoot (*Chenopodium subglabrum*), American licorice (*Glycyrrhiza lepidota*), and sand dropseed.

Dryland Agriculture: This map unit reflects currently plowed agricultural fields consisting of dryland crops.

Development: This map unit reflects anthropogenic infrastructure and includes roads (wider than 12m), homesteads and associated infrastructure or plantings, and the Chivington Ditch.

Disturbed: This map unit reflects anthropogenic activity outside of development areas. These are areas dominated by non-native weedy species like *Bassia (=Kochia) scoparia* and *Salsola australis*, among others. These areas often occur where saltcedar (*Tamarix ramosissima*) reduction and removal efforts occurred and where large machinery used to reduce *Salsola* tumbleweeds was used.

Reclaimed agricultural land: This map unit reflects areas of unknown land use history (although presumably past plowed agriculture) that have been replanted to native grass species or have been left fallow. Within the established park boundary, this occurs in a majority of the northern section. Species composition is a patchy distribution of native grasses and weedy areas comprised of both native and non-native species. Native grasses predominantly include blue grama, sideoats grama, sand dropseed, and small patches of switchgrass. Forb species occasionally occur, including scarlet globemallow, rush skeletonplant (*Lygodesmia juncea*), twogrooved milkvetch *Astragalus bisulcatus, Physalis heterophylla, Cirsium ochrocentrum*, or *Conyza canadensis*, among others. Weedy areas tend to have more bare ground and abundant smotherweed (*Bassia (=Kochia) scoparia*) or prickly Russian thistle (*Salsola australis*) with or without sand dropseed. Local areas with more fine-textured soils have patches of buffalograss. Sporadic shrubs occur, including rubber rabbitbrush (*Ericameria nauseosus*) and sandsage, especially near fencelines or on the periphery of the vegetation type.

Wildlife Resources

A prairie dog complex occupies an estimated 228 ac (92 ha) of SAND with average density of the complex estimated at 16.6 prairie dogs/ac (41/ha) (Sovell 2007). A prairie dog complex is defined as a group of prairie dog colonies distributed such that individual prairie dogs can physically disperse from one colony to another. The Multistate Prairie Dog Conservation Team, for mapping and management purposes, has defined the black-tailed prairie dog movement distance that encompasses the majority of inter-colony movement to be 4.3 mi (7 km) (Luce 2003). Consequently, any colonies that are within 4.3 mi (7 km) of each other are considered part of the same complex. There are four prairie dog colonies within the vicinity of SAND. Portions of two of these four colonies are within the established boundary of SAND, one colony is within the authorized boundary, and one colony exists just outside the northwest corner of the authorized boundary (Figure 2). One of the two colonies sharing portions of their area with SAND is in the north of the park and is referred to as the “north colony” in this plan. The other colony is in the south half of SAND and is referred to as the “south colony”. The greatest distance between any two of these colonies is less than 1 mi (1.6 km) and together these four colonies form a single complex. Burrowing Owls (Athene cunicularia) occur on the prairie dog complex at SAND and Mountain Plover (*Charadrius montanus*) have been recorded within the complex, but just off SAND (Sovell 2007). Within and near SAND there are numerous indications of predators including dens of American badger (*Taxidea taxus*) and coyote (*Canis latrans*), and Ferruginous Hawk (*Buteo regalis*) have been recorded in the vicinity of SAND (Sovell 2007) and are hunting at SAND.

Prairie dogs are important to the proper functioning of native shortgrass prairies and have been proposed as keystone species in North American grasslands (Miller et al. 1994). As a keystone species, prairie dogs impact grassland ecosystems by increasing habitat heterogeneity, modifying ecosystem processes, and enhancing regional biodiversity (Ceballos et al. 1999). There are three primary pathways that prairie dogs exert their influence on shortgrass prairies: through grazing, burrowing, and by acting as prey for other species (Hooglund 2006). Many species use prairie dog colony-sites for food and shelter including the American badger, black-footed ferret (*Mustela nigripes*), coyote, Ferruginous Hawk, golden Eagle (*Aquila chrysaetos*), Prairie Falcon (*Falco mexicanus*), Burrowing Owls, prairie rattlesnake (*Crotalus viridis*), and tiger salamander (*Ambystoma tigrinum*) (Hooglund 1996). Clipping of vegetation and grazing by prairie dogs creates open habitats preferred by grassland birds like Mountain Plover and Horned Lark (*Eremophila alpestris*) (Dreitz 2005). The viewpoint that prairie dogs act as keystone species, however, is not without controversy. Knowledge of the effects prairie dogs have on grassland ecosystems may be more limited and equivocal than has been proposed (Stapp 1998). Stapp (1998) suggests, given the variation in grasslands inhabited by prairie dogs (e.g. mixed vs. shortgrass prairies), that they may affect the flora and fauna of these systems in variable ways not yet fully understood. That prairie dogs have effects on many animals is acknowledged (Kotiliar et al. 1999), and their impacts on animal and plant communities are disproportionately large relative to their abundance. Consequently, prairie dogs are critical to the integrity of the shortgrass prairie (Hooglund 2006) and efforts directed towards their conservation will positively impact the grassland ecosystem and grassland species.

The policy of the NPS for managing animal populations relies upon allowing natural processes to maintain them and to conserve and recover the black-tailed prairie dog wherever possible (NPS 2006). Control of prairie dogs on NPS property is allowed only for purposes of human health and safety, good neighbor relations, to reduce conflicts with other park objectives such as the preservation of cultural resources, to protect property when it is not possible to change the pattern of human activities, or when removal meets specific park management objectives (NPS 2006). When removal does occur the NPS will work to ensure that it does not cause unacceptable impacts on native resources, natural processes, or other park resources. Whenever the size of a park animal population is reduced, the NPS will use scientifically valid resource information obtained through consultation with technical experts, literature review, inventory, monitoring, or research to evaluate the identified need for population management (NPS 2006). This need must then be documented in an appropriate park management plan (NPS 2006).

Cultural Resources

SAND was established to commemorate the Sand Creek Massacre of 29 November 1864, which is one of the most tragic events in American history. On that date, Colonel John M. Chivington launched a surprise attach involving approximately 700 soldiers of the U.S. Army on a peaceful encampment of approximately 500 Cheyenne and Arapaho Indians who believed they were under U.S. Army protection (NPS 2000). The established boundary of SAND contains the site of the Native American village where the attack originated. A few 100 yards northeast of the Indian village on private land adjoining SAND, but within the authorized boundary of SAND, is located the area referred to as the “sandpits” (Figure 2). Here is where many of the Indians fled upon initiation of the sunrise attack, entrenched themselves in two large pits dug into the banks of Big Sandy Creek, and continued their defense against the attacking soldiers (NPS 2000). Both sites are located east of the creek and in the northern half of the area authorized for SAND. The village is not within the current existing prairie dog complex, but one of the two sandpits is bordered on the north by the north colony (Figure 2).

Plan goal

The primary goal of the Sand Creek Massacre National Historic Site (SAND) Black-tailed Prairie Dog Management Plan is to manage for long-term, self-sustaining prairie dog populations at SAND while avoiding negative impacts to plant community structure and to landowners that do not wish to accommodate prairie dogs on their properties. An associated effect of the Plan is the increased long-term viability of species closely dependent on the prairie dog ecosystem.

Plan objectives

Objective 1: Document the status and history of prairie dogs at SAND
Objective 2: Identify the future estimated population trends of the prairie dogs at SAND given the current ecological and climate conditions
Objective 3: Identify strategies for within and outside of SAND that have proven to be effective in managing prairie dogs
Objective 4: Determine the range for a minimum population size of black-tailed prairie dogs sufficient to continue to fulfill their role as a keystone species at SAND
Objective 5: Define the potential future impacts resulting from the use of the identified control strategies such as future changes in prairie dog population sizes, future expansion dynamics of prairie dogs, and changes to local plant community structure within the confined prairie dog colonies.
Objective 6: Determine an effective tool to monitor changes in estimated occupied acreage.
Objective 7: Use adaptive management method to evaluate progress of prairie dog management efforts and adjust as needed to accomplish program goals.
Objective 8: Identify and implement management actions that provide for a sustainable population of healthy prairie dogs at a size acceptable to landowners and manager at SAND and that maintains habitat with a diverse cover of native plant species acceptable to landowners and managers at SAND.

Federal and State Status of the Black-tailed Prairie Dog

In 1998 the United States Fish and Wildlife Service (Service) received a petition to list the black-tailed prairie dog as threatened throughout its range. Subsequent to the petition for listing, the Service initiated a status review of the prairie dog and upon its completion in 2000, determined that listing of the black-tailed prairie dog was warranted but precluded by higher listing priorities. At that time the species was designated as a federal candidate for listing. Candidate species status was based on the significant threats including sylvatic plague (*Yersinia pestis*), habitat loss due to urbanization and conversion of grassland to farmland, and inadequate regulatory mechanisms, which have resulted in general declines in prairie dog populations since 1980 (Luce 2003). Resent estimates for Colorado indicate that the State's prairie dog population is either stable or growing slightly in acreage (White et al. 2005). In Colorado, the black-tailed prairie dog is designate as a pest species and there is a range-wide lack of adequate regulatory mechanisms for prairie dogs (Luce 2003).

In 2004 the Service removed the black-tailed prairie dog from the Federal candidate list. This determination was based on new information about the range-wide impact of disease, chemical control and other lesser factors, as well as higher estimates of the number of acres of occupied black-tailed prairie dog habitat. The Service determined that the prairie dog is not likely to become an endangered species within the foreseeable future and no longer meets the Endangered Species Act definition of threatened (USFWS 2004).

The Status and History of Prairie Dogs in Colorado and at SAND

Estimates for the historical number of acres occupied by black-tailed prairie dogs in Colorado ranges from 3 million to 7 million ac (1 million to 3 million ha) (Clark 1989, Knowles 1998). Current estimates place the number at about 631,102 ac (255,899 ha) (White et al. 2005), which suggests about a 10-fold decline in the number of acres occupied by prairie dogs in Colorado.

Approximately 6,600 ac (2428 ha) of black-tailed prairie dog occupied habitat exist on lands managed by the NPS (USFWS 2004). The NPS policy is to conserve and recover the species wherever possible. It is the desire of the NPS to sustain prairie dog populations at SAND while avoiding negative impacts to landowners who do not wish to accommodate prairie dogs on their properties.

In eastern Colorado the overall historical trend has been for a decline in the area occupied by prairie dogs, which has been attributed to plague and conversion of native prairie to other uses. However, area occupied by prairie dog populations in some areas has increased. Trend information at the Comanche National Grasslands, Timpas Unit that is approximately 90 miles south of SAND, indicates that occupied habitat has increased. Augustine et al. (2007) estimated 10,653 ac (4,311 ha) of occupied habitat on the Timpas Unit in 2005, a 36 percent increase from 2001 when 1,579 ac (639 ha) were estimated as occupied. A proportion of this increase in acreage occupied by prairie dogs occurred during the drought years of 2001 to 2004. In 2005 a sylvatic plaque event occurred and the area occupied by prairie dogs declined 85% to 3,212 ac in 2006. Trends for t he number of acres occupied by prairie dogs are provided for the Timpas Unit in Table 1.

Table 1. Summary of Site-Specific Estimates in acres (ha) of Black-tailed Prairie Dog Occupied Habitat at the Comanche National Grassland, Timpas Unit from 1999 to 2006 (Augustine et al. 2007).

	Year						
	1999	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Acres	1,579 (639 ha)	3,138 (1,270 ha)	4,225 (1,710 ha)	4,893 (1,980 ha)	8,747 (3,540 ha)	10,653 (4,311 ha)	3,212 (1,300 ha)

Interviews with local landowners who own property adjacent to SAND indicate that prairie dog colonies within the area surrounding SAND have expanded in size over the last decade, similar to the increases observed within the Comanche National Grasslands. Prairie dogs have been present to the northwest of SAND since the 1980s in the north-central portion of Township 17S, Range 46W, Section 11, Sixth Principle Meridian. Photographs from the National Aerial Photography Program indicate that in 1989 prairie dogs occupied an estimated 65 ac (26 ha) of shortgrass prairie in section 11. From aerial photographs taken in 1998 it is estimated that prairie dogs occupied 405 ac (164 ha) in section 11 and had expanded into section 4 where they occupied an additional 120 ac (49 ha). By 2006 the colony had expanded onto SAND and covered a total estimated area of 1,453 ac (588 ha), 41 ac (17 ha) within SAND and prairie dogs were present in Township 17S, Range 46W, Sections 4, 10, 11, 13 and 14, Sixth Principle

Meridian (Figure 2). This colony is the colony referred to as the north colony in this plan and environmental assessment.

A prairie dog colony also exists in the southeast corner of SAND (referred to as the “south colony” in this plan and environmental assessment). Aerial photography indicates that this colony was not present in 1989 or 1998. However, by 2001 prairie dogs occupied an estimated 60 ac (24 ha) within what is now the established boundary of SAND in Township 17S, Range 45W, Section 30, Sixth Principal Meridian. At this time there is no evidence in the aerial photographs that prairie dogs existed on the private land adjacent to what is now SAND. By 2006 monitoring of the prairie dog colonies at SAND recorded that the south colony had expanded to include 187 ac (76 ha) within SAND and had moved onto private land in Township 17S, Range 45W, Sections 19, 29, 31 and 32, Sixth Principle Meridian (Figure 2).

In summary, the north prairie dog colony at SAND expanded from private land in Section 14 onto SAND, while the south colony originated within the current boundary of SAND sometime after 1998 and has expanded from SAND onto adjacent private lands.

Expected Future Estimated Trends of the Prairie Dog Complex at SAND Given the Current Ecological and Climatic Conditions

Evidence from aerial photographs suggests that the area occupied by the prairie dog complex at, and surrounding, SAND is expanding. The two prairie dog colonies within SAND are expanding colonies, each of which is surrounded by some shortgrass prairie that is suitable for colony expansion. The northern colony appears to be expanding into section 13 within SAND from the adjacent private land of section 14. The majority of section 13 consists of reclaimed agricultural land that contains mixedgrass prairie comprised of native grasses that are suitable for colony expansion as well as weedy patches (Neid et al. 2007). In this habitat the native grasses predominantly include blue grama, sideoats grama (*Bouteloua curtipendula*), and sand dropseed (*Sporobolus cryptandrus*) with very little buffalograss. Although the shortgrass prairie native to the area is predominantly comprised of blue grama and buffalograss, which is preferred by prairie dogs, they are likely to continue their expansion in section 13 into the reclaimed agricultural land. The rate of expansion may be slower than it would be on native shortgrass prairie, particularly during wetter years, because some grasses found in the reclaimed land are denser and taller than either blue grama or buffalograss.

The south colony has occupied nearly the entire suitable shortgrass prairie habitat east of the Big Sandy and the Chivington Ditch within the boundary of SAND. Lands west of the Big Sandy and Chivington Ditch consist of a mixture of sandsage and grasses, and are less suitable habitat for prairie dogs. Private property to the north and south of the SAND boundary and private lands adjacent to the south colony consist of native shortgrass prairie, very suitable to prairie dogs. Property to the east of the south colony is currently plowed agricultural land that the prairie dogs have expanded into in recent years. Land uses on the private properties where prairie dogs expansion is occurring currently include livestock grazing and dryland agriculture. These activities are expected to continue into the future on the private lands.

Research on expanding prairie dog complexes indicates there is a lot of variation in the rate of colony expansion. However, there is potential for the complex at SAND, if left undisturbed, to expand in the future. The expansion of prairie dog colonies can be influenced by a number of factors including predation, sylvatic plaque, and the amount of rainfall and the subsequent effects that soil moisture has on the height of ground vegetation. At higher rates of precipitation prairie dog colonies expand at lower rates, while during periods of below average rainfall or drought prairie dog colonies tend to increase their rates of expansion (Augustine et al 2007). It is surmised that this occurs because tall, dense vegetation that grows during periods of high annual precipitation diminishes visual contact with predators and with other prairie dogs, which assists them with the identification and avoidance of ground and aerial predators (Franklin and Garret 1989, Hygnstrom 1995). Consequently, prairie dogs will not expand into suitable grassland if their line of sight to those grasslands is obstructed by vegetation (Terrall 2006). During periods of drought, when vegetation is low and the lines of sight are unobstructed, rates of colony expansion are enhanced (Vermiere 2004). In addition, during periods of drought as forage resources become more limited prairie dogs may expand the area over which they forage in order to meet their nutritional needs.

The current vegetation community near prairie dog colonies at SAND both within and outside of the park boundary includes shortgrass prairie, reclaimed agricultural land containing mixedgrass prairie, fallow agricultural fields, and currently plowed agricultural fields (Figure 2). All of these habitats are exploitable by prairie dogs, some more than others, and their presence should facilitate expansion of SAND’s prairie dog complex. As mention in the previous paragraph, it is thought that drought will facilitate this expansion (Vermiere et al. 2004, Knowles 1986), while higher than average rainfall will impede it (Reading and Matchett 1997). Climatic conditions at SAND since 1999 have been characterized by below normal rates of precipitation with drought or abnormally dry conditions in June during the growing season (Figure 3).

Given the availability of unoccupied suitable habitat both within SAND’s boundary, and on adjacent private land and the recent history of drought in eastern Colorado it is likely that without implementation of a control program, the prairie dog complex at SAND will exhibit natural population expansion in the future (Hooglund 2006, Vermeire et al 2004). When prairie dogs are at high density, with suitable unoccupied habitat at the colony edge, and with favorable climatic conditions affording high visibility into that habitat, their colonies will expand rapidly. The first two conditions occur at SAND and the third condition is likely to occur in at least some future years supplying the prairie dog complex at SAND the opportunity to rapidly expand. The rate at which this expansion will occur is difficult to state with certainty. Prairie dogs under certain conditions, however, have exhibited extremely high rates of expansion. Colonies that have been observed for a year or longer exhibit rates of expansion in the area they occupy of anywhere from 40% to over 100% (Uresk and Schenbeck 1987, Garret and Franklin 1989, Hooglund 1995). The complex at SAND could undergo similar rates of expansion.

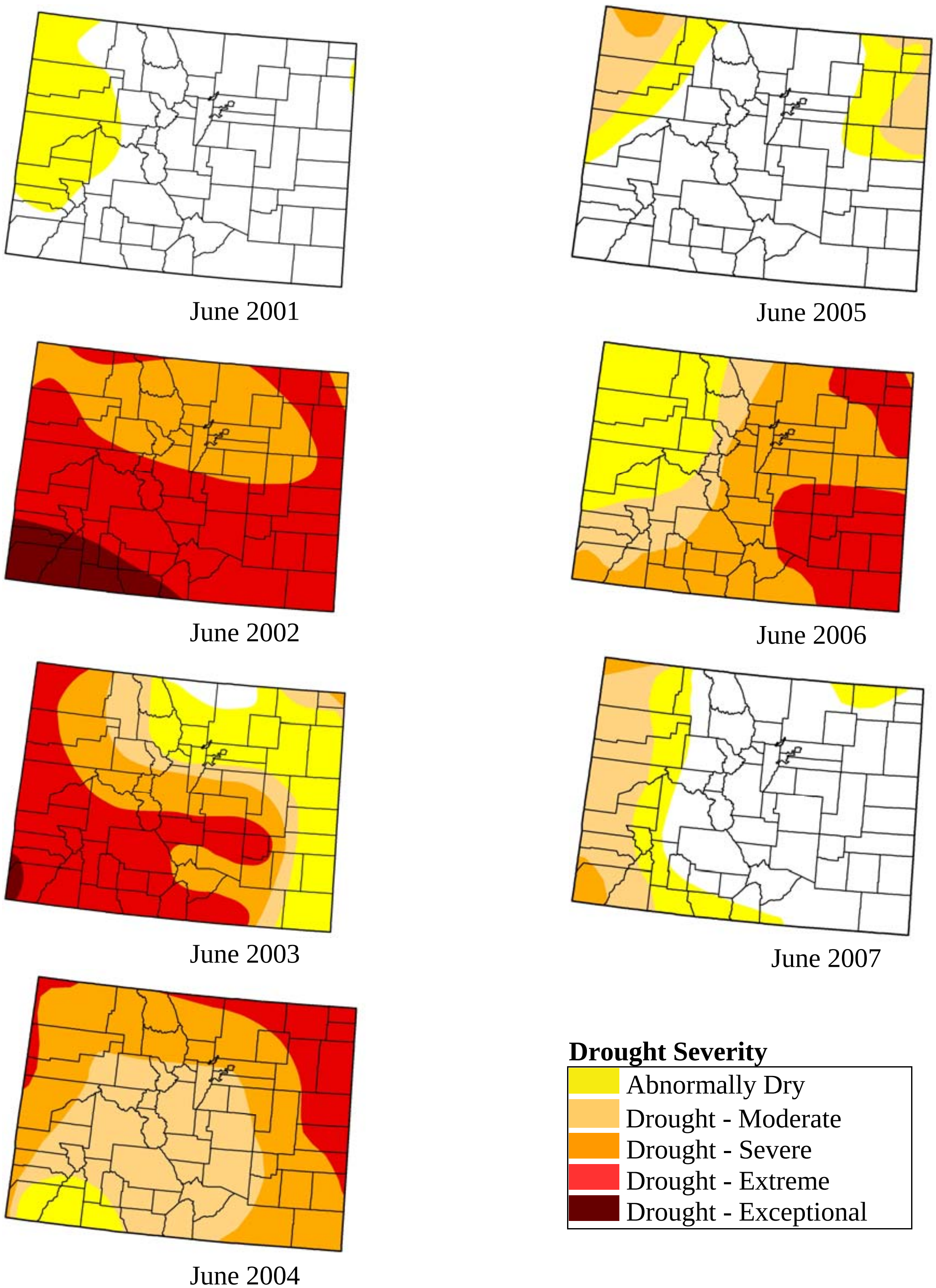

Figure 3. Drought status of Colorado for the period 2001 to 2007 as determined in June during the growing season. Images for 1999 and 2000 for Colorado are not available but national images depict abnormally dry conditions for the year 2000 at SAND, but not for 1999.

Strategies for Managing Black-tailed Prairie Dogs at SAND and on the Adjacent Private Lands

Management of black-tailed prairie dogs at SAND is needed to meet the management goals of the NPS at SAND of avoiding undesirable changes to the plant community including domination of the colony by non-native herbaceous plants (Larson 2003, Johnson and Collinge 2004, Rondeau 2005, Walsh Environmental Scientists and Engineers 2005) and maintaining favorable relationships with surrounding landowners by preventing colony expansion onto private lands. There are a number of lethal and nonlethal options available for managing prairie dogs including:

- use of vegetative barriers and/or grazing management adjustments to establish vegetative barriers,
- conservation easements,
- the use of fencing and other visual barrier techniques,
- live trapping and translocation of prairie dogs,
- directed shooting to site-specific areas, and
- use of approved rodenticides to control prairie dog populations.

Prairie dog populations rebound quickly after crashes because fecundity and recruitment of the remaining individuals is enhanced (Hooglund 2006). Reduction in population densities of prairie dogs at SAND is likely to then create a dynamic favoring rapid recovery of the complex to pre-control population sizes. Prairie dog removal will result in an increase in resources available for exploitation by newborns, leading to higher rates of recruitment for the first few years immediately following control (Hooglund 2006). The effect will be rapid recovery of the prairie dogs to pre-control abundances. By controlling colony population size, SAND will be able to prevent changes in the plant community composition resulting from the cumulative impacts of prairie dog grazing intensity and duration, which can include the introduction of weedy plant species (Larson 2003). Controlling population density will also prevent expansion of prairie dogs onto the private property adjacent to the colonies. However, given the proclivity of colonies to rebound quickly from natural or unnatural crashes, success will require continued removal of prairie dogs over the long-term. For this reason, preventing expansion of the prairie dog complex at SAND onto the adjoining private land will require a long-term commitment in resources and funding by the NPS.

Vegetation Barriers and/or Grazing Management

Barriers constructed of natural vegetation have been used to discourage the expansion of prairie dog colonies. This method is based on the fact that prairie dogs require a visually unobstructed landscape and prefer areas where vegetation is less than 30cm in height (Franklin and Garrett 1989, Roe and Roe 2003, Terrall 2006). Natural dense vegetation (e. g. shrubs) that are 40 cm or greater in height and that are a minimum of between 80 and 103 m in width, proved effective in reducing colony expansion into adjacent areas (Crosby and Graham 1986, Truett and Savage 1998, Roe and Roe 2003, Terrall 2006). A vegetation barrier greater in width could prove more effective in preventing prairie dog expansion, but the standard mentioned above is effective in preventing prairie dog expansion.

Limitation or postponement of livestock grazing has been reported as an effective technique for controlling colony expansion. Grazing is not currently occurring on SAND and given the current size of SAND, the use of grazing to control vegetation height would be difficult in such a small area. The use of grazing is presented here for informational purposes and grazing may not be relevant to the situation at SAND. Deferral of livestock grazing from May to September can reduce prairie dog population growth rates, population density, and the surface area occupied by the colony (Snell and Klavachick 1980, Schenbeck 1985, Cable and Timm 1987, Reading and Matchett 1997). A major limitation of deferred grazing is that the effects are most pronounced in mixed and tallgrass prairies, while benefits in shortgrass prairie are meager (Hooglund 2006) and possibly nonexistence during periods of drought.

Conservation Easements

When managers are concerned with the expansion of prairie dogs from public lands onto adjacent private lands, then these adjoining private lands may be considered for financial incentive payments or conservation easements to enhance existing, contiguous colonies (Cooper and Gabriel 2005). Landowner incentive programs could provide an economic incentive to landowners who agree to maintain or expand occupied prairie dog habitat. The goal of any incentive program should be for native grassland conservation and to achieve long-term persistence of the ecosystem, prairie dogs, and allied species (Luce 2003). Such a program would benefit economic sustainability in the region, by compensating private landowners who voluntarily agree to maintain native grasslands and not to control prairie dogs or significantly alter their habitat within agreed-upon areas (Luce 2003). Livestock grazing and other compatible uses could continue on lands under contract.

Fencing and Other Visual Barriers

Artificial visual barriers have afforded varying rates of success and are not as effective as natural vegetation in preventing expansion of colonies (Franklin and Garrett 1989, Hygnstrom 1995, Merriam et al 2004, Foster-McDonald et al. 2006). Franklin and Garrett (1989) reported that burlap fencing and felled ponderosa pines (*Pinus ponderosa*) were successful in preventing expansion of prairie dog colonies, but maintenance costs made their use prohibitively expensive. Other research using a variety of materials including silt fencing, galvanized sheet metal, and polyethylene plastic mesh fencing found that these materials were unsuccessful in preventing colony expansion (Hygnstrom 1995, Merriam et al. 2004, Foster-McDonald et al. 2006). A major problem with using artificial fencing as barriers is durability - they are badly damaged by wind, ungulates, and cows. The polyethylene mesh fencing that has proven durable (Merriam 2004, Foster-McDonald et al. 2006) has not been effective in controlling colony expansion (Hygnstrom 1995, Foster-McDonald et al. 2006). This may be because the see-through visibility of mesh fencing is 60%. Use of solid materials that increases visual occlusion may improve effectiveness (Hygnstrom 1995), but to the authors knowledge this has not been tested.

Fencing could be used as a temporary measure to prevent expansion of prairie dogs onto private lands until a vegetation barrier thick and wide enough to prevent expansion were established. However, visual barriers made from plastic snow fence material were ineffective at controlling prairie dog expansion (Hygnstrom 1995). Exclosures made of a polyweave material in Colorado also proved ineffective at keeping prairie dogs from returning to burrows (Robinette 1992). Merriman et al. (2004) used silt fence and galvanized steel sheeting as an artificial visual barrier, but the barrier did not prevent prairie dog colony expansion. These studies indicated that visual barriers with lower porosity or solid barriers might prove more effective. Additionally, barriers that were more durable and less vulnerable to environmental damage, and secured in trenches to prevent movement of prairie dogs under barriers might increase effectiveness of artificial barriers (Terrall 2006).

Live Trapping and Translocation of Prairie Dog Populations

The translocation of prairie dogs outside of SAND to reduce the population is a very resource-intensive endeavor. A number of issues must be dealt with for translocations to be successful including selection of suitable release sites, capturing and transporting animals, preparing release sites with attendant soft release infrastructure, and monitoring and managing animals (Truett et al. 2006). Soft release infrastructure includes retention baskets or fenced enclosures, sometimes combined with artificial underground nest chambers, which all help to reduce dispersal and predation (Truett et al. 2006). Release sites must be carefully selected. The most successful sites have short vegetation (<12 cm tall) and pre-existing burrows; sites without these qualities may need modification such as creation of artificial burrow cavities (Hooglund 2006). Translocation of prairie dogs into areas without preexisting burrows results in survival rates of between 0-40%, rates that are unacceptable under most circumstances (Truett et al. 2006). Control of predators may be needed prior to or following release. Post-release monitoring to detect and remedy potential problems such as dispersal and predation is recommended, and providing a food subsidy may reduce dispersal and elevate survival (Truett et al. 2006). The time and costs needed to accomplish the requirements necessary for successful translocation make this strategy difficult to implement. In addition, suitable nearby recipient sites are usually absent or available only in small number, limiting the utility of this management technique (Hooglund 2006).

Trapping and relocating back onto SAND any prairie dogs that encroach into private land has its limitations. Only a small number of acres (approximately 3,682 ac/1,490 ha) of suitable prairie dog habitat exists at SAND. All suitable prairie dog habitat within SAND adjoins private land making it impossible to relocate encroaching prairie dogs to an area where colony expansion is less likely to require control. Using trapping and relocating to move prairie dogs from private land to more suitable areas off SAND is possible, but the issues outlined above would also be acting here making such a proposition difficult.

Trapping and relocating prairie dogs could be used to augment the population at SAND. This could be particularly effective if sylvatic plaque ever occurs at SAND. Areas with intact burrows, which would exist after a sylvatic plaque event, make the best recipient sites and relocation of prairie dogs to SAND after such an event should have a high probability of success (Hooglund 2006).

Directed Shooting to Site-Specific Areas

The NPS may directly reduce animal populations by shooting where human-prairie dog conflicts can not be curtailed using other means (NPS 2006). Shooting, as do all lethal management actions, must be approved by the NPS Regional IPM Coordinator in consultation with NPS T&E Species Coordinator and the FWS. Shooting would be used as a management tool to prevent the expansion of prairie dogs onto private lands adjacent to SAND, which is a priority of the management plan.

Shooting reduces the size and density of prairie dog colonies and may have potential as a management tool (Hooglund 2006). Continuous shooting can remove up to 65% of the individuals from a colony, but shooting must be repeated annually, there are safety concerns, and the general public's acceptance of this method is uncertain, making shooting an impractical strategy (Hygnstrom 1994, Vosburgh and Irby 1998). Also, shooting can never be used to completely exterminate a colony because a portion of the population becomes wary and gun-shy making them impossible to shoot.

One benefit of this method is that harvested prairie dogs can be used to supply food resources to captive ferret rearing programs and raptor rehabilitation centers.

Use of Approved Rodenticides to Control Prairie Dog Populations

Rodenticides, particularly zinc phosphide, have proven effective in controlling prairie dog colonies with 66% to 97% of individuals being removed after pre-baiting (the removal rate falls to 30% to 73% in absence of pre-baiting). The application should include prebaiting with clean oats the day before zinc phosphide treated oats are administered. Zinc phosphide is most effective if used in late summer or early fall when prairie dogs are still very active and the availability of green forage is limited. Zinc phosphide can also be used in winter or early spring whenever prairie dogs are active and green vegetation is unavailable. Zinc phosphide, is a restricted use pesticide that requires users to be certified by the Colorado Department of Agriculture. Successful control requires about 400 grams of toxic oats per hectare with 4 grams placed just inside the entrance hole of every burrow (Hooglund 2006). Zinc phosphide is not retained in tissues and should not kill scavengers feeding on poisoned prairie dogs, nor does it appear to harm many birds and mammals that frequent prairie dog colonies, but it will kill seed-eating birds and mammals including some songbirds, squirrels, chipmunks, and rabbits (USEPA 2002).

The fumigant aluminum phosphide is very effective at controlling prairie dogs, but because of the hazards to desirable non-target wildlife including burrowing owls, American badgers, prairie rattlesnakes, rabbits, and other non-target species (Hygnstrom 1995) it is not a viable rodenticide. Gas cartridges are very effective as burrow fumigants for prairie dogs (Hygnstrom and VerCauteren 2000) and users are not required to be certified pesticide applicators. Gas cartridges contain 2 active ingredients, sodium nitrate and charcoal. The gas cartridge is ignited and placed in the burrow after which the burrow entrance is sealed with soil. The main combustion product is carbon monoxide. This gas rapidly interferes with respiration and results in suffocation. Unfortunately, gas cartridges have the same effect as does aluminum phosphide on non-target animals (Witmer and Fagerstone 2003). Consequently, gas cartridges are not recommended for broad scale use, but they could have limited use in eliminating prairie dogs that have encroached onto private land. Fumigants cost between $30 and $40 per acre, which is three to four times the cost of zinc phosphide treated-grain baits (Virchow et al. 2002). For this reason zinc phosphide is considered the better alternative.

Population Densities Appropriate for the Acreage of Suitable Prairie Dog Habitat at SAND

Average density estimates of black-tailed prairie dogs range from 5 to 36/ac (11 to 90/ha) (Fracka et al. 2008). This range of density represents the mean number of prairie dogs found within a colony whether it is a stable colony or a colony undergoing expansion. This range represents the desired density for the prairie dogs at SAND.

There are 2,486 ac (1,006 ha) of shortgrass prairie present within the current established boundary of SAND and 1,196 ac (484 ha) of reclaimed agricultural land for a total of 3,682 ac (1,490 ha) of grassland suitable for prairie dogs (Neid et al. 2007) (Figure 4). If all 3,682 suitable acres were occupied at 20 prairie dogs per acre there would be a total of 73,640 individual prairie dogs at SAND. This number represents a population where all peripheral habitat along the fence-lines of SAND's boundary would be occupied by prairie dogs, which would allow for dispersal of these peripheral prairie dogs onto the adjacent private land. A buffer strip of 100m maintained free of prairie dogs along the outside boundaries of SAND within the shortgrass prairie and reclaimed agricultural land would remove approximately 170 acres of suitable habitat leaving 3,512 ac (1,421 ha) available for habitation and at 20 prairie dogs per acre there would be 70,240 individuals. Present estimates of prairie dogs at SAND are 16.6 per acre with 228 ac (92 ha) of occupied habitat for a total estimate of 3,785 individuals (Sovell 2007). At this density the population in the southern colony has reduced the vegetative cover and increased the cover of bare ground, which is common with the intensity of grazing associated with prairie dogs (Archer et al. 1987).

Although the implication of long-term control to prevent dispersal into the surrounding private land is unknown, high densities of prairie dogs restricted to the same area can cause declines in habitat quality and resource abundance (Johnson and Collinge 2004, Rondeau 2005). For a discussion of the adverse changes that can be expected, see the next section of this plan. The exact density of prairie dogs that will avoid these declines in habitat quality is unknown. In order to avoid changes in vegetation induced by grazing prairie dogs, their population size must be regulated at SAND. Changes by prairie dog grazing include increases in the amount of bare ground and establishment of both native and exotic weedy species (Larson 2003, Rondeau 2005, Walsh Environmental Scientists and Engineers 2005).

Recommendations include maintaining prairie dog densities at SAND at the low end of the reported range or to between 5 to 15 individuals per acre (12 to 37/ha). Monitoring should be implemented to identify whether there are adverse changes in the vegetation structure within the prairie dog complex. Also, to discourage colony expansion onto adjoining private lands a 100 m buffer at the edges of the prairie dog colonies should be maintained along fence lines adjoining private lands. The buffer should be planted with a dense cover of native vegetation greater than 40cm in height (e. g. rabbittbrush, *Chrysothamnus nauseosus*) or sandsage (Figure 4). Extermination of prairie dogs in this 100 m buffer should be augmented with control administered throughout the colony that will reduce prairie dog densities to between 5 and 15 individuals per acre (12 to 37/ha). This would result in a total population of between 17,160 to 52,680 individuals inhabiting 3,512 ac (1,421 ha) at peak occupancy. Prairie dog populations maintained within this range of density should help prevent adverse changes to colony vegetation structure.

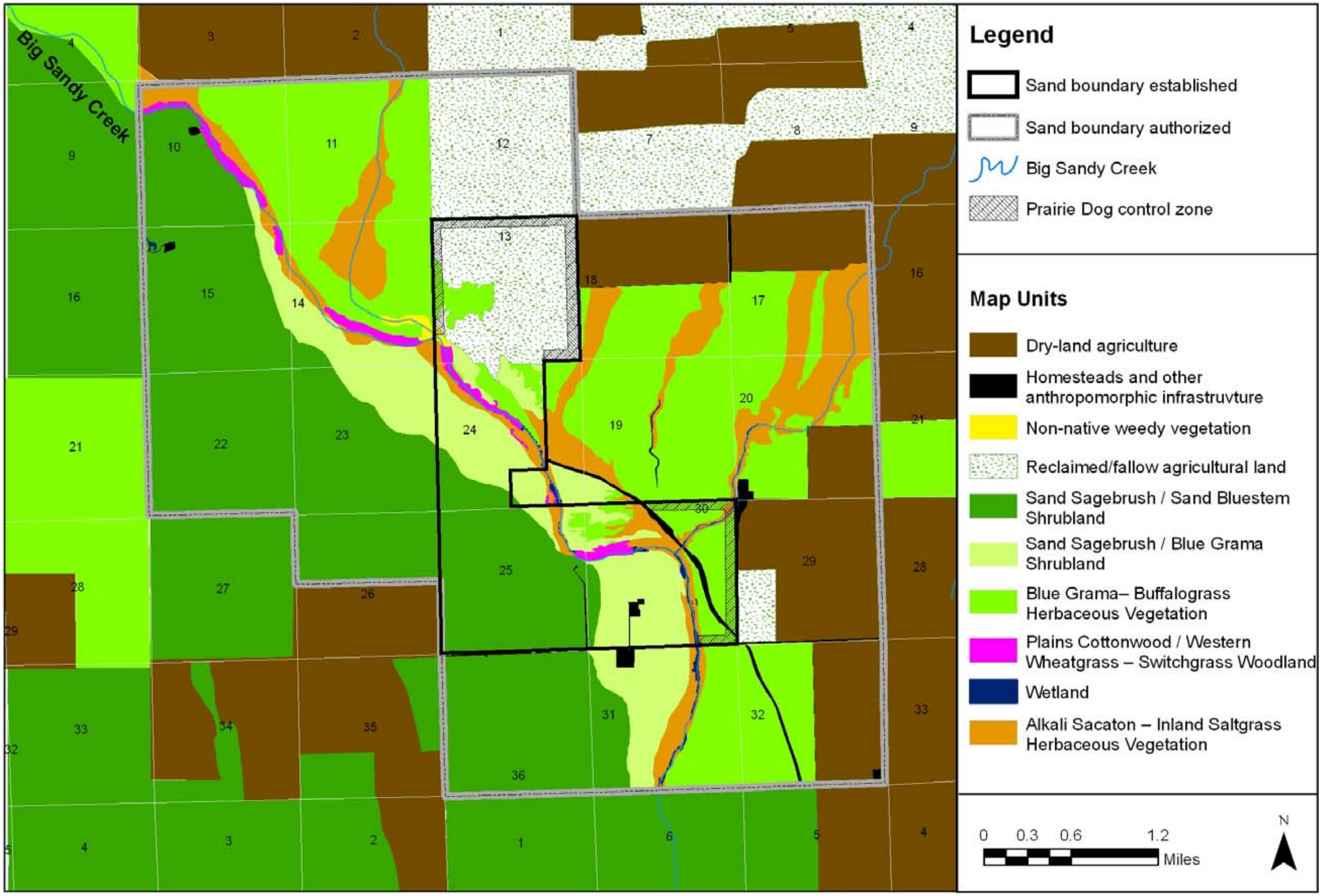

Figure 4. Vegetation map of Sand Creek Massacre National Historic Site (after Neid et al. 2007) with identification of prairie dog control zones where prairie dogs will be exterminated and native vegetation will be planted to dissuade dispersal of prairie dogs onto adjacent private land.

The Potential Future Impacts Resulting from Prairie Dog Control

Future Changes in Prairie Dog Population Sizes

Interviews with private landowners and review of aerial photography for the area indicate that over the last decade, the acres occupied by prairie dogs has been expanding within the area authorized for SAND. It is likely that the complex will continue to expand. Black-tailed prairie dog complexes are capable of exhibiting rapid rates of expansion and individual colonies show dramatic increases in size over short periods (Uresk and Schenbeck 1987, Garret and Franklin 1989, Hooglund 1995).

Sylvatic plaque has never been reported in the immediate area of SAND, but landowners have observed that prairie dog populations within the larger area surrounding SAND near Sheridan Lake and Swede Lake have experienced sylvatic plaque-induced declines (Scherler pers. comm.). Sylvatic plaque can cause severe declines in both prairie dog numbers and in the area they occupy, with colony area declining by as much as 89% and numbers declining by as much as 95% (Pauli et al 2006). If sylvatic plaque were to infect the prairie dog complex at SAND, the complex would likely experience severe declines within one year (Pauli et al 2006).

Future Expansion Dynamics of Prairie Dogs after Control is Implemented

Control efforts on the part of the NPS are likely to create a dynamic that should favor rapid recovery of the complex to pre-control population sizes, because those prairie dogs removed from the population will result in more resources for newborns to exploit, ultimately increasing the success rate for recruitment of newborns. Following population control, intraspecific competition for forage and space decreases, and density-dependent regulation should be minimal (Pauli et al. 2006). Because of the abundant resources, individuals within a controlled colony should enjoy greater reproductive success and survival, mature more rapidly, and reproduce earlier, all of which will cause the population to experience rapid growth (Garrett et al. 1982, Rayor 1985, Pauli et al 2006). For this reason, populations rebound quickly after crashes, whether induced naturally or through control, because fecundity of the remaining females and recruitment of newborns is enhanced (Hooglund 2006). The size of colonies being controlled can expand by 30% per year for several years following control, however, if control is particularly intense increases of 71% can occur for one or two years post-control (Uresk and Schenbeck 1987, Hooglund 2006). Analysis of the mean rates of fecundity and survival for black-tailed prairie dogs suggests colony abundance would require reductions of 55% per year to maintain populations at the prior level (Crosby and Graham 1986). In populations that have been reduced by 75% or more, recovery to pre-control population sizes requires 3 to 5 years (Crosby and Graham 1986, Knowles 1986). Because of the rapid rate that prairie dog populations can recover from control, preventing expansion of the prairie dog complex at SAND onto the adjoining private land will require a long-term commitment in resources and funding by the NPS. However, if densities of prairie dogs inhabiting SAND are not controlled the population will expand into suitable habitat on adjoining private land in the future. To prevent such expansion onto adjacent private lands will require some form of control including extermination of prairie dogs from private lands. If SAND desires to maintain vegetation composition within the complex free of weedy species than some form of population reduction within the complex at SAND is probably necessary (Rondeau 2005, Walsh Environmental Scientists and Engineers 2005). It is possible to prevent grazing of private ranchlands by prairie dogs through extermination only of individuals that disperse onto private lands, but such a strategy will not prevent intense grazing by individuals restricted to SAND, which could alter preferred plant composition at SAND (Larson 2003, Johnson and Collinge 2004, Rondeau 2005, Walsh Environmental Scientists and Engineers 2005).

Changes to Local Plant Community Structure within the Confined Colonies

Plant communities subjected to excessive grazing that does not permit desirable forage species to maintain them-selves, undergo obligate changes in plant community composition (Bonham and Lerwick 1976, Archer et al. 1987, Johnson and Collinge 2004). Such changes occur in prairie dog colonies that are surrounded by unsuitable habitat (Larson 2003). In shortgrass prairie, prairie dogs cause a shift to perennial warm season grasses such as buffalograss and purple threeawn (*Aristida purpurea*), an increase in forbs (which in time can become the dominate cover type), reductions in canopy height to half that of nearby uncolonized grassland, and increases in plant species diversity (Whicker and Detling 1988, Winter et al. 2002). Prairie dog effects on plant composition reflect the cumulative impacts of grazing intensity and grazing duration (Whicker and Detling 1988). As both the density of prairie dogs and the duration that the colony has been active increases, the changes to the grassland becomes more pronounced. It is at intermediate levels of disturbance, when occupation has been for an intermediate length of time and impacts are moderate that plant species diversity is maximized. As grazing severity increases (either intensity or duration) both species diversity and grass cover declines, while forbs become more dominant (Whicker and Detling 1988). When prairie dog movements within the landscape are not restricted, they will leave areas they have impacted through intense grazing and will colonize adjacent unoccupied habitat. The small scale movements of the colony that are continually occurring allows for impacted areas to recover before they are reoccupied by prairie dogs and once again grazed (Hooglund 2006).

When prairie dog populations are isolated because they are surrounded by unsuitable habitat they will continually populate the area of suitable habitat at high density (Johnson and Collinge 2004). Because prairie dog movements on the landscape are restricted and they can not leave areas they have impacted through excessive grazing, the areas are never allowed to recover. Highly impacted prairie dog colonies in urban areas where the colony is surrounded by unsuitable habitat provide superior environments, relative to non-colonized areas, for many native and introduced weedy species (Larson 2003). In these urban areas, grazing by prairie dogs creates bare and disturbed soils, conditions that provide "safe sites" for weedy species that can avoid or tolerate prairie dog herbivory, such as Russian thistle (*Salsola* spp.), kochia (*Bassia scoparia*), diffuse knapweed (*Acosta diffusa*), and field bindweed (*Convolvulus arvensis*) (Rondeau 2005, Walsh Environmental Scientists and Engineers 2005). In time, invasive grasses, weedy forbs, and other non-native herbaceous plants dominate urban colonies (Walsh Environmental Scientists and Engineers 2005).

Similar to urban settings, all of the habitat outside the boundary of SAND can be considered unsuitable habitat whether it is suitable grassland or unsuitable shrubland because the private landowners desire extermination of prairie dogs from these habitats. In effect, what would occur at SAND is the same as occurs in urban settings where prairie dog colonies are surrounded by unsuitable habitat. Consequently, it is reasonable to suspect the habitat occupied by prairie dogs at SAND would become highly impacted through excessive and continual grazing by prairie dogs. Recovery of these impacted areas will not be possible because prairie dogs will never leave SAND and disperse into the surrounding grassland, and weedy species will eventually then dominate the SAND prairie dog complex. In urban landscapes complexes do not decline, but rather persist indefinitely in highly disturbed environments that are dominated by exotic species and that never recover to a more natural state (Larsen 2003). The landscape surrounding SAND is fragmented by cultivated agricultural fields (Figure 2) and populations of many important prairie dog predators no longer exist at SAND including coyote, swift fox, and black-footed ferret. For these reasons, the complex at SAND will be ecologically similar to colonies impacted by urban development and it is unlikely that prairie dog populations would be self-regulating at SAND. Rather they will persist at a high density (Magle 2007) and the resulting continuous grazing will create a dynamic favoring invasion by weedy species (Larson 2003, Rondeau 2005, Walsh Environmental Scientists and Engineers 2005).

In summary, if management actions restrict the prairie dogs to continued occupation of SAND's suitable prairie habitat, then over time the SAND complex will exhibit increased cover of the warm season grasses buffalograss and purple threeawn, a general decrease in perennial grass cover, a corresponding increase in the cover and diversity of forbs, and establishment of introduced weeds. Avoiding this change in plant community composition will require maintaining prairie dog numbers at low density; however, there is no information identifying at what density prairie dogs will not degrade the habitat. Consequently, it is recommended that SAND maintain its prairie dog population at between 5 and 15 individuals per acre (12 to 37/ha), the low end of the range in colony size estimated for prairie dogs. In addition, monitoring should be implemented to verify that plant species composition is not changing.

Impacts to Cultural Resources

Any form of ground disturbance can have an impact on cultural resources. The movement, scattering, or destruction of historical artifacts can prevent archeologists from reconstructing the events that took place at a cultural site. Prairie dogs, because they are burrowing animals that rely upon a subterranean existence for survival during parts of their daily (e.g. sleeping) and annual activities (e.g. reproduction, rearing of young) could disturb the cultural resources present at SAND. The north colony, because it borders one of the 'sand pits' has the potential to disturb archeological artifacts important to reconstructing the events of the 1864 massacre. The habitat where the sand pits are located, however, is a sandy creek bottom unsuitable for habitation by prairie dogs and it is unlikely that prairie dog activity would occur within the sand pit. This is also true of the other archeological sites at SAND that reside within the creek bottom. However any historical activity occurring outside of the riparian zone in upland shortgrass prairie could be threatened by the burrowing activities of prairie dogs. In areas where prairie dogs are active it would appropriate for the Park to perform archeological surveys. Once cleared of archeological resources these areas could be left to the prairie dogs. If resources are identified the Park could then undertake actions to protect the areas from disturbance by prairie dogs.

The Preferred Management Action and the No Action Alternative

The No Action alternative, Alternative A, and the Preferred Action alternative are described below.

The Preferred Action alternative involves chemical means to exterminate prairie dogs from private lands and to control prairie dog densities at SAND. Zinc phosphide treated oats is the preferred method of lethal control of the prairie dog population at SAND

All lethal management actions must be approved by the NPS Regional IM Coordinator in consultation with the NPS T&E Species Coordinator and the FWS.

No Action Alternative

Prairie dogs densities at SAND would not be controlled and prairie dogs would not be exterminated from the private land surrounding SAND. No management actions would be implemented under this alternative.

Prairie dogs through their burrowing activities have the potential to disturb archeological sites and there is the potential for the towns at SAND to inhabit the areas of the Indian village and the sandpits. The potential for disturbance of the archeological sites persists with the No Action alternative. Exclosures constructed around the sites if they become threatened may mitigate impacts. However, fencing has proven ineffective in preventing prairie dog dispersal (Robinette 1992, Hygnstrom 1995, Merriman et al. 2004) and it is likely that fencing alone will not prevent prairie dog activity within the enclosed areas.

Alternative A

With this alternative the density of prairie dogs within the complex at SAND would not be controlled, but prairie dogs would be exterminated from areas where they are not desired including private lands, the Indian village, and the sandpits.

This alternative would not regulate prairie dog densities on SAND outside of the archeological sites and there is potential for grazing by prairie dogs that would induce changes in the vegetation composition within the complex. Under this alternative there is potential for excessive grazing that does not permit desirable forage species to maintain them-selves. In time, invasive grasses, weedy forbs, and other non-native herbaceous plants could dominate the vegetation of the SAND prairie dog complex (Walsh Environmental Scientists and Engineers 2005).

Management of prairie dog populations will occur under Alternative A and prairie dogs are not expected to impact the archeological sites.

Preferred Action Alternative

The Preferred Action alternative includes a combination of lethal control using zinc phosphide-treated grain baits to exterminate prairie dogs from private lands adjoining SAND and the planting of tall, dense natural vegetation to discourage colony expansion onto adjoining private lands. In addition, zinc phosphide will be used to regulate prairie dog population densities within areas of the complex occupying SAND and to exterminate prairie dogs that disperse into the Indian village and the sandpits (Figure 4). Zinc phosphide baits should be used in the fall when prairie dogs are still active and green forage is limited and after pre-baiting, which improves efficacy. To prevent prairie dog expansion onto adjoining private lands, a 100 m buffer planted with a dense cover of native vegetation greater than 40cm in height (e. g. rabbittbrush or sandsage) (Figure 4) should be maintained along fence lines adjoining private lands. Complete extermination of prairie dogs in this 100 m buffer should be implemented. The south colony is already expanding onto the adjacent private land while the north colony is not. Consequently, construction of the natural vegetation barrier should be initiated on the south colony and expanded to the north colony as funding and time permits or at such time as the north colony does threaten expansion onto adjoining private land.

The Preferred Action alternative will include control administered throughout the colony that will reduce prairie dog densities to between 5 and 15 individuals per acre (12 to 37/ha). This is necessary to prevent adverse changes to colony vegetation structure including increases in bare ground and the establishment of both native and exotic weedy species (Larson 2003, Rondeau 2005, Walsh Environmental Scientists and Engineers 2005). If population density falls below 5 individuals per acre (12/ha) lethal control efforts should be suspended and prairie dogs invading private lands adjoining SAND should be considered as candidates for translocation to colonies on SAND. Sylvatic plaque has never been reported from SAND or the surrounding area, but it has been reported from the region at Sheridan Lake and Swede Lake (Scherler pers. comm.). Epidemics of sylvatic plague cause rapid declines in prairie dog populations and any evidence of sylvatic plague in the complex at SAND should trigger the suspension of prairie dog population density control activities.

Management of prairie dog populations will occur under the Preferred Action alternative and prairie dogs are not expected to impact the archeological sites.

Monitoring Protocols Required to Identify Future Impacts of Prairie Dog Control

Prairie Dog Monitoring

Monitoring should be undertaken to ensure that the control program is maintaining prairie dog density at the stated goal of between 5 and 15 individuals per acre (11to 37/ha). Monitoring of black-tailed prairie dogs will be accomplished using the protocol developed for seven national parks (Severson and Plumb 1998, Plumb et al. 2001). Sampling should be conducted prior to lethal control with zinc phosphide to estimate a baseline density and to evaluate if the population is already within the desired range of density. Zinc phosphide is most effective if used in late summer or early fall when prairie dogs are still very active and the availability of green forage is limited. Follow up sampling should occur after lethal control has been completed to assess if the control was effective. Sampling at three or four years post treatment with zinc phosphide will identify if the population has recovered to pre-control population density. Sampling should be conducted in June or July after emergence of young from burrows, but before young-of-the-year disperse. Severson and Plumb (1998) found that visual counts of prairie dogs, using maximum rather than mean values, on 10-ac plots (4 ha) were significantly related to estimates of density from mark-recapture techniques. The best model defining the relationship between maximal counts and estimates from mark-recapture studies was $Y = 3.04 + 0.40X$, where Y is the maximum visual count and X is the estimated population density. The inverse of this equation $X = (Y - 3.04)/(0.40)$, is used to index numbers of black-tailed prairie dogs from visual counts. Researchers have concluded that density estimates based on maximal visual counts can be used to compare prairie dog density among years (Menken et al 1990, Severson and Plumb 1998).

The field methodology will follow the sampling approach of Plumb et al. (2001). This method requires setting up a 200 m x 200 m or 10 ac (4 ha) plot in each prairie dog colony and conducting visual counts of prairie dogs. Plots must be established 24 hours prior to conducting counts in order for prairie dogs to return to normal behavior following the intrusion of people walking through the colony. Visual counts are conducted on the 10 ac (4 ha) plot using binoculars with four counts taken on each of three consecutive days. Boundaries of the 10 ac (4 ha) plot are delineated using fluorescent orange stakes and counts are initiated after waiting 30 minutes before beginning the first count, with 15 minutes between counts (Plumb et al. 2001). The maximum count of prairie dogs recorded over the 12 samples (4 counts/day x 3 days of counting) is used in the equation of the previous paragraph to estimate colony density. This estimate is then compared to the control goal of a density between 5 and 15/ac (11to 37/ha).

Vegetation Monitoring

In order to detect changes induced by prairie dogs in plant species canopy cover, composition, and frequency over time, randomly-chosen permanent vegetation monitoring plots should be established. Ideally, eight plots should be monitored, four in each of the prairie dog colonies. The primary sampling objective is to detect a 20% change at $P = 0.1$ for dominant species, bare ground, litter, and exotic weedy species in canopy cover and frequency. To determine a baseline vegetation composition, sampling should be conducted prior to treatment of the prairie dog complex with zinc phosphide. This baseline data will also identify the dominant species that will be targeted in the vegetation monitoring program. The baseline composition serves as a reference condition for the desired vegetation composition. The first management objective is to prevent an increase in the cover and frequency of bare ground (or maintain the current cover and frequency of native grasses and forbs). The second management objective is to prevent colonization of exotic weedy plant species or to decrease their current cover and frequency if they already exist in the prairie dog complex. Sampling at two and four years post treatment of the prairie dog complex with zinc phosphide will identify any changes in the cover and frequency of bare ground and exotic weedy plant species. Differences in the amount of annual precipitation will cause natural variation in the cover and frequency of bare ground within the shortgrass prairie at SAND. Identifying the expectable range of variation is necessary to assess increases in bare ground attributable to grazing by prairie dogs. Monitoring at three year intervals over the next 10 years should be adequate to identify trends in changes of bare ground and exotic weedy plant species at SAND.

Sampling Metrics

Two distinct metrics of vegetation composition are measured: cover and frequency. Frequency is defined as the percentage of possible plots within a sampled area occupied by the target species. Occupation is defined by occurrence; the abundance of the species within the plot does not matter, only whether it is present. Because the target species will more likely occur in very large plots compared to small ones, frequency is dependent on plot size and shape. Frequency values from different studies are not comparable unless the plot size and shape used were identical. Plot size determines the frequency value. For larger plot, the likelihood that an individual will occur within the plot is greater, resulting in a larger overall frequency value. If plots are large enough, all of them will contain the target species (100% frequency). This leaves no sensitivity to an increase in frequency. If too small, there will be little sensitivity to a decrease in frequency. In the shortgrass prairie a frequency frame with square frames measuring 0.31 m x 0.31 m was the best fit for the sampling common species like blue grama, three-awn grass, and bare ground, where as for the less common species, such as annual weeds, a frequency plot measuring 1 x 1 m was appropriate (Rondeau 2005). A key advantage of using frequency is that the only decision required by the observer is whether or not the species occurs within the plot.

Cover is the downward projection of vegetation on the ground as viewed from above. Cover measurements are one of the most common measures of community composition because it equalizes the contribution of species that are very small, but abundant, and species that are very large, but few. Of the two measures, cover and frequency, cover is the most directly related to biomass. A disadvantage of cover measures is that it can change dramatically over the course of a growing season, while frequency measures are fairly stable after germination is complete. Annual variability tends to be highest with measures of canopy cover. That is, canopy cover of live vegetation may be sensitive to annual precipitation or grazing events, whereas frequency (especially of perennial plants) are less likely to reflect annual events. To facilitate comparison between years, a given plot’s data must be collected at the same time of year each year (within one to two weeks of the previous year).

Statistical Analysis

Repeated measures ANOVA (Hopkins 2003) will be used to ascertain if there are detectable difference in canopy cover and frequency of bare ground and exotic weedy species among years.

A significant result from the repeated-measures ANOVA indicates that there is a year effect, but it does not indicate which pairs of years differ from each other (Elzinga et al. 1998). A paired t-test is used to investigate differences among years in cover and frequency of bare ground and exotic weedy species within a plot. Increases in bare ground and exotic weedy species(with concurrent declines in native grasses and forbs) indicates that excessive grazing by prairie dogs is not permitting desirable forage species to maintain them-selves.

Plot Design

A stake is placed at the center of each plot. Four transects are then established at each plot by placing flexible 50 m tapes along the cardinal directions and marking the beginning (center of plot), middle, and end of each transect with two-foot rebar (Figure 5).

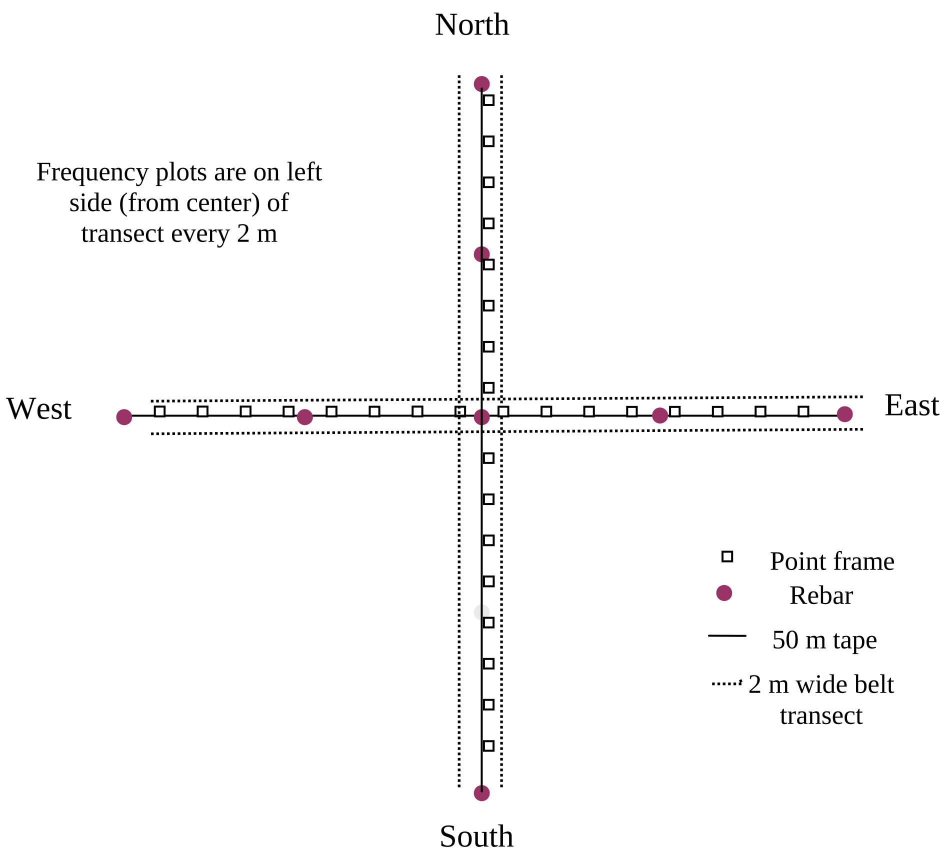

Figure 5. Configuration of a vegetation sampling plot.

Data Collection

Shrub canopy cover is estimated using the line-intercept method along each of the four transects with 1 cm increments (Bonham 1989). Within the canopy of a plant, gaps in live green vegetation less than 10 cm in length are considered to be continuous cover.

To estimate canopy cover of grasses, forbs, litter, and bare ground, eight point-frames (or microplots) (Bonham 1989), each 55 x 30 cm with 50 points (each point 5 cm apart) are placed every 5 meters along each of the four 50 m transects (Figure 5). The first frame placement is randomly selected, then each subsequent frame is placed 5 m from the preceding one. Only green to light green plants are measured as live grass or forb cover. Dead plants including standing dead (usually brown in color), ground litter, or stump remains of grass clumps are recorded as litter. Bare soil, macrophytic crusts, or pebbles are considered bare ground. Shrubs are not recorded in the microplot because shrub cover is measured using the line-intercept method (see preceding paragraph). The ground cover below shrubs (e.g. grass, litter, or bare ground) in a microplot is recorded as cover for that location. The canopy cover of grasses, forbs, litter, and bare ground should sum to 100%. In wet years, it is possible to have greater than 100% cover within a microplot because forbs (e.g. Russian thistle) often form an overstory with blue grama or other species growing beneath.

Frequency of dominant or indicator species is measured with 25 nested-frequency plots per 50 m transect (Elzinga et al. 1998) placed every 2 m on the left side of the transect (as viewed from center stake) beginning at the 2 m mark. The appropriate plot size for detecting statistical differences in the frequency of a species is influenced by the density and dispersion of that species within a community (Hyder et al. 1965 as cited in Winter et al. 2002). Small plots sample the dominant species (e.g. blue grama grass) at optimal frequencies, but fail to detect less common species. Three different plot sizes (nested frequency plots) should be used to measure frequency because concurrent use of small and large sizes ensures adequate sampling of both common and uncommon species (Hyder et al. 1975 as cited in Winter et al. 2002). The nested-frequency frame sizes used are as follows: a) 0.1 m x 0.1, b) 0.31 m x 0.31 m, and c) 1 m x 1 m. The 0.1 m x 0.1 m and 0.31 m x 0.31 m frame sizes are placed in the lower left corner (as viewed from center) of 1 m x 1 m plot. The species included in the nested-frequency plots should include the dominant species like three-awn grass and blue grama.

Reference photographs should be taken from both ends of each transect (landscape views) as well as at the 3rd and 5th microplots (views looking straight down).

Monitoring the cover and frequency of bare ground and exotic weedy species within the prairie dog complex at SAND will allow SAND to measure how successfully the native character of the plant community is being maintained. The information from the monitoring program will assist with adaptive management of the natural resources at SAND. If the desired range in target density for prairie dogs results in unfavorable changes to the plant community, the target density can be adjusted lower and subsequent monitoring used to measure whether the new density effectively permits desirable forage species to maintain them-selves.

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