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Natural Resource Stewardship and Science

Prairie Restoration on the Southern Plains

Lessons Learned from a Multiphase Project in Nine Parks

Natural Resource Report NPS/NRSS/NRR—2017/1485



ON THE COVER

Top Row from Left: Prairie habitat at Chickasaw NRA (Photo Credit: Heidi Sosinski); Assessing prairie habitat at Washita Battlefield NHS (Photo Credit: Kris Johnson); A prescribed fire at Bent's Old Fort NHS (NPS Photo); Center Strip: Prairie habitat at Sand Creek Massacre NHS (NPS Photo); Lower Row from Left: Seed collector demonstration (NPS Photo), Dikcissel in grass at Fort Larned NHS (Photo Credit: Kelly Ford), Prairie/pastures at Pecos NHP.

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Natural Resource Report NPS/NRSS/NRR—2017/1485

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Contents

Page

Executive Summary ix

Acknowledgments xi

Introduction 1
- Grasslands of the Southern Plains 2
  - Ecoregions of the Southern Plains 2
  - Importance of NPS Grasslands in the Southern Plains 4
- Prairie Restoration 5
  - Barriers to Successful Restoration 6
  - Restoration Process and Goals 7
- Prairie Restoration Projects in Southern Plains Parks 8
  - A Capacity-Building Approach 10
  - Project Goals 12
- Park-specific Restoration Projects 12
  - Bent's Old Fort National Historic Site 12
  - Chickasaw National Recreation Area 12
  - Fort Larned National Historic Site 12
  - Lake Meredith National Recreation Area 12
  - Lyndon B. Johnson National Historical Park 13
  - Pecos National Historical Park 13
  - San Antonio Mission National Historical Park 13
  - Sand Creek Massacre National Historic Site 14
  - Washita Battlefield National Historic Site 14

Introduction to Prairie Restoration 15
- Initial Phase 15
- Implementation Phase 16
- Monitoring Phase 17
- Adaptive Management 17

Conceptual Planning 19
- Vision 20
- Need for Restoration 20
- Desired Condition 21
- Restoration Goals 21
  - Conceptual Planning in the Southern Plains 22

Site Assessment 25
- Trends and Considerations 27
  - Site Assessment in the Southern Plains 29

Reference Conditions 31
- Reference Site 32
- Ecological Site 33
  - Reference Conditions in the Southern Plains 36

Contents (continued)

Page

Administration 37
Administration in the Southern Plains 37
Compliance 38
Resources 39
Institutional History (Documentation) 40
Institutional History in the Southern Plains 42
Coordination & Partnerships 42
Coordination & Partnerships in the Southern Plains 44

Restoration Implementation 47
Implementation Planning 47

Site Preparation 53
Mechanical Site Preparation 53
Mechanical Site Preparation in the Southern Plains 55
Exotic Plant and Animal Removal and Management 56
Methods for Exotic Species Control 57
Exotic Species Control in the Southern Plains 60
Invasive Plant Removal 61
Invasive Plant Removal in the Southern Plains 62
Holding Crops 62
Holding Crops in the Southern Plains 64

Native Seed Acquisition and Propagation 67
Native Seed Acquisition 67
Native Seed Collection and Storage 69
Propagation 73
Native Seed Purchasing 73
Native Seed Acquisition and Propagation in the Southern Plains 74

Revegetation 77
Seeding 77
Transplanting 79
Irrigation 80
Site Protection 81
Revegetation in the Southern Plains 81

Passive Restoration 85
Passive Restoration in the Southern Plains 86

Maintenance and Management 89
Herbicide Application 90
Hand-Control of Exotics 91
Mowing 91
Grazing 91
Conservation Grazing in the Southern Plains 93

Contents (continued)

Page

Prescribed Fire....94
Prescribed Fire in the Southern Plains....98
Mastication....99

Monitoring....101
Photographic Monitoring....102
Rapid Assessment Monitoring....103
Effectiveness Monitoring....103
Long-term Monitoring....104
Monitoring of Restoration Sites in the Southern Plains....106

Interpretation....107
Interpretive Themes....107
Interpretive Media....108
Interpretation in the Southern Plains....110

Conclusions....113
Lessons Learned....116
Collaborative Framework....118

Literature Cited....119

Figures

Page

Figure 1: Map of the southern Plains showing the nine NPS sites that participated in prairie restoration projects. 3

Figure 2. Establishment of native forbs such as prairie coneflower (*Ratibida columnifera*) in restoration sites may be hindered by low average annual precipitation and frequent droughts in the southern Plains. 7

Figure 3. The natural and cultural heritage of the southern Great Plains includes native wildlife, vegetation and ecological systems. 8

Figure 4. Washita Battlefield NHS 10

Figure 5. Evaluation of grasslands in Sand Creek Massacre NHS. 11

Figure 6. Grasslands surrounding Fort Larned NHS are dominated by nonnative smooth brome (*Bromus inermis*). 13

Figure 7. Restored shortgrass prairie in Sand Creek Massacre NHS 14

Figure 8. For the purposes of this report, the restoration process is divided into three overlapping phases: the initial or planning phase, the implementation phase and the monitoring phase. 17

Figure 9. Adaptive management is an iterative process of assessment, implementation, monitoring and adjustment (Williams et al. 2007). 18

Figure 10. Habitat requirements for wildlife can inform reference conditions for restoration projects. 35

Figure 12. Wind erosion in an area without vegetation in Bent's Old Fort NHS 55

Figure 11. Dust storm in eastern Colorado in 1937 (Western History Collection, University of Oklahoma). 55

Figure 13. A seed sorter 75

Figure 14. The Dew Drop Drill is an example of a small seed drill that can be pulled behind an ATV. 78

Figure 15. Broadcast seeding by hand and using erosion control mats can be effective in small restoration sites such as at Bent's Old Fort NHS. 79

Figure 16. A seed mix used at Bent's Old Fort NHS. 80

Figure 17. Buffalo grass (*Bouteloua dactyloides*) plugs grown by seed for restoration efforts at Bent's Old Fort NHS. 80

Figure 18. In the abandoned prairie dog town at Sand Creek Massacre NHS, exotic species like Russian thistle (*Salsola spp.*) are now limited to areas around burrows. 87

Figure 19. Bent's Old Fort NHS maintains a small number of livestock primarily for interpretive purposes. 94

Figure 20. Decadent grass, containing dead or dying plant material. 94

Figure 21. Repeat photographs from grasslands monitoring in Washita Battlefield NHS. Although the photographs were taken within weeks of another in subsequent years, the transect had thicker grass and more forbs growing in 2016 (right) than in 2014 (left) 102

Figure 22. An example of a resource brief prepared for the prairie restoration project in southern Plains parks. 111

Figure 23. The Bent's Old Fort restoration site in July 2011 under drought conditions with field bindweed (*Convolvulus arvensis*) and a lot of bare ground. 115

Tables

Page

Table 1. Ecoregions of the Southern Plains 4
Table 2. Excerpts from NPS Management Policies Relevant to Prairie Restoration Projects (NPS 2006). . 9
Table 3. Capacity-Building Principles Used During Prairie Restoration Projects 11
Table 4. Components of a Prairie Restoration Project..... 16
Table 5. Summary of the Components of Conceptual Planning 20
Table 6. Types of Restoration Goals[1] 23
Table 7. Components of a Site Assessment Prior to Prairie Restoration in the Southern Plains 26
Table 8. Sources of Information That Inform Reference Condition 32
Table 9. Summary of the components of Administration 38
Table 10. Implementation Planning..... 48
Table 11: Sample restoration implementation timeline for Bent's Old Fort NHS taken from from the Bent's Old Fort NHS Restoration Plan (NPS and Lady Bird Johnson Wildflower Center 2011a)..... 49
Table 12. Hierarchal System of Seed Source Preference for Restoration Projects (Scianna et al. 2011) . 68
Table 13. Factors Related to the Use of Purchased or Collected Native Seed in Prairie Restoration Projects..... 69
Table 14. Seeding Techniques 78
Table 15. Maintenance and Management Planning 90
Table 16. Types of monitoring that may be used to document changes in a restoration site 102
Table 17. Indicators and measures used to assess the restoration site at Lyndon B. Johnson NHP during a 2014 rapid assessment 103
Table 18. Selected Lessons Learned during the Prairie Restoration Projects on the Southern Plains... 114

Vignettes

Page

Restoration Vision at Pecos NHP 21
Restoration Goals for Lyndon B. Johnson NHP 22
Pollinators and Biotic Integrity 27
Site Assessment in Lake Meredith NRA 28
Ecological Site Descriptions Contributed to Reference Conditions at Bent's Old Fort NHS 33
Challenges in Defining Reference Conditions at Pecos NHP 34
Capacity-Building 40
Personnel Changes 41
Butterfly Garden at Fort Larned NHS 43
Collaboration with USFWS Burn Team at Lyndon B. Johnson NHP 44
Adapting Restoration Implementation to Current Conditions 50
Mechanical Site Preparation at Bent's Old Fort NHS 54
Mechanical Site Preparation at Lyndon B. Johnson NHP 54
Feral Hogs 57
Testing Exotic Control Techniques at Lake Meredith NRA 58
Johnsongrass (Sorghum halepense) 59
Brush Removal in the Rancho de las Cabras Unit, San Antonio Missions NHP 63
Holding Crops and Restoration at Bent's Old Fort NHS 64
Native Seed Collecting and Propagation Resources on the Web 68
Native Seed Collection Dos and Don'ts 70
Collecting Native Seeds at Bent's Old Fort NHS 71
Switchgrass (Panicum virgatum) 72
Vine mesquite (Panicum obtusum) 73
Restoration Along the Acequia Trail in San Antonio Missions NHP 81
Revegetation at Sand Creek Massacre NHS 82
Passive Restoration Following Tamarisk Removal in Bent's Old Fort NHS 86
Mowing to Reduce Shrub Cover in Grasslands in Sand Creek Massacre NHP 92
Changing Conditions for Use of Prescribed Fire at Bent's Old Fort NHS 95
Collaborative Framework for Resource Management in the Southern Plains 96
Collaborative Framework for Resource Management in the Southern Plains (continued) 97
Planning for Prescribed Fire at Washita Battlefield NHS 99
Grasslands Rapid Assessment for Natural Resources Condition Assessment at Lyndon B. Johnson NHP 105
Native Garden at Washita Battlefield NHS 109

Executive Summary

Between 2008 and 2015, nine national park sites in the southern Great Plains conducted restoration projects to restore degraded sites in shortgrass and mixed-grass prairie ecosystems. This multipark project sought to restore the biological function of park grasslands and restore cultural landscapes, both vital to the fundamental resources and values of these parks. Participating parks included Bent's Old Fort National Historic Site and Sand Creek Massacre National Historic Site in Colorado, Pecos National Historical Park in New Mexico, Lake Meredith National Recreation Area, Lyndon B. Johnson National Historical Park, and San Antonio Missions National Historical Park in Texas, Chickasaw National Recreation Area and Washita Battlefield National Historic Site in Oklahoma and Fort Larned National Historic Site in Kansas.

Major goals of the project included not only restored prairie sites in park areas, but also opportunities for parks to gain experience in and to build capacity for conducting such restoration projects in the future. The parks worked collaboratively with one another, with the Southern Plains Inventory and Monitoring Network (SOPN), other National Park Service programs, and outside experts including specialists from the Lady Bird Johnson Wildflower Center. Parks also shared equipment, expertise and lessons learned with one another during the project. This interpark sharing was especially beneficial to the participating parks given the small size of their resource management staffs.

The parks followed restoration guidelines developed and endorsed by the Society for Ecological Restoration, adapting them specifically to the unique conditions found in the shortgrass and mixed-grass prairie and for use in NPS sites. Loss of native grasslands in the southern Plains has occurred through conversion of land to agricultural uses, overgrazing, loss of natural disturbances such as fire and invasions of exotic species, threatening the very nature of the prairie landscape. Less is known about the restoration techniques that are most effective in short and mixed-grass systems relative to those in tallgrass prairie ecosystems. But it is generally thought to be more difficult to restore these systems because of factors such as frequent periods of drought and persistent winds that impact the shortgrass steppe and mixed-grass prairie.

The restoration process used by the parks included developing a conceptual plan to guide restoration efforts, assessing current condition at the site to be restored, and identifying reference conditions in order to evaluate the effectiveness of restoration treatments. Based on the information compiled in the initial phase of the restoration, treatments were accordingly planned and scheduled with the understanding that adaptive management would be an integral part of the process.

Restoration treatments included site preparation to repair physical degradation of the site due to soil compaction, furrowing or other alterations, to control exotic and invasive species and to hold the soil as appropriate with cover crops. An integral part of the restoration projects was the acquisition of native plant materials by native seed collection, propagation and/or purchasing. Seeding was the most commonly used revegetation technique in the restoration sites as it was cost-effective and could be used in large areas. Transplanting seedlings grown from seed in a greenhouse and salvaged or wild plants was applicable at some sites. Transplantings can be especially useful for species that do not generate well from seed or because of another factor such as blowing soil that inhibits seed germination.

Maintenance and management treatments following revegetation efforts were conducted to continue to provide conditions for native plants to thrive and to control exotic species.

Common maintenance and management techniques used in prairie restoration sites included mowing, mastication, prescribed fire and grazing.

Administrative functions took place in all phases of the project and included compliance, managing fiscal, personnel and equipment resources, and building an institutional history of restoration efforts to be used by future resource managers.

Interpretation and educational outreach is an integral component of all resource management projects in NPS sites. The parks and partners involved in the prairie restoration projects developed brochures, resource briefs and websites that provided overviews of the project. Individual parks completed a number of specific interpretive projects such as the development of native gardens. Information and lessons learned in this project were also shared with other resource management professionals.

Given the complexity and great timespan required to complete restoration in shortgrass and mixed-grass prairies, the status of the restoration projects in southern Plains parks must be considered ongoing. This report serves as a progress report on the parks' restoration efforts, with a special emphasis on providing lessons learned using examples and vignettes from the restoration efforts in the nine parks.

Acknowledgments

This report shares the results of and the lessons learned from a multipark prairie restoration project that took place in nine NPS sites in five states over eight years. Complex project such as the restoration efforts undertaken in the participating parks are the result of many different people and organizations working together for common goals.

The authors offer great thanks to the following park staff members who participated in these projects: Biotechs Adam Heberlie and Danette Ulloa, Bent's Old Fort NHS; Zach Cartmell, Resource Management, Capulin Volcano NM; Noel Osborne, Chief of Resource Management, Chickasaw NRA; George Elmore, Chief Ranger, and Ellen Jones, Park Ranger, Fort Larned NHS; Arlene Wimer, Chief of Resource Management, and John Lysaught, Biotech, Lake Meredith NRA; Cheri Dorshak and Regina Carrico, Pecos NHP; Greg Mitchell, Natural Resources Program Manager, San Antonio Missions NHP; Karl Zimmermann, Park Operations Manager, and Durwood Miller, Sand Creek Massacre NHS; and Dick Zahm, Park Ranger, Washita Battlefield NHS. We are also very grateful to Dusty Perkins for his efforts to initiate and obtain funding for the first phase of this project.

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Dr. Mark Simmons, 1960-2015. Mark's death in 2015 was a tragic loss to science and to his colleagues.



The 12-acre prairie restoration site in the Johnson City Unit, Lyndon B. Johnson NHP

Introduction

Since 2008, prairie restoration projects have been ongoing in at least nine National Park System (NPS) sites in five states in the southern Great Plains. Eight of these parks (Bent's Old Fort National Historic Site, Chickasaw National Recreation Area, Fort Larned National Historic Site, Lake Meredith National Recreation Area, Lyndon B. Johnson National Historical Park, Pecos National Historic Site, Sand Creek Massacre National Historic Site and Washita Battlefield National Historic Site) are in the Southern Plains Inventory and Monitoring Network (SOPN), one of 32 I&M networks in the National Park System. San Antonio Missions National Historical Park, in the Gulf Coast Network, joined the multipark project as it also contained degraded grasslands in need of restoration similar to grasslands in SOPN parks.

The nine parks that participated in prairie restoration efforts all contain shortgrass or mixed-grass prairie that have been degraded by human use. Most NPS units in the southern Plains have a close interrelationship between natural and cultural resources. A number of the park sites that participated in restoration efforts tie cultural significances to park purposes and fundamental resource values. In many parks, the prairie landscape shaped many important aspects of the human story including settlement, trade and westward expansion. Southern Plains parks also have great significance to American Indian tribes such as Puebloan peoples, Chickasaw, Choctaw, Kiowa, Comanche, Cheyenne and Arapaho. For example, important events in tribal histories occurred in places such as along the Washita River and Sand Creek. Additionally, the plants and animals of the southern Plains are intricately tied to native cultures.

While each park's grasslands had characteristics that made them unique, all parks faced a common challenge: the difficulty of restoring shortgrass and mixed-grass prairies in the semi-arid southern Plains, a region characterized by frequent droughts and persistent winds. Additionally, NPS sites in the southern Plains are small, in geographic size and/or staff size, limiting their ability to conduct complex resource management projects.

A primary feature of the prairie restoration projects was a capacity-building approach that yielded experience and knowledge about prairie restoration techniques that can continue to be used in southern Plains parks. In addition to capacity-building, the other major goal was to initiate restoration efforts in each park using a systematic process that began with conceptual planning.

Grasslands are often considered the most endangered habitat on earth, especially in North America.

Since restoration of shortgrass and mixed-grass prairie ecosystems cannot be completed in a short period of time, such as that covered by this project, this document is a progress report for a larger restoration process. This report overviews the planning, evaluation, implementation, management, monitoring and information-sharing methods and processes used in the restoration efforts. The report notes successes, failures, highlights and lessons learned from restoration efforts in each park, and is designed to be an educational resource for others planning or implementing restoration in shortgrass and mixed-grass ecosystems. Case studies, or vignettes, illustrate important points. Some of the techniques used were specific to restoration projects in grasslands, but other concepts are more widely applicable to other ecosystems.

Grasslands of the Southern Plains

Grasslands are among the most productive ecosystems on earth (Williams and Diebel 1996) and they are the dominant ecosystem in the Great Plains. Grasslands are also considered the most endangered habitat on earth, especially in North America (Samson and Knopf 1996).

Many grassland systems have undergone significant changes since first being described by early Europeans. Exotic species[1] invasions, expanding row-crop agriculture, overgrazing, mineral exploration and establishment of woodlots and shelterbelts all have contributed to grassland degradation and significant ongoing loss of genetic diversity in grasslands in North America. Outside of NPS sites, few areas are currently protected, and many grassland systems have undergone significant changes from past human use.

Mixed-grass and shortgrass prairie are the dominant ecosystems in southern Plains parks (Figure 1; Table 1). The southern Plains extend from Kansas south to Texas and New Mexico, and include a variety of grassland ecoregions, each characterized by a distinct group of species, relationship between species and processes, and environmental conditions, such as precipitation, elevation, and temperature regime.

Ecoregions of the Southern Plains

Western short grasslands lie west of the Texas panhandle and extend north through western portions of Oklahoma and Kansas. They support one of the highest diversities of birds, mammals, and butterflies in the United States. Bird populations that are endemic to shortgrass prairie are the fastest-declining bird populations in North America (Samson and Knopf 1994).

Central and southern mixed grasslands (mixed-grass prairie) lie in eastern Colorado, western Kansas, western Oklahoma and Texas. Mixed-grass systems support the highest number of plant species compared to other prairie types because tall- and shortgrass ecoregions meet. Mixed-grass prairies support many reptile species and provide important breeding areas for birds and stopover sites for migratory birds, particularly in wetland areas.

The **central forest/grassland transition zone**, present in Chickasaw NRA and the surrounding area in Oklahoma and Texas, is comprised of a mixture of savanna (grassland with scattered trees), prairie, and woodland. Most of this ecoregion has been converted to farmland, leaving few natural remnants.

Agricultural conversion, overgrazing, and fire suppression have fundamentally altered North American prairie dynamics. Prior to European settlement, grasslands in the southern Plains were regularly disturbed by fire (natural and human-ignited), mammal migrations, and grazing by native ungulates. The vast majority

1. The terms "exotic species" and "nonnative species" are used interchangeably in this report.

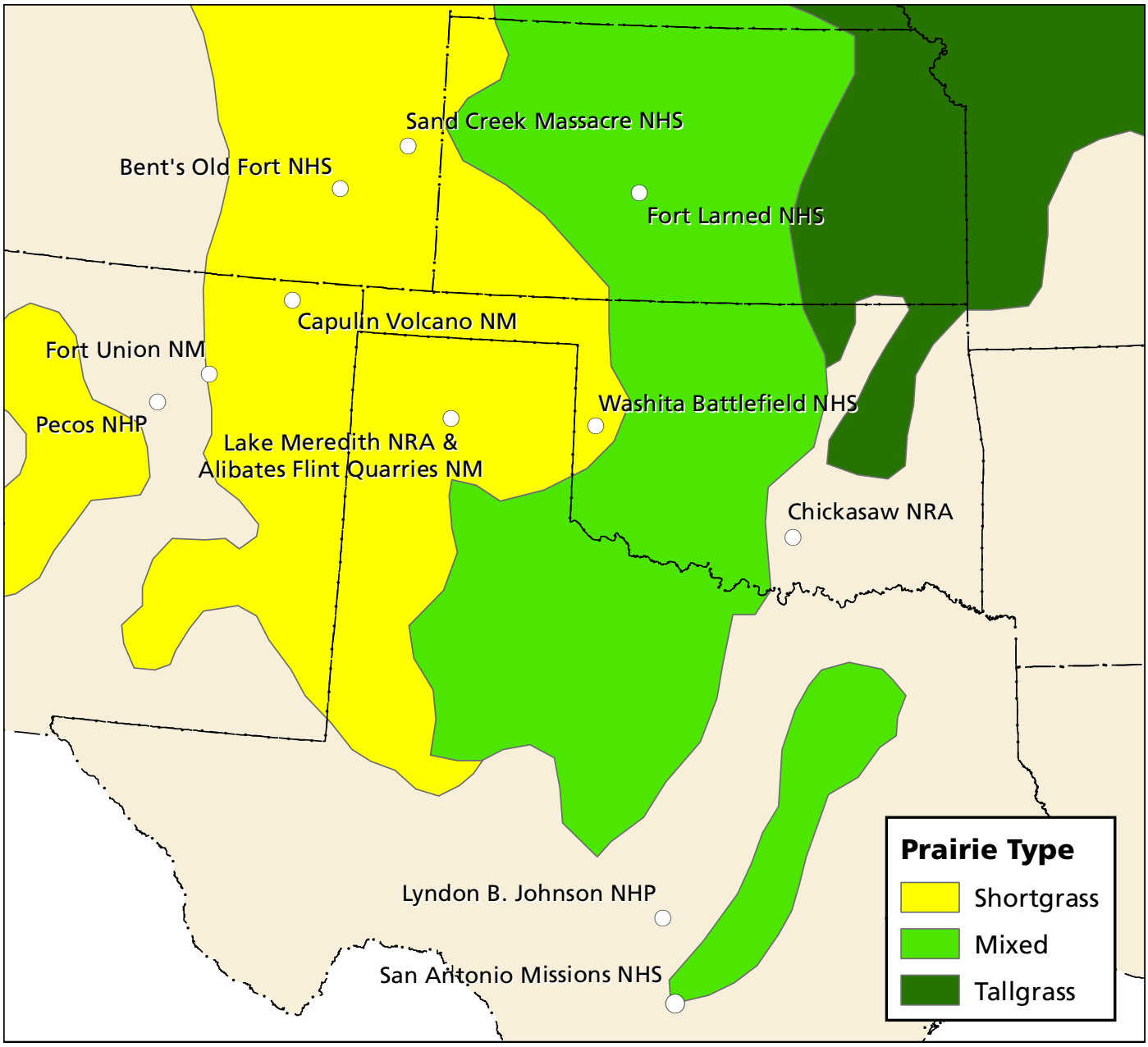


Figure 1: Map of the southern Plains showing the nine NPS sites that participated in prairie restoration projects. The boundaries between shortgrass, mixed-grass and tallgrass prairies are gradational and this map shows approximate boundaries. A single park unit may contain more than one type of grasslands. For example, a park within the shortgrass region might have components of mixed-grass due to topography and microsite conditions. Parks outside these three major zones of prairie types also may contain prairie ecosystems. Map adapted from an image (courtesy of USDA) by Heidi Sosinski.

of the changes in the prairie's natural systems began with Euro-American settlement, particularly after the passage of the 1862 Homestead Act that promoted economic opportunity for settlers. Under the Act, a homesteader could claim 160 acres of land, provided they lived on the land and improved it by building a dwelling and sowing crops. Many homesteads were abandoned before settlers were eligible to file for a land deed after five years. Since the homesteading era, family farms have gradually transitioned to ownership by large corporate agribusinesses, which converted large tracts of land to monocultures (single crop).

Estimates for loss of mixed-grass prairie range from 30 - 99.9% (Samson et al. 1998). While less shortgrass prairie has been converted to agriculture than mixed-grass or tallgrass,

Table 1. Ecoregions of the Southern Plains

Ecoregion	Description	Parks	
Western Short Grasslands	The most arid of Great Plains grasslands, and have great bird, mammal and butterfly diversity	Bent's Old Fort NHS, Lake Meredith NRA, Sand Creek Massacre NHS, Pecos NHP, Washita Battlefield NHS	
Central and Southern Mixed Grasslands	Contain a high number of plant species due to mixing of short and tallgrass prairies	Bent's Old Fort NHS, Chickasaw NRA, Fort Larned NHS, Lyndon B. Johnson NHP, San Antonio Missions NHP, Washita Battlefield NHS	
Central Forest/ Grassland Transition Zone	Consists of a mixture of prairie, savanna and woodlands. The transition zone receives the most precipitation of southern Plains areas.	Chickasaw NRA	

the historical and evolutionary impacts of cattle grazing may be more evident in this system (Knopf 1996). Extensive areas of shortgrass prairie are now dominated by invasive perennial and annual plant species whose presence is attributed to overgrazing by domestic livestock and dryland farming (Weaver et al. 1996).

Landscape-scale agricultural changes were associated with many smaller-scale alterations, including exotic species invasions, damming and pumping surface water and aquifers for local irrigation and development, livestock and human traffic, and encroachment by woody shrubs due to wildfire suppression. Perhaps most significantly, American bison (*Bison bison*), which contributed to shaping the structure of shortgrass prairie communities, were regionally extirpated by the 1880s.

Few grasslands are preserved in the southern Great Plains, and many of those that are protected today were previously altered. The establishment of woodlots and shelterbelts and the invasion of woody shrubs in water corridors significantly contributed to the loss of genetic diversity in grasslands, which in turn has led to the decline of several animal species such as the burrowing owl (*Athene cunicularia*) and the black-tailed prairie dog (*Cyonomys ludovicianus*). These species were once abundant but are now considered rare or are listed as threatened, endangered, or of special concern by state agencies.

Importance of NPS Grasslands in the Southern Plains

Due to the above threats and the relative paucity of grasslands in public ownership, grasslands on lands managed by the National Park Service are critically important and are places to showcase exemplary grassland management. The NPS southern Plains grasslands are of particular significance because they act as natural oases within a landscape of agriculture.

Native grasslands are a highly significant aspect of virtually every park in the southern Great Plains. All parks that participated in prairie restoration projects have General Management Plans (GMPs) and/or Resource Management Plans that identify the inseparable nature of natural and cultural landscapes, and the priority need to restore mixed-grass and shortgrass prairie. For parks with a cultural emphasis, the prairie was a dominant landscape feature that shaped the cultural landscape(s) of the park. For parks with a natural resource or recreation emphasis, prairie is the dominant ecosystem through which other natural resources depend and interact. It is hard to find a single more

fundamental resource of the Great Plains than the plains themselves.

However, NPS grasslands are degraded due to previous uses, altered disturbance regimes and other causes. Grassland restoration will improve biological integrity and restore the historic scene by placing the historic events and objects within the context of the prairie environments in which they took place. For example, the Canadian River at Lake Meredith NRA provided a natural habitation corridor containing good water and rich grasslands in the otherwise arid shortgrass plains. Ample evidence exists of the area's use by American Indians, who were later followed by American explorers and settlers. In the hill country of central Texas, Samuel Johnson purchased the area now known as the Johnson Settlement Unit of Lyndon B. Johnson NHP in 1869 to set up a cattle operation. The spot was chosen for its access to water at the Pedernales River and for abundant grasses, and it served as a gathering spot for area cattle to be driven north for shipment.

Healthy grasslands are also important to several rare and listed species that live in the southern Plains, including four that are known to occur in parks restoring prairies: the burrowing owl (*Athene cunicularia*), black-tailed prairie dog (*Cyonomys ludovicianus*), mountain plover (*Charadrius montanus*), and Texas horned lizard (*Phrynosoma cornutum*). Two additional species may occur in some parks, the lesser prairie chicken (*Tympanuchus pallidicnctus*) and swift fox (*Vulpes velox*).

As the threat of climate change looms, healthy, resilient, restored grasslands may act as both species refugia and vital genotype banks. Changes in climate, along with anthropogenic climate effects, are expected to alter the type (e.g., rain versus snow) and amount of annual precipitation in the southern Plains (NPS 2011). The seasonality of large precipitation events may also change and wind patterns may be altered (Finch 2012). Increased drought may also alter the seasonality, severity and frequency of fire as well as post-fire regeneration. Climate change may cause the distribution of Great Plains grasslands to shift northwestward (Finch 2012). Climate change is also expected to alter the spread of exotic plants in unknown ways (Finch 2012). Range expansions of new plant species into parks on the southern Plains may also be possible.

The National Climate Assessment for the Great Plains (Shafer et al. 2014) projects more frequent high temperatures (> 100° F/38° C), causing more heat stress and more evapotransportation. Winters are projected to be shorter and more mild. These climatic changes are expected to have associated phenological changes that may disrupt the balance of ecosystem functions (Shafer et al. 2014).

The SOPN, which contains eight of the nine parks who participated in prairie restoration projects, completed an analysis of park natural resources based on interviews and questionnaires from individual park staff. This analysis indicated that the restoration of native prairie grassland community was the highest priority issue facing the network (Perkins et al. 2005). San Antonio Missions NHP also identified restoring native prairie as a priority for the park.



Texas Horned Lizard

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed



Burrowing owls

Prairie Restoration

The plains have given the American people some of their most powerful national images. Yet, those iconic "amber waves of grain" are more a reflection of contemporary human relationships with the land than of America's natural beauty. Because it can be hard to imagine what these grasslands might have looked like prior to Euro-American settlement and the introduction of large-scale agriculture, restoring even small tracts of native prairie provides a window into the nation's natural heritage that would otherwise be irrecoverable. With shoulder-high big bluestem (*Andropogon gerardii*), and some of the richest biodiversity in the country, restored prairies can provide sources of food, medicine, and spirituality. Prairies also provide cultural,

aesthetic, educational, and scientific benefits and valuable ecosystem services. Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Society for Ecological Restoration International Science & Policy Working Group 2004). An ecosystem is considered "restored" when it has sufficient stable biotic and abiotic components and functionality that allow it to be self-sustaining without further assistance or manipulation. A restoration process can take years or even decades.

Prairie restoration requires a long-term commitment as success may take years, or even decades, and progress may occur only intermittently.

Prairie restoration and the knowledge of restoration practices and techniques in prairie ecosystems has greatly increased over the last few decades. However, the majority of these restoration projects have occurred in eastern Great Plains tallgrass. Relatively few published studies of restoration projects in the western plains in mixed-grass and shortgrass systems exist.

Restoration can sometimes be accomplished by the removal of existing vegetation, followed by reseeding with desirable species, especially in tallgrass prairie. However, in shortgrass and mixed-grass systems, the process is usually more complex, requiring a return of the environmental conditions that favor the growth and establishment of native species (Baer et al. 2004, Suding et al. 2004). In these systems, a feasible approach for prairie restoration is to enhance the mechanisms favoring the competitive advantages of desirable species while suppressing mechanisms that favor undesirable or nonnative species.



Restoration treatments can support the vigor and health of native grass and forbs.

It is important to recognize that prairie restoration requires a long-term commitment (Society for Ecological Restoration International Science & Policy Working Group 2004). It is extremely unrealistic to expect complete restoration within the scope of a single project. Rather, restoration success will most likely be achieved incrementally over numerous years with a myriad of challenges and successes along the way.

Barriers to Successful Restoration

There are five potential barriers to the success of restoration projects in the southern Plains. The first barrier is altered soil condition. Soil condition may need to be assessed for successful establishment of desired grasses. Initial studies indicate that warm-season (C4) grasses are most successful under low nitrogen regimes, while cool-season (C3) grasses become more dominant with moderate levels of nitrogen. If nitrogen levels become too high through land management practices or positive feedback loops that favor invasive species, desirable species recruitment can be diminished due to competition from exotic species. This barrier can be overcome by conducting soil analyses and potentially manipulating soil dynamic properties.

A second barrier is creating suitable conditions for forb regeneration (Figure 2). Some of restoration practices in tallgrass systems may be applicable to shortgrass and mixed-grass. However, initial restorations at Bent's Old Fort NHS during the 1990s indicated lower forb regeneration and potentially longer recovery times due to lower and more variable amounts of rainfall compared to tallgrass systems (Figure 2). Lower average annual precipitation (Weaver et al. 1996) combined with an increased frequency of droughts in shortgrass prairie (Simms 1988) are major drivers that differentiate shortgrass from tallgrass prairie.

A third barrier is the competitive interactions between native and exotic species. The same conditions that are conducive to successful germination of native species can also provide areas for exotic species invasion. The use of native seeds with local genotypes, prescribed fire, site-specific control of exotics with herbicides and cover crops can give desirable native species a competitive advantage that allows them to become established. By documenting how these three barriers can be overcome in southern Plains parks, this project

added empirical knowledge to a working restoration model that can be applied to other NPS units in the mixed- and shortgrass prairie ecosystems.

The lack of adequate water to support restoration efforts is the fourth potential barrier. The semi-arid shortgrass prairie experiences frequent droughts. Since it is not possible to provide supplemental water through irrigation to many restoration sites, restoration must depend on only moisture available from infrequent precipitation. The southern Plains does not regularly receive sufficient precipitation to support abundant germination of seeds and survival of seedlings, greatly impacting responses to revegetation treatments.

A final barrier is the potential challenges to the restoration process introduced by climate change. Viewing the development of restoration prescriptions through the lens of "Climate-Smart Conservation" (2014) can be invaluable to developing effective restoration prescriptions. While anticipating factors such as changes in temperature and precipitation are important when planning restoration efforts, restoration goals may still be to re-create historic conditions or to maintain current park ecosystems.



Figure 2. Establishment of native forbs such as prairie coneflower (*Ratibida columnifera*) in restoration sites may be hindered by low average annual precipitation and frequent droughts in the southern Plains.

Restoration Process and Goals

The restoration process includes a wide variety of activities, such as conceptual planning, site assessment, implementation planning, logistics, the control of exotic plants and animals, soil preparation and manipulation, planting and seeding of native species, effectiveness and long-term monitoring, passive restoration and adaptive management (Southwest Exotic Plant Management Team 2015). Each of these activities independently can be successful or face challenges. Success may come rapidly in one area while another may experience years-long setbacks depending on climate, resources, and conditions. For example, during this project, the southern Plains experienced a major drought, which impeded the progress of revegetation efforts.

Adaptive management is an inherent part of prairie restoration. The challenges that managers face while conducting restoration treatments may include changing climatic conditions, such as periods of drought and extreme temperature, persistence of exotic plant infestations, changes to the physical characteristics of a site from previous land use and other factors that often require the adjustment of planned actions. Adaptive management also assists restoration specialists as it enables them to utilize lessons learned from previous restoration efforts to modify their approach.

The goal of ecological restoration is usually to return an anthropogenically-altered ecosystem to its "natural state" with an emphasis on the presence, abundance and health of native species and natural diversity. Restoration efforts in NPS sites may also have cultural goals. Restored ecosystems help provide important ecological services, such as cleaning air and water, evaporative cooling, reducing greenhouse gases, and maintaining biodiversity. Restoration can repair damage to an ecosystem, renew economic opportunities and rejuvenate traditional cultural practices. Restoration can be achieved in many ways and may include broad efforts to link the damaged ecosystem to the larger landscape

and ecosystem, repair ecological processes, or involve stakeholders as restoration partners.

Native plant species have evolved with and are adapted to local climate conditions, common diseases, and herbivores apart from human influence and are key components of functional native systems. Native plants also provide ecological services that benefit people, aesthetically and economically. For example, native grasses are well-adapted to fire. After a fire, new growth sprouts from roots and attracts native grazing animals, many of which were hunted by early Americans. Underground grass roots enrich the soil by bringing up deeply-buried minerals and providing channels for rainwater to infiltrate the ground and replenish aquifers. People also use grasses as forage for livestock, grains for food, and as materials for rope, basketry and other crafts.

Unfortunately, nearly 25% of North American native plant species are at risk of becoming extinct, largely due to the presence of nonnative species. These nonnative plants, whether introduced accidentally or intentionally as agricultural crops or landscape ornamentals, frequently outcompete native species and become invasive. Exotic plant invasions lead to individual species loss, endangered natural habitats, soil erosion, and loss of the genetic diversity necessary for stable, balanced ecosystems. Today, much of the prairie in the southern Plains is dominated by invasive species[1] associated with anthropogenic disturbances such as fire suppression, water development and agriculture.

By restoring native plants, animals, and processes of the prairie, the natural and cultural heritage is restored to the southern Great Plains region (Figure 3). Additionally, the prairie restoration also increases visitor understanding of natural and cultural resources in NPS sites.

Prairie Restoration Projects in Southern Plains Parks

Mixed-grass and shortgrass prairie are dominant ecosystems in all nine parks included in this project. Together, these restoration projects represent a significant step toward restoring the key habitat of these parks in the southern Great Plains.

The aim of the restoration efforts is to stop or reverse the loss of prairie ecosystems in participating parks. The methods used by the parks to achieve restoration were developed and endorsed by the Society of Ecological Restoration (Society for Ecological Restoration International Science & Policy Working Group 2004 and Clewell et al. 2005). SER is, unquestionably, the premier scientific organization in this field.

Prairie restoration projects fall under the guidance of NPS Management Policies (Table 2) (NPS 2006). The sections on Restoration of Natural Systems (4.5.1), Management of Natural Landscapes (4.4.2.4), Cultural Landscape (5.3.5.2) and Biotic Cultural Resources (5.3.5.2.5) address returning lands disturbed by human activities to natural conditions and process, cultural landscapes and biotic cultural resources.

Efforts to restore damaged and degraded prairie were conducted in nine NPS sites in Texas, Oklahoma, Kansas, Colorado and New



TOMMYE FOUTS-ZETTNER

Figure 3. The natural and cultural heritage of the southern Great Plains includes native wildlife, vegetation and ecological systems.

1. This report uses the term "invasive species" to designate species, usually woody or shrubby ones, that invade grassland habitats. These species may be either native or nonnative.

Table 2. Excerpts from NPS Management Policies Relevant to Prairie Restoration Projects (NPS 2006).

Section	Policy
4.5.1 Restoration of Natural Systems	The Service will reestablish natural functions and processes in parks unless otherwise directed by Congress. Landscapes disturbed by natural phenomena, such as landslides, earthquakes, floods, hurricanes, tornadoes, and fires, will be allowed to recover naturally unless manipulation is necessary to protect other park resources, developments, or employee and public safety. Impacts on natural systems resulting from human disturbances include the introduction of exotic species; the contamination of air, water, and soil; changes to hydrologic patterns and sediment transport; the acceleration of erosion and sedimentation; and the disruption of natural processes. The Service will seek to return such disturbed areas to the natural conditions and processes characteristic of the ecological zone in which the damaged resources are situated. The Service will use the best available technology, within available resources.
4.4.2.4 Management of Natural Landscapes	Natural landscapes disturbed by natural phenomena, such as landslides, earthquakes, floods, hurricanes, tornadoes, and fires, will be allowed to recover naturally unless manipulation is necessary to (1) mitigate for excessive disturbance caused by past human effects, (2) preserve cultural and historic resources as appropriate based on park planning documents, or (3) protect park developments or the safety of people. Landscape and vegetation conditions altered by human activity may be manipulated where the park management plan provides for restoring the lands to a natural condition.
5.3.5.2 Cultural Landscapes	The treatment of a cultural landscape will preserve significant physical attributes, biotic systems, and uses when those uses contribute to historical significance. Treatment decisions will be based on a cultural landscape's historical significance over time, existing conditions, and use. Treatment decisions will consider both the natural and built characteristics and features of a landscape, the dynamics inherent in natural processes and continued use, and the concerns of traditionally associated peoples.
5.3.5.2.5 Biotic Cultural Resources	Biotic cultural resources, which include plant and animal communities associated with the significance of a cultural landscape, will be duly considered in treatment and management. The cultural resource and natural resource components of the park's resource stewardship strategy will jointly identify acceptable plans for the management and treatment of biotic cultural resources. The park's resource stewardship strategy will anticipate and plan for the natural and human-induced processes of change. Before any major treatment of a cultural landscape is undertaken, there must be an understanding of the degree to which change contributes to or compromises the historic character of the landscape, and the way in which natural cycles influence the ecological processes within the landscape. Treatment and management of a cultural landscape will establish acceptable parameters for change and manage the biotic resources within those parameters.

Mexico in partnerships with participating parks and with national experts in grassland ecology and restoration. An integral component of the effort was to develop the internal capacity (e.g., the partnerships, knowledge, skills, and expertise) within southern Plains parks to conduct similar restoration efforts in the future by learning what techniques are applicable for shortgrass and mixed-grass prairie and to build an institutional knowledge of prairie restoration techniques.

By working together, the parks were able to build upon the strengths of each site's past restoration experience by sharing expertise, learning opportunities and equipment in a cost-effective and mutually-beneficial manner. The project was funded primarily by two NPS Project Management Information System (PMIS) projects, supplemented by other park-specific grants, the Federal Lands Transportation Program, and park budgets.

Five parks, Bent's Old Fort NHS, Chickasaw NRA, Lyndon B. Johnson NHP, Sand Creek Massacre NHS and Washita Battlefield NHS (Figure 4), participated in Phase I between 2008 and 2011. The first phase was in concert with experts from the Ladybird Johnson Wildflower Center under a cooperative agreement. Specialists from all five parks and the Wildflower Center collaborated on restoration plans for each park and initiated restoration treatments.

Phase II took place between 2013 and 2015 and included four additional parks (Fort Larned NHS, Lake Meredith NRA, Pecos NHP, and San Antonio Missions NHP) plus four parks that participated in Phase I. The second phase built on the knowledge and expertise gained in Phase I as parks continued or expanded their restoration efforts.

The collective approach enabled parks to have access to most of the equipment necessary for prairie restoration including seed harvesters, a seed drill, broadcast seeders, mowing equipment, and UTV with attached weed sprayer. To ensure efficient communication



KATIE KELLERLYNN

Figure 4. Washita Battlefield NHS

and information exchange, park staffs, partners and project leaders met once a year and also held regular ongoing discussions and conference calls ensured efficient communication and exchange of information.

Dr. Mark Simmons and Dr. Steve Windhager of the Ladybird Johnson Wildflower Center assisted with the development of restoration plans, the review of seed mixes, seed collection, and site preparation.

A major emphasis was to expand from the initial restoration efforts to build a capacity of regional expertise to use in future projects.

Beyond restoring individual degraded prairie areas, this project allowed the NPS to begin addressing the large backlog of sites in shortgrass and mixed-grass prairies that need restoration. Though the areas of land being restored by the NPS are small, these projects also were opportunities to share information about the importance of ecological restoration with visitors, local communities, and the region. The restoration methods developed by this project and lessons learned from these pilot restoration efforts are available to other NPS sites in shortgrass and mixed-grass prairie ecosystems.

A Capacity-Building Approach

A major emphasis of the prairie restoration projects in southern Plains parks was to build a capacity of regional expertise in planning and implementing prairie restoration to use in future projects (Table 3). Phase I began with an initial training workshop led by Ladybird Johnson Wildflower Center staff. This workshop was followed by a series of park-specific workshops where each of the participating parks developed restoration plans together.

This collaborative approach promoted the development of internal expertise to serve as a resource for future restoration efforts. Utilizing teams of restoration specialists from multiple parks and other experts allowed for direct information transfer throughout the project. Site assessments including specialists from multiple parks were much more comprehensive than they would have been if conducted only by the staff of one park (Figure 5).

Throughout the project, the capacity-building approach was further enhanced through information transfer through interpretive products, as well as building an institutional history of each park effort. The interpretive component of the project aimed to facilitate information transfer to reach audiences including park visitors, other resource management professionals and those interested in conservation of the Great Plains.

An added benefit of this collaborative approach was the knowledge gained by the natural resource managers involved. In turn, this knowledge will enable managers to improve the planning and implementation of future projects.

Given the difficulty, complexity and great length of time required to complete restoration in shortgrass and mixed-grass prairie, the status of these restoration projects in southern Plains parks must be considered as ongoing. Likewise, the capacity-building effort to support future restoration projects is also ongoing, but a substantial base of institutional knowledge and interpark relationships was indeed built between 2008 and 2015. This report is intended to further the efforts to build capacity for conducting restoration in southern Plains grasslands by sharing experiences, both successful and challenging, that were encountered during these projects. It discusses the concepts of prairie restoration in shortgrass and mixed-grass systems and uses the experiences in the nine parks to illustrate them. Vignettes and lessons learned sections

Table 3. Capacity-Building Principles Used During Prairie Restoration Projects

Capacity-Building Component	Mechanism to Build Capacity
Training Workshops	Training workshops attended by staff from multiple parks enabled the shared building of a foundation of knowledge
Park-Specific Workshops	Initial planning workshops for each park were attended by all participating parks to exchange ideas and experiences
Collaborative Planning	All phases of restoration planning were shared among participating parks
Collaboration between Program Groups	Different program groups, such as fire and exotic plant managers, worked together with park and network staff to conduct planning and treatments that met multiple program goals and missions
Shared Experiences	Regular communication included conference calls and face-to-face meetings allow for the sharing of experiences, both successful and failed.
Institutional History	Documentation of restoration planning, implementation treatments and maintenance and management to inform future resource managers about restoration efforts undertaken
Shared Equipment	Equipment that was shared among all participating parks was a cost-effective way to obtain resources needed for restoration projects
Shared Staff	Knowledgeable interns that were shared between parks provided cost-effective assistance for parks who needed assistance for short periods of time.
Presentations	Presentations at conferences and other venues facilitated sharing of experiences
Outreach	Reports, briefs, webpages and social media platforms were used to share additional experiences and lessons learned.
Interpretation	Collaboration with park interpretive staff enabled understanding of restoration efforts with both internal and external park audiences.

provide specific examples from the restoration efforts and broader concepts respectively. Vignettes are short examples of applications of restoration techniques, or snippets of park restoration projects. Lessons learned sections provide concise overviews of major concepts that can be applied to future restoration projects.

The capacity-building approach not only facilitated information transfer, but also cost effectiveness. The skills to undertake successful ecological restoration will enable NPS personnel to take a larger role in the future planning of such projects, reducing the need for expert consultation. In addition, this project fostered collaboration with other NPS programs to accomplish much of the restoration follow-up, including maintenance and management of the restoration sties, as part of these program's routine efforts. The Southern Plains Fire Group is involved in future treatments that require prescription burns or mastication (on-site grinding and chipping). The Southern Plains Fire Group and the Southern Plains I&M programs will be conducting ongoing monitoring of the effects of such burns as well as changes over time in the condition and health of the grasslands being restored. As monitoring efforts identify concerns over exotic plants, that information will be used in planning with the Exotic Plant



Figure 5. Evaluation of grasslands in Sand Creek Massacre NHS.



Prescribed burn

Management Teams (EPMTs) for future treatments.

Project Goals

Overall goals of the restoration projects in nine southern Plains parks were to:

- Train park staff in applicable restoration techniques;
- Develop a conceptual plan for restoration activities at each of the nine parks;
- Assess current conditions at park locations and develop park-specific restoration plans, including identification of reference conditions;
- Implement restoration actions, including site preparation, exotic plant control, revegetation, and maintenance and management of the restorations site;
- Establish a monitoring program for the restoration sites to facilitate evaluation of restoration treatments and identify alternative restoration strategies that could be applied via adaptive management;
- Establish a group of staff familiar with a variety of restoration projects to support future projects or help with decisions to adaptively manage current projects.

Park-specific Restoration Projects

Bent's Old Fort National Historic Site

The vision for restoration at Bent's Old Fort NHS is to evoke an inseparable and reciprocal connection between the natural resources, cultural resources, and people through shared experience, activity and the healing of the land. The restoration site was an abandoned row-crop field/abandoned prairie dog town. The restoration goal is to return the site to a mixed-grass prairie including previously dominant native species, such as alkaki sacaton (*Sporobolus airoides*) and blue grama (*Bouteloua gracilis*).

Chickasaw National Recreation Area

Through restoration of mixed-grass prairie, Chickasaw NRA can develop its own identity while providing visitors with a sense of place, and real connection to an iconic Oklahoma landscape that many will not have previously experienced. The restoration site is an abandoned agricultural field dominated by the highly invasive Johnsongrass (*Sorghum halepense*). Restoration goals for the site include the development of functional mixed-grass prairie in the uplands and enhanced woodland health in riparian areas, reflecting the area's historical climax communities.

Fort Larned National Historic Site

The Fort Larned NHS Cultural Landscape Report advises efforts to re-establish prairie grasses and forbs in order to place the fort into the proper scene for its period of significance of 1859 - 1878. The native bluestem-grama prairie surrounding the fort has been significantly altered by plowing and seeding of nonnative species. Today, native grasslands are largely replaced by exotic grasses, especially smooth brome (*Bromus inermis*) (Figure 6). Restoration efforts began with the development of a butterfly garden at the new visitor parking lot led by a local school teacher who is a volunteer at the historic site.

Lake Meredith National Recreation Area

Bottomland prairie in Lake Meredith NRA has been significantly altered over time, especially by infestations of nonnative plants. A 4.2-acre restoration site that was dominated by Russian thistle (*Salsola spp.*) and kochia (*Kochia scoparia*) was used to evaluate the effectiveness of different control techniques that could then be used in other areas that need restoration. In addition to the restoration efforts that took place as part of this project, tamarisk (*Tamarix spp.*) control projects have occurred in Lake Meredith.

Lyndon B. Johnson National Historical Park

A 12-acre restoration site in the Johnson City Unit is being restored to a condition similar what existed when the Johnson family moved to the area in the 1860s. The restored prairie, also the site of a former pecan grove, provides an opportunity for visitors to understand both current and historic human interaction with the landscape. It also offers a sense of place that educates the public about why the Johnson family settled there. Historical ecological accuracy is the primary vision for this prairie restoration. Additionally, the restored prairie will provide habitat for local wildlife and serve as a demonstration of sound restoration techniques.

Pecos National Historical Park

With its several centuries of human occupation and close interconnectedness of the human story to the landscape, Pecos NHP utilizes a holistic approach towards resource management, forgoing the traditional division between cultural and natural resources. Invasion of woody vegetation is one of the primary ways that grasslands are being degraded in the park. Restoration efforts in the past were focused on removing encroaching trees and shrubs from areas that previously were prairie in order to be consistent with the historical context of the park and its mission. Currently, the park is focusing their restoration efforts on converting areas covered by monocultures of exotic species into native grasslands.



Nonnative Russian thistle (*Salsola spp.*)

San Antonio Mission National Historical Park

Prairie restoration is occurring in two sites in San Antonio Missions NHP. Exotic vegetation is being removed and replaced with native species in an 11-acre site along the Acequia Trail, which is part of an urban trail system



Figure 6. Grasslands surrounding Fort Larned NHS are dominated by nonnative smooth brome (*Bromus inermis*).

near Mission San Juan. The second restoration site is in the Rancho de las Cabras Unit, the ranch of Mission San Francisco, which is located south of San Antonio. Native prairie has been invaded by thorny brush at this site. Restoration efforts are focusing on removing this woody vegetation and revegetating the area with native grasses and forbs. Successful restoration will return the landscape in these areas to a condition and appearance that better reflects the mission period.

Sand Creek Massacre National Historic Site

The park is restoring the site 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's mission is to preserve the cultural landscape of the site as closely as practical to that of the time of the Sand Creek Massacre in 1864. Initial restoration efforts focused on a small area along the site boundary where the accumulation of nonnative vegetation had dominated native vegetation (Figure 7).

Washita Battlefield National Historic Site

The restoration goal is to return the meadow and riparian woodland to a condition similar to that found in 1868, when the Cheyenne encampment of Peace Chief Black Kettle was attacked. The grasslands in the site were previously plowed and have been invaded by nonnative grasses, especially bromes. Restoration efforts have included seeding by native grasses. The park has been unable to use other restoration techniques, such as prescribed fire, because of drought conditions.



Figure 7. Restored shortgrass prairie in Sand Creek Massacre NHS.



NPS PHOTO

Introduction to Prairie Restoration

Undertaking an ecological restoration project is often a complex process that involves careful planning, multiple treatments of restoration activities, and long-term maintenance and monitoring. Together, the entirety of a prairie restoration project may take years or even decades.

A prairie restoration project includes a number of distinct components or steps (Table 4): conceptual planning, site assessment, establishment of reference conditions, administration, implementation, maintenance, and monitoring. Many, if not most, restoration projects that occur in national park sites also include an interpretive component.

Broadly conceptualized, these components take place in three phases, parts of which may occur concurrently (Figure 8). The initial or planning phase takes place prior to the initiation of restoration activities and includes developing the conceptual plan, conducting the site assessment, and defining reference conditions, along with administration functions, particularly compliance. The implementation phase includes all restoration activities, including implementation planning, site preparation, native seed acquisition, revegetation and passive restoration, and post-restoration maintenance and management treatments. The monitoring phase spans nearly the complete breadth of a restoration project, ideally from the site assessment until long after restoration activities have concluded. Each of these phases can be iteratively repeated throughout the restoration process as needed.

Initial Phase

The initial or planning phase consists of all aspects of a restoration project that must be completed prior to initiating restoration treatments. It includes developing a conceptual plan, conducting site assessment, establishing reference conditions and administration, which consists of compliance, resources, maintaining an institutional history and coordination and partnerships.

Careful planning at the beginning of the restoration process ensures that all assessments, treatments, and monitoring efforts are well reasoned, and that the goals and objectives are delineated and designed for success. Restoration is generally only one of many natural resource management activities

Table 4. Components of a Prairie Restoration Project

Component	Description
Conceptual Plan	Sets the overall goal, vision and desired outcome for the restoration project.
Site Assessment	Determines the current condition and trend of the site to be restored.
Reference Conditions	Describes an ecosystem with ecological integrity that serves as a reference while planning restoration efforts and will be used to evaluate the effectiveness of the restoration.
Administration	Consists of all administrative functions related to the restoration projects, including compliance, budgeting, managing personnel and equipment, keeping documentation to build an administrative history, and developing partnerships.
Restoration Implementation	Includes restoration treatments such as site preparation, native seed acquisition and propagation, revegetation and passive restoration.
Maintenance & Management	Maintains the restoration site by perpetuating natural disturbances such fire and grazing and controls unnatural disturbances such as exotic plants.
Monitoring	Gathers information on the condition of the restoration sites that can be used to assess current condition, identify trends in condition, and the site's responses to restoration treatments and environmental conditions.
Interpretation	Communicates the significance of prairie ecosystems in NPS sites, the connection of grasslands to the site's fundamental resources and values and the role that restoration treatments have in maintaining site integrity and ecosystem health.

Thorough planning is one of the most important elements of a successful restoration project.

ongoing in a NPS unit. Thus, developing a plan for restoration activities allows managers to understand the complexities and costs of a restoration project, and to identify synergies among resource management programs, other park programs and operations, other NPS programs and with park partners and neighbors.

Thorough planning is one of the most important elements of a successful restoration project. First, a planning team needs to carefully consider the area to be restored and develop a conceptual plan that clearly defines desired outcomes. A site assessment provides a description of the overall current conditions and identifies the types and conditions of plant, animal, and soil communities within the restoration area. For the prairie restoration projects in the southern Plains, the planning teams used reference conditions to identify desired ecological communities. Reference conditions were based on reference sites within the parks and/or in nearby protected areas, or were hypothetical if appropriate reference sites were not available.

Finally, the planning component of a restoration project incorporates administrative elements such as building an institutional history as well as compliance, budgeting, making implementation schedules, staffing, and other issues. It also includes developing and managing partnerships.

Implementation Phase

The implementation phase consists of developing an implementation plan and then conducting prescribed restoration treatments. An implementation design plan identifies the actions to be taken to restore the site, and incorporates the principles of adaptive management in order to make adjustments to changing environmental and physical conditions at the restoration site. It also helps managers adapt to changes in financial or administrative resources.

Restoration activities typically begin with site preparation, usually consisting of mechanical land preparation, exotic species control and eradication, invasive species control[1], and/or use of holding crops. Plant materials for revegetation are acquired via native seed collection or purchase and may include propagation. Revegetation treatments such as seeding are commonly at the heart of many restoration projects, but restoration may

1. This report uses the term "invasive species" to designate species, usually woody or shrubby ones, that invade grassland habitats. These species may be either native or nonnative.

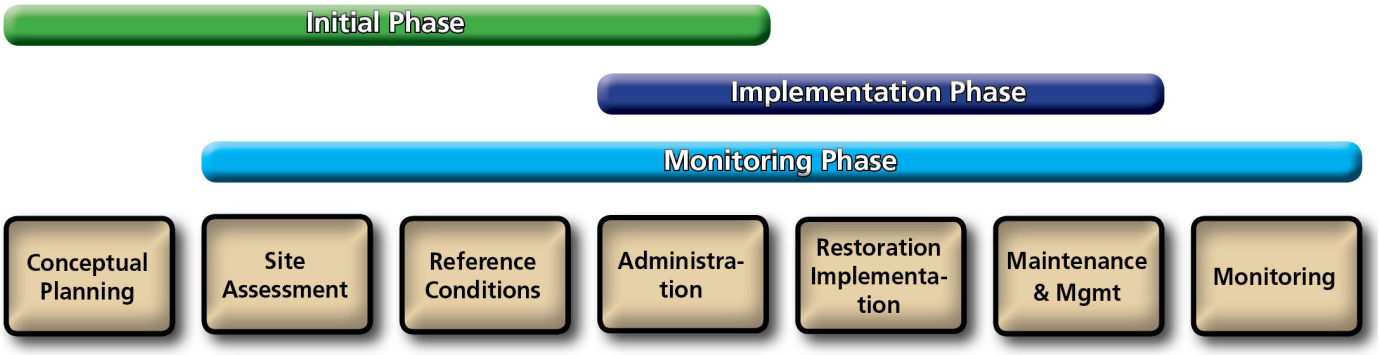


Figure 8. A prairie restoration project is complex and consists of many discreet components that all contribute to success. For the purposes of this report, the restoration process is divided into three overlapping phases: the initial or planning phase, the implementation phase and the monitoring phase. The initial or planning phase consists of conceptual planning, site assessment, reference conditions and administrative tasks such as compliance that occur prior to starting restoration treatments. The implementation phase consists of actions taken to re-establish a functioning ecosystem in the restoration site. Monitoring occurs throughout the restoration project from the initial site assessment, and throughout and following the implementation phase. It provides information on the effectiveness of restoration treatments taken and allows managers to adjust restoration efforts based on current conditions and an understanding of how conditions in the site have changed through time. Although there is a general sequence of actions in a restoration project, other managers may organize the restoration process differently and each step may be revisited and repeated using the principles of adaptive management.

also be passive whereby native vegetation reestablishes itself after site preparation creates conditions that favor native species. Maintenance and management activities take place after revegetation in order to continue to control exotic species and support native vegetation. These treatments may include the use of prescribed fire, mowing or grazing.

Monitoring Phase

Monitoring spans nearly the complete breadth of a restoration project. Monitoring prior to the initiation of restoration helps determine current condition. Monitoring during restoration allows for the use of adaptive management and the ability to tailor restoration activities to the successes or failures of previous restoration treatments, presence or absence of drought, and other variables. Monitoring also is critical for evaluation the success of a restoration project and being able to apply the lessons learned to other potential restoration projects.

Adaptive Management

Adaptive management is an integral part of prairie restoration projects. The operating definition of Adaptive Management used by the Department of Interior is:

> Adaptive management [is a decision process that] promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders (Williams et al. 2007).

In its simplest form, adaptive management can be viewed as an iterative process (cycle) of assessment, monitoring and decisions (Figure 9). Although there are numerous

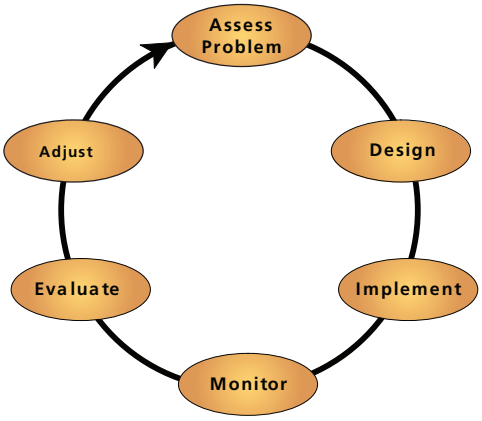


Figure 9. Adaptive management is an iterative process of assessment, implementation, monitoring and adjustment (Williams et al. 2007).

variations on what elements are included in the cycle, adaptive management is generally characterized as a sequence of steps that form a feedback loop. This loop includes assessing the current state of the resource, determining the desired state of the resource and what management options are available for achieving that desired state, designing and implementing treatments that help the site attain the desired state, monitoring the resources and evaluating how well alternative management options were at achieving the desired state of the resource, and adjusting any or all of the above based on the responses of the site to treatments (Holling 1978).

Adaptive management is an iterative process, facilitated by decisions that are repeated over time. Some parts of a restoration project such as mechanical site preparation are generally not repeated within a single project. These components may still benefit from adaptive management principles as they are informed by information or experience gleaned elsewhere. Similarly, the capacity-building approach that southern Plains parks used for their restoration projects offered managers at different parks the opportunity to learn from actions taken in other parks and adapt them to their own park.

Viewed this way, adaptive management principles as applied to prairie restoration projects in the southern Plains included both the more formal and generalized adaptive management cycle of assessment, implementation, evaluation and adjustment, as well as the capacity to learn from other restoration projects and adaptively apply them. This increased the ability to make adjustments within an individual project since it could incorporate insights gained other projects, including pilot efforts taken near the outset of a project. Adaptive management also promotes the ability to alter restoration plans to account for current climatic conditions current and expected future climatic conditions, in addition to other factors, such as a new invasion of an exotic species. Adaptive management principles are core to the Climate-Smart Conservation process (Stein et. al. 2014).

In this way, adaptive management can be used throughout a prairie restoration project, from the initial stage through the implementation phase to the monitoring phase.

Further, utilizing a learning or adaptive approach to incorporate small pilot efforts within a restoration site is also a useful strategy to adopt in shortgrass and mixed-grass systems. This approach is almost experimental and allows resource specialists to adapt restoration strategies to the specific local site conditions, and alter and improve restoration strategies as the project proceeds.



NPS PHOTO

Conceptual Planning

The first step in a restoration project is in-depth conceptual planning that identifies the restoration site and describes restoration goals and vision, and is built upon an understanding of the ecological systems that influence the site (Clewell et al. 2005, Lady Bird Johnson Wildflower Center Undated). Conceptual planning examines the primary purpose of the proposed restoration and how it influences the desired outcome and approach toward achieving that outcome. This initial planning phase is where restoration team members consider whether the restoration is based on a cultural context, a temporal reference, ecological function, or other objectives. This step is essential for defining site-specific objectives and the criteria by which success can be measured.

Ecological restoration in short and mixed-grass prairie ecosystems in the southern Plains is often complex. Restoration can occasionally be accomplished by simple removal of existing exotic and/or invasive vegetation and reseeding with desirable species. However, the process is often substantially more complicated, requiring a return of the environmental conditions that favor the growth and establishment of those species (Baer et al. 2004, Suding et al. 2004). For this reason, the southern Plains projects placed a strong emphasis on planning restoration efforts before initiating restoration activities. During planning, restoration specialists considered the ecological conditions and barriers that may impede restoration and developed site-specific strategies for overcoming them in depth. Additionally, planning efforts explored how restoration could be integrated within the surrounding landscape. Planning teams also considered each individual project within the context of how it fit within the park's significance and purpose, the overall goals and objectives of each park, and the park's General Management Plan, Resource Management Plan and Comprehensive Interpretive Plan. Discussions also included the interpretive themes for the planned restoration projects.

Conceptual planning for restoration describes and identifies the project's vision, the need for restoration, desired condition given the site's current ecological drivers and considering the impacts of climate change and explicit restoration goals (Table 5) (Clewell et al. 2005, Lady Bird Johnson Wildflower Center

Table 5. Summary of the Components of Conceptual Planning

Component	Description
Vision	The vision for a prairie restoration project answers the following questions: What is the project's vision? What is the vision for the resource? Why was the vision selected? Why is restoration an important part of the vision? How is restoration related to the park's purpose and significance?
Need For Restoration	The need for restoration is identified by answering the following questions: Why does the site need to be restored? What previous uses, past management, or lack of management contributed to the site's current condition? What physical or biologic attributes indicate a need for restoration? What characteristics of the site are not in alignment with historical or ecological integrity of the park?
Desired Condition	The desired condition is identified by answering the following questions: What types of ecosystems could be restored or created given current ecological functions at the site? What ecological system is most appropriate given park purpose, site constraints, and project goals? How can a restored ecosystem contribute the park purpose?
Restoration Goals	Restoration goals are identified by asking the following questions: Is it possible to recover the damaged or degraded ecosystem? If the ecosystem has been destroyed, can be replaced? Will restoration goals be met by a transformation to another ecological system? Can a replacement ecosystem substitute for a historic condition? How can restoration help meet other park goals?

Lady Bird Johnson Wildflower Center. Undated. Ecological Restoration Design Planning Worksheet.

Undated). It provides a clear rationale, along with goals and objectives. Conceptual planning has a deep interconnectivity to other steps in the planning process, including site assessment, identification of reference conditions and desired community, restoration implementation planning and administration, which includes making explicit plans, schedules, budgets, and details for all stages of restoration.

Vision

A vision for the restoration project clearly states the outcome and rationale, including an exploration of why restoration is needed. The vision is grounded in the natural and cultural resource context of the park and incorporates how the proposed restoration project contributes to meeting the park's mission and purpose. The vision includes a broad overview of the project, the characteristics of the natural and cultural resources of the proposed restoration site, and an evaluation of the reasons why the vision itself was selected.

Need for Restoration

A critical step in planning for successful restoration is an understanding of the current condition of the site. Current condition is dependent on site history, including what happened at the site that precipitated the need for restoration, the regional context, local impacts from past land uses and other factors, such as climate change and severe weather events. The planning process includes naming and briefly describing the kind of ecosystem that was degraded, damaged or destroyed. The need for restoration may be based on physical, biological and/or cultural factors. All possible components of a restoration project must be addressed in the restoration design.

Many ecosystems in need of restoration are dysfunctional because of damage to the physical environment, such as soil compaction, soil erosion or surface water diversion. Descriptions of how previous land uses and physical conditions impacted the ecosystem components, including community structure (grassland, savanna, etc.), taxonomic composition and life forms (forbs, grasses, shrubs, trees, etc.), moisture regimes (hydric, xeric, etc.), geomorphological context (montane, alluvial, etc.) and landscape context are necessary.

The extirpation of native species, the occurrence of rare or endangered species, the presence of nonnative or invasive plant or animal species, habitat fragmentation, changes in ecological pathways away from historical systems, anthropogenic disturbances to the ecosystem, or other impacts or stressors

VIGNETTE: Restoration Vision at Pecos NHP

Pecos NHP represents a pinyon-juniper ecotone gateway sandwiched between prairies of the southern Great Plains and the Rio Grande Valley. The region has a long and rich history of human influence including, but not limited to, indigenous Puebloan cultures, Spanish explorers, Civil War battles and events, the Santa Fe Trail, Route 66, the railroad and the Forked Lightning Ranch. The grasslands were no exception, having been maintained for centuries by the Ancestral Puebloans by clearing and for hunting big game. During the 20th century, pastures were cleared as the ranching era came into being. Thus, resource management at Pecos NHP necessitates finding the right balance between preserving the historical and ecological integrity of the park, and this balance is reflected in their vision of restoration.



View from Forked Lightning Ranch

Given this history, the concept of prairie restoration takes on a slightly different meaning than simply restoration of native prairies. Rather it encompasses restoration and maintenance of grasslands and pastures as part of a historic landscape that includes centuries of human influence. One of the challenges of this balance is the dynamics between pinyon-juniper and grasslands, and recognizing how the ecological site conditions dramatically influences the feasibility of restoring and maintaining historic grasslands and where the ecological tendencies of the pinyon-juniper dictate allowing a succession path toward pinyon-juniper.

to an ecosystem can also cause a need for restoration.

Desired Condition

For restoration to be effective, the environment must be capable of sustaining viable, reproducing species populations that comprise the biota of a desired ecosystem. The desired condition consists of the expected results of the restoration and identifies anticipated improvements and benefits. Benefits may be ecological (e.g., increased biological diversity), economic (e.g., ecosystem services), cultural (such as significant species or landscapes), aesthetic (natural beauty), and/or educational and scientific. Sociocultural improvements may include recreation, community engagement and demonstration and inspiration. Desired condition may be constrained by current and future ecological functioning at the site, and the characteristics and constraints of the site itself. Desired condition also has an interrelationship to park purpose and significance.

Restoration Goals

Goals express the ideal states and conditions that an ecological restoration effort attempts to achieve. Carefully and succinctly written goals become the basis for project evaluation at a later date. Most ecological restoration projects share a common suite of ecological goals, such as recovering ecosystem integrity, health, and the potential for long-term sustainability. These goals generally are restated for each individual restoration project along with other specific park-wide goals that may be interpretive or related to cultural resource management.

In general, restoration goals are often derived from the vision combined with the reference ecological condition. Restoration goals should

VIGNETTE: Restoration Goals for Lyndon B. Johnson NHP

The conceptual planning for restoration of a 12-acre grassland savanna area at Lyndon B. Johnson NHP had both ecological and interpretive goals. The ecological objectives were to restore a site that has been altered by exotic vegetation, agricultural berms, a gravel road and encroachment by woody species. Historical accuracy of the grassland savanna that existed at the time when the Johnson family settled the area in the 1860s will help meet the park's interpretive goals and fulfill the Johnson City unit's purpose (NPS & LBJWC 2011c). Restoring the prairie will demonstrate the landscape that enticed settlers, show the mosaic of plant communities in a mixed-grass landscape and preserve the historic landscape. This foundation of obtaining historical accuracy of the Johnson Settlement landscape influenced every aspect of conceptual planning for restoration at Lyndon Johnson NHP.



be realistic and feasible. Ecological models and research into current and desired conditions help craft attainable goals. Restoration goals fall into five broad types: recovery, replacement, transformation, substitution of a novel landscape or substitution of a replacement ecosystem (Table 6) (Clewell et al. 2005).

Some ecosystems can be recovered or restored to a known or probable historic condition, particularly when degradation or damage is not severe, anthropogenic pressures are light, and when the ecologically-young vegetation in a newly restored ecosystem tends to resemble mature vegetation of the pre-disturbance state. Other restorations may not be able to approximate a historical model or desired condition based on historical vegetation communities because contemporary constraints (such as the degree of damage, regional context, climate change and physical limitations) prevent it.

Ecosystems must be replaced when they have been completely destroyed. Another restoration alternative is transformation. Transformation is the conversion to a different kind of ecosystem that may be necessary when changes in the region make the historical ecosystem no longer viable. Substitution restoration may install either a novel ecosystem or a replacement one when the landscape has been irreversibly altered and/or no data exists as to historical condition.

Ecological restoration projects typically also have social and cultural goals. Clearly stating them provides the basis for public understanding of the project benefits. Public appreciation is conducive to garnering fiscal support, attracting stakeholder participation, and fostering a connection to the restored ecosystem among local residents. For more information on social and cultural aspects, refer to the chapters on ecological restoration design, administration and interpretation.

Conceptual Planning in the Southern Plains

Given that the majority of NPS units in the Southern Plains Network are small, sharing information, resources and expertise between parks is critical, especially for complex restoration projects in short and mixed-grass prairie ecosystems. The individual prairie

Table 6. Types of Restoration Goals[1]

Type	Description
Recovery	Restoration of a degraded ecosystem with the goal of bringing it to its previous condition.
Replacement	Restoration of an ecosystem that was entirely destroyed by replacing it with one of the same kind. The new ecosystem must be entirely reconstructed on a site that was denuded of its vegetation. This is a common approach on surface-mined lands and brownfields (severely damaged urban and industrial lands).
Transformation	Restoration that consists of a transformation to another kind of ecosystem in the bioregion to replace one which was removed from a landscape that became irreversibly altered or the conversion of an ecosystem to a different kind of ecosystem or land-use type. Transformation may be necessary when changes in the regional context make the historical landscape no longer viable.
Substitution of a Novel Landscape	Restoration that is achieved by substituting a destroyed ecosystem with a novel landscape which may have never previously existed in the bioregion. This approach is applied when the system can no longer support the historical or desired condition. The new system should be derived from native species and community associations, but assembled to suit the current site conditions.
Substitution of a Replacement Ecosystem	Restoration that occurs via the construction a replacement ecosystem because the site lacks any data as to historical condition. The replacement ecosystem may resemble a historical system, but there is no reference for comparison.

[1]Clewell, A., J. Rieger, and J. Munro. 2005. Guidelines for Developing and Managing Ecological Restoration Projects, 2nd Edition. www.ser.org and Tucson: Society for Ecological Restoration International. Available at http://www.ser.org/docs/default-document-library/ser_international_guidelines.pdf (accessed July 15, 2016).

restoration projects in each site were facilitated and aided by collaboration and cooperation with resource managers from other parks, greatly increasing the capacity of the NPS to address the need to rehabilitate and restore degraded and damaged ecosystems in these smaller park units.

The prairie restoration in the southern Plains project included planning workshops for the five parks (Bent's Old Fort NHS, Chickasaw NRA, Lyndon B. Johnson NHP, Sand Creek Massacre NHS, and Washita Battlefield NHS) that were involved in the first phase of the project between 2009 and 2011. These workshops were held in conjunction with the Lady Bird Johnson Wildflower Center. The first training workshop was held at Lyndon B. Johnson NHP, where larger restoration principles and their application to shortgrass and mixed-grass prairie were discussed in addition to completing planning and assessment activities for the park. These ecological restoration principles are summarized in Clewell et al. (2005) and Society for Ecological Restoration International Science & Policy Working Group (2004).

Resource specialists from the five parks participated in all workshops. Additionally, other representatives from the park's other divisions and programs, such as cultural resources, maintenance, interpretation, operations and management, participated in the individual park's planning workshops. The participation of resource managers from other SOPN parks was an essential component of the capacity-building approach of the prairie restoration in the southern Plains projects.

The outcome of these planning workshops was restoration plans for each of the five parks. These plans and the experience gained developing them provided resource management personnel in southern Plains parks with an improved capacity to plan prairie restoration projects utilizing restoration techniques suitable for use in short and mixed-grass prairie.

In the second phase of the project, planning workshops for Lake Meredith NRA and Pecos NHP took place. Because of NPS travel restrictions, it was not possible to hold restoration workshops on-site for two of the additional parks, Fort Larned NHS and San Antonio Missions NHP, that initiated restoration in the second phase of the project. However, information sharing between parks continued, via conference calls, the use of a sharepoint site, training in use of shared equipment, and one-on-one discussions and site visits.

Lessons Learned

- Comprehensive conceptual planning ensures that a restoration plan is suitable for the site, identifies the need for restoration and has goals that are in concert with the site's purpose and fundamental values.
- Involvement of interdisciplinary teams from across park divisions enables sharing of expertise and promotes understanding of a restoration program's goals and objectives, and how prairie restoration can have multifaceted outcomes and significances within park operations.
- Linking prairie restoration to a park's significance and its cultural resources, and placing it within both the ecological history of the area and expected future condition, can benefit a prairie restoration project by making it more effective while promoting a better understanding of the importance of healthy grasslands within NPS sites, including cultural sites where there are important links between natural and cultural resources.



NPS PHOTO

Site Assessment

An initial site assessment is an integral part of restoration planning and usually takes place in conjunction with conceptual planning. Site assessments consider current condition, current biota, soil types, potential reference sites for refining site-specific objectives and potential local seed sources in detail (Table 7). At this point, restoration specialists also evaluate how past land use may influence the restoration strategy and whether potential barriers to restoration are still present.

The full site assessment is more detailed than the preliminary site assessment that is part of conceptual planning that only identifies the need for restoration, while ensuring that restoration is consistent with park goals and is generally feasible.

The full site assessment comprehensively evaluates current condition. Components include vegetation, wildlife, microorganisms, climate and soil stability and nutrient level. The site assessment also evaluates natural processes, how past land use may influence the restoration effort and identifies any characteristics of the site that need to be corrected prior to or during restoration activities. Additionally, the overall landscape health and landscape context are analyzed. Many ecological processes such as pollination, seed/juvenile dispersal, migration, fire, flooding, etc. occur at the landscape scale. As landscapes become more urbanized or more agrarian, the ability of these processes to continue may be impacted.

A site assessment takes into account the historical community composition when known, with the understanding that component species may have changed due to larger environmental changes. Ecological Site Descriptions are important aids in characterizing historical community composition. Ecological sites are part of a system developed by the USDA Natural Resources Conservation Service (NRCS) that classifies sites with similar physical characteristics such as soils, hydrology and physiographic features, and that support characteristic plant communities that respond similarly to natural processes, land management, climate and disturbance. Ecological sites are discussed further in the Reference Condition chapter.

Table 7. Components of a Site Assessment Prior to Prairie Restoration in the Southern Plains

Component	Description
Past Site Uses	Identify and describe the past site uses and/or historical occurrence(s) that have led to the need for restoration.
Previous Site Monitoring or Assessments	Compile previous site monitoring information from the site using available monitoring and assessment reports and data sets. Describe the historical community composition, if known. Identify any trends in site condition that may exist. Identify what variables need to be monitored to assess how the site responds to restoration treatments. Identify any information or monitoring data needed prior to developing restoration implementation plan (e.g., information on groundwater levels, flow rate, soil properties, biota usage, etc.).
Physical Site Conditions	Identify any physical site conditions that may inhibit the recovery of the site such as compacted soils, loss of topsoil (including important soil biota), high degrees of water or wind erosion, etc. Evaluate soil stability and hydrologic function. Describe the hydrologic features of the site and how restoration will contribute to maintaining functional hydrology. Compile climatic information, including any data related to climate change and climate forecasts.
Baseline Ecological Inventory	Describe existing site conditions and biota, including species composition and diversity and identify the NRCS ecological site. Identify any biota that are currently present on site which could inhibit restoration (e.g., overabundance of grazing/browsing animals, presence of invasive plant species or pathogens, assess genetic alteration of native species, etc). Identify any critical species (ecosystem engineers) or keystone species missing from the site which could inhibit restoration. Describe biotic integrity.
Landscape Context	Describe the landscape context of your site. Identify any changes in the landscape context (either ecological or cultural) which could preclude critical ecosystem processes (migration, fire, flooding, etc.) from occurring.
Ecological Feedback Loops	Identify which ecological feedback loops will support restoration development, and which will inhibit it. Evaluate if a desired feedback loops could be fostered to encourage restoration, such as establishing vegetation which builds soil organic matter, which in turns may store more water and increases cation exchanges in the soil, and thereby increases vegetation.
Disturbances	Identify and describe disturbance factors (grazing, fire, flooding) that occurred on the site in the past before the site became degraded, including the seasonality, frequency and intensity of disturbance. Describe if and how have these disturbance factors have changed. Identify stressors such as drought, exotic plants, etc.
Trend	Identify and describe any trend in the condition of the site to be restored, including whether the site is continuing to degrade and/or if current condition is the result of a current stressor such as drought conditions.
Potential Reference Sites	Identify potential reference sites. Identify current locales and information about historic conditions that may be used as references. Describe the reference condition.
Potential Seed Sources	Identify potential seed sources on park and neighboring land for species either present or missing from the restoration site that may be used in revegetation treatments.

Lady Bird Johnson Wildflower Center. Undated. Ecological Restoration Design Planning Worksheet.

A site assessment also considers the status of the current community within a continuum between ecological health versus degradation. The disparity between the two will determine the types of restoration strategies required, as well as the time and resources it will take to move the community toward the target state. Further, a baseline ecological inventory will help describe the characteristics of the abiotic environment and important aspects of biodiversity, such as species composition and community structure. This inventory also identifies the normal periodic stress events that maintain ecosystem integrity and function.

A site assessment utilizes both a field assessment at the start of the project and other assessment and monitoring data. If a park has had a recent Natural Resources Condition Assessment, this report may provide valuable information on the condition of indicators such as grasslands, soils, and exotic plants. NPS inventory and monitoring networks such as the SOPN conduct regular monitoring of vegetation, exotic plants, upland communities and other vital signs. A Geologic Resources Inventory, if available, may also provide information on a park's soils, hydrology and related topics. Incorporating these existing data may also

VIGNETTE: Pollinators and Biotic Integrity

Biotic integrity refers to the ability of a biotic community to support and maintain ecological processes, composition and functional organization within the normal range of variability expected for the site. As such, integrity includes a myriad of components that make up ecological systems, including its organisms and the processes that support a functioning ecosystem. Pollinators represent a prime example of such a component as they encompass a substantial contribution to both biodiversity and functioning through the act of pollination. For example, there are hundreds of native insect pollinator species found throughout the Great Plains. According to the National Research Council (National Research Council 2007), more than 75% of 240,000 flowering plant species worldwide are pollinated by animals, with a majority of those depending on insects for pollination. Thus, pollinators play a critical role in the biotic integrity of prairies, as well as most managed and natural ecosystems.



Biotic integrity can be a complex issue as illustrated by native bee flies (Bombyliidae family) on an exotic teasel (*Dipsacus spp.*) at Bent's Old Fort NHS.

help identify trends in the condition of a park's prairie resources.

Trends and Considerations

Understanding the trend in the condition of a proposed restoration site is essential in planning restorations. For example, an increase in exotic or invasive species may result from land use (overgrazing or mowing), air quality, a climatic factor, or perhaps a shift in some other abiotic or biotic factor (e.g., thatch increase, lack of disturbance, changes in soil chemistry or biota).

Physical site conditions, such as compacted soils, loss of topsoil, high levels of water or wind erosion, and impacts of human management practices, maybe the root cause of impaired prairie ecosystems. If a site has been physically degraded, the current conditions may reflect resulting fundamental ecological changes that may be permanent. Therefore, restoration of the ecosystem may need to advance along a different successional pathway than that of a less-degraded physical system.

Evaluation of soil stability, hydrologic function and biotic integrity are all part of the site assessment. Soil stability is the capacity to retain soil and limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water. High soil aggregate stability, e.g., the ability of soil aggregates to resist disruption by outside forces such as rain or wind, is associated with greater soil stability. Soils with well-developed soil surface layers, with relatively high organic matter, that support high root biomass and that contain a high diversity of soil microorganisms tend to have high aggregate stability (USDA 2014). Areas that have had soil disturbances, have lost soil organic material, and include bare ground may have reduced soil stability. In addition to evaluating the characteristics of the soil itself, this assessment looks for signs of erosion, such as water flow patterns, rills and gullies, and plant pedestals. Wind and water erosion may impact prairie soils in different ways, and this evaluation may help identify which erosional agent is the greatest threat to the soils at the restoration site.

VIGNETTE: Site Assessment in Lake Meredith NRA

The site assessment at Lake Meredith NRA led to a change in site for a pilot restoration project. The original site chosen for restoration had many attributes that were appropriate: it was the proper size for an initial effort, was not in a visible location and suffered from a past land use history that degraded it. The initially-chosen site apparently had been a corral or holding pen during the ranching period prior to recreation area establishment. However, access to the site was very difficult, requiring materials to be moved by ATV at best. Therefore, restoration techniques such as mowing, irrigation, exotic plant control and seeding treatments would have been quite labor-intensive for the several years it would take to change its trajectory from a degraded site towards meeting restoration goals.



The restoration site in Lake Meredith NRA.

With the help of collaborative partners during the site assessment, another similar site was chosen with much easier access. The alternative site also provided better conditions for the use of fire as a restoration tool as it had roads on three sides to serve as natural fire breaks.

Hydrologic function is the capacity of an area to capture, store, and safely release water from rainfall, run-on, and snowmelt. It also includes the ability of an area to resist a reduction in this capacity and to recover this capacity after a reduction occurs. An assessment of hydrologic function includes looking for evidence of water erosion, including sheet and splash erosion, and evaluating the soil surface's ability to resist erosion and store water.

Biotic integrity is the capacity for supporting ecological processes within the normal range of variability, to resist a loss in this capacity and to recover this capacity when losses do occur. The biotic community includes plants, animals and microorganisms occurring both above and below ground. A site assessment includes descriptions of the diversity of plant communities across the landscape and at the smaller site-specific scale, and species composition including the forb, grass and shrub species.

Other considerations include any biota on the site that could inhibit restoration, the absence of critical species and disturbance factors. Biota that could potentially inhibit restoration include an overabundance of grazing or browsing animals, invasive plant species (both nonnative and native), pathogens and/or genetic alteration of native species. Critical species include ecosystem engineers who significantly modify the ecosystem by their presence within it, such as beavers, prairie dogs, crayfish or harvester ants. Keystone species such as bison, while not constructing the ecosystem itself, still have a disproportionate effect on the system relative to their abundance. Disturbance factors, such as grazing, fire and flooding, need to be understood, including the magnitude and frequency of their occurrence (seasonality and intensity) along with an evaluation of how and if these disturbance factors have changed and how they may continue to change in the future. Disturbances such as drought, ground disturbances, and exotic species invasions are also a part of this evaluation.

The landscape context, including both ecological and cultural contexts, may preclude critical ecosystem processes (migration, fire, flooding, public use, altered hydrologic patterns, etc.) from occurring in a site. Therefore, a site assessment evaluates whether original restoration goals need to be adjusted to accommodate the landscape context and what negative impacts originating from adjoining lands may have on restoration goals.

Ecological feedback loops may either continue to degrade the site or be used to restore the health of the system. It is essential to identify these feedback loops, how they will be monitored and how positive feedback loops may be utilized as part of restoration design.

During a site assessment, any apparent trend in the condition of the site is noted, along with any stressors such as drought that may be impacting the current trend. For example, a severe drought may increase the amount of a drought-tolerate exotic annual plant such as Russian thistle (*Salsola spp.*) because of lack of competition from native species.

Potential reference sites are identified to help determine reference condition and may be a nearby tract of prairie in good condition. Seed sources may need to be identified if revegetation treatments will be part of the implementation. Reference conditions will be discussed in the next chapter, and native seed collection will be discussed in the native seed acquisition and propagation chapter.

Site Assessment in the Southern Plains

Involvement of restoration specialists from other parks and park partners helped each park identify the most appropriate sites for restoration projects. Choosing appropriate sites was important, especially in these initial efforts, as they usually lead to more successful restoration outcomes. Information sharing between park units also involved specialists with different areas of expertise, thereby greatly increasing the capacity for the interpark teams to comprehensively assess a site and design implementation strategies. The interdisciplinary teams made of staff members from multiple parks were especially helpful to southern Plains parks because they all have small resource management staffs. Given the complexity of initiating prairie restoration projects, this pooling of resources was crucial.

On-site assessments by a multidisciplinary team are ideal, but administrative constraints such as budget limitations, travel restrictions and other factors, limited the ability to conduct such on-site assessments for some parks, especially in the second phase of this project. Therefore, alternatives to on-site evaluations were identified, including utilizing or adapting existing monitoring information or other avenues of expertise-sharing via one-on-one consultation, conference calls or other means.

Lessons Learned

- Involvement of restoration specialists from other parks and park partners can help identify the most appropriate sites for restoration projects.
- Information sharing between park units greatly increases the capacity to conduct comprehensive site assessments and identify implementation strategies as collaborative teams are likely to include specialists with different areas of expertise. Because prairie restoration is inherently complex, this pooling of resources is crucial.
- On-site assessments by multidisciplinary teams are the preferred method to conduct site assessments for restoration projects.
- Constraints such as budget limitation may require use of alternative strategies in order to complete site assessments. For example, existing monitoring data and other avenues of expertise sharing can contribute to site assessments in such situations.



DAWNELLE MALONE

Reference Conditions

Reference conditions provide descriptions of system attributes that characterize the ecological integrity while accounting for the natural variability desired for the prairie restoration site (Table 8). The reference condition builds on the restoration vision identified in conceptual planning and takes into account current condition, cultural considerations, ecosystem descriptions and other information. The reference serves as a potential target in planning restoration projects and is also utilized to evaluate restoration efforts (Society for Ecological Restoration International Science & Policy Working Group 2004). The reference conditions should also be consistent with goals outlined in the conceptual plan.

In prairie restoration projects on the southern Plains, resource specialists differentiated the term "reference condition" from the term "desired condition" that the NPS uses in National Environmental Policy Act (NEPA) and other planning processes. Desired condition, as used in NPS planning, is too broad to be used to guide restoration efforts and, given NEPA, has a legal connotation that would not be applicable.

In many cases, there is too much uncertainty as what the targeted conditions should be for an individual restoration site given variables such as the past use, climate change and other factors. Therefore, it would be premature to call these targeted reference conditions in restoration efforts "desired conditions," particularly in the context of NEPA compliance, because they may be subject to revision as more information about the site becomes available as restoration proceeds. In this light, a succinct definition of reference condition as used to guide restoration is a tentative but measurable desired condition. Thus, a reference condition serves as an interim measure that has no legal connotation under NEPA. However, in some circumstances, parks may decide that there is enough confidence that the reference condition reflects the conditions wanted in the site, and adopt it as a desired condition for NEPA purposes.

Table 8. Sources of Information That Inform Reference Condition

Source	Description
Reference Site	A good ecological analogue to the restoration site with similar soils, geography, climate, size, spatial context and other characteristics. Reference sites generally are local. A nearby or neighboring patch of prairie may serve as a good reference site for restoration projects for parks in the southern Plains.
Ecological Remnants in Restoration Site	Parts of the ecosystem in the site to be restored that are intact can inform the reference condition.
Ecological Site Description	Ecological Site Descriptions are reports from the NRCS about the distinctive kinds and amount of vegetation that inhabit lands with specific characteristics that serve as useful starting points for restoration planning.
Historical Information	Historical information, including historical descriptions, historic photographs, aerial photographs and other documentation about the restoration site can add important insight into what reference conditions for a restoration site should be.
Local & Regional Plant Lists	Species lists and herbarium specimens can provide information on species that may have grown in the site to be restored.
Wildlife Habitat Needs	If providing habitat for wildlife species is identified as part of a restoration effort's conceptual plan, utilizing information about wildlife habitat requirements is an important aspect of determining the reference conditions.
Cultural Considerations	Cultural factors related to the interrelationships between historic use of the restoration site and the interplay between natural and cultural resources are especially important for prairie restoration projects in sites with cultural significances.
Expert Opinion	Incorporating expert opinion from restoration ecologists and specialists who have in depth knowledge of local conditions and systems can help craft reference conditions targeted to the unique attributes of the site to be restored.

Information is adapted from Society for Ecological Restoration International Science & Policy Working Group (2004)

***Reference conditions** are the targeted conditions that encompass ecological integrity used to guide restoration efforts.*

***A reference site** is a particular place that serves as a good analogue of the restoration site.*

Reference conditions may or may not be based on a specific reference site.

A reference condition can be based on a single reference site or ecosystem and/or it can be modeled on the basis of Ecological Site Descriptions, ecological remnants in the restoration site, historical information, local and regional plant lists, wildlife habitat needs, cultural considerations and/or expert opinion (Table 8).

Reference Site

A reference site or ecosystem is considered to be a good analogue of the restoration site and is usually a particular place that has several characteristics in common with the site needing restoration (White and Walker 1997). Reference sites are especially useful when monitoring data on them are available. A drawback of extant reference sites is that they represent a single state or a "snapshot" of an ecosystem (Society for Ecological Restoration International Science & Policy Working Group 2004). Additionally, historic site conditions may not persist into the future, especially under expected changes in climatic conditions. In short, a reference site can only represent a moment in time, and is only one of many potential states within the historic range for the particular ecosystem. Further, a reference site reflects the particular localized events that occurred there during ecological development. Because each site presents a unique set of circumstances and because no two ecological areas are identical, a reference site cannot be a perfect model for the site to be restored. Therefore, restoration planning needs to try to account for any differences between the characteristics of the reference site and the restoration site.

Selecting reference sites is also more difficult when current conditions or constraints in the site to be restored have altered the historic trajectory of the site or when the region lacks

VIGNETTE: Ecological Site Descriptions Contributed to Reference Conditions at Bent's Old Fort NHS

Bent's Old Fort NHS used Ecological Site Descriptions to help craft reference conditions for their restoration efforts. Three ecological sites make up most of the historic site: loamy plains, salt meadows and sandy bottomland, with loamy plains and salt meadows most relevant to the site to be restored. The loamy plains historically supported grassland communities dominated by warm-season mixed-grasses such as western wheatgrass (*Pascopyrum smithii*) and blue grama (*Bouteloua gracilis*), although tallgrasses, cool-season grasses and forbs such as Mexican hat (*Ratibida columnifera*) made up an important component of the plant community. Woody plants such as fourwing saltbush (*Atriplex canescens*) typically make up 5 to 10% of the community (NPS in preparation). The salt meadow ecological site is found on bottomland soils with a historic plant community that was composed of 80 to 85% grasses, 3 to 10% forbs and 2 to 10% woody species.



This area of the loamy plain ecological site has no evidence of past agricultural use, but was probably grazed.



Bindweed (*Convolvulus arvensis*) dominated the severely degraded field prior to restoration efforts.

Prior to the start of restoration efforts, the site to be restored at Bent's Old Fort was an abandoned prairie dog town that occupied a severely degraded "go-back" agricultural field. The Ecological Site Descriptions helped inform reference conditions and were also used to help identify reference sites within the park (NPS and Lady Bird Johnson Wildflower Center 2011a).

comparative ecosystems to the restoration area (Clewell et al. 2005).

Because a single site is not likely to be completely analogous to the site to be restored, the reference condition may be more applicable when it is assembled from multiple reference sites and/or other sources of information. The resulting composite description of the reference condition gives a more realistic basis for restoration planning (Society for Ecological Restoration International Science & Policy Working Group 2004).

Ecological Site

An ecological site is "a distinctive kind of land with specific characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation" (NRCS 2016). Ecological sites have similar soils that support characteristic plant communities and respond similarly to natural processes, land management, climate and disturbance (NPS &

VIGNETTE: Challenges in Defining Reference Conditions at Pecos NHP

Determining reference conditions for a site with a long period of historical significance may present challenges in addition to the uncertainties inherent in identifying references. The human story of Pecos NHP extends from at least the Puebloan time period, when the first pueblo was built at Pecos at approximately 1100 CE, through the historic ranching era. It includes the arrival of the Spanish in the 1600s CE and the establishment of the Pecos Mission and the Civil War. Environmental conditions were also dynamic during these time intervals, especially in the proportion of pinyon-juniper woodlands to grasslands. At the time of Spanish contact, the area adjacent to the pueblo was clear of trees, most likely due to firewood harvesting. During the Spanish period, grasslands experienced some encroachment of pinyon-juniper woodland (Knudten and Bzdek 2008). Today, the lower elevations in the park consist of an interspersion of pinyon-juniper and grasslands. The reasons for infilling of pinyon-juniper is likely influenced by both ecological site conditions as well as the long history of changing human use of this landscape (Johnson and Smith 2011).



The ratio of pinyon-juniper to grassland has changed over time at Pecos NHP (shown hypothetically above). Part of determining reference conditions for this park is consideration of the time periods to use as references and what the vegetation communities may have been present at those times.

These changes over time makes for a set of different reference conditions that reflect the dynamic environment. In order to guide restoration efforts, managers need to consider both the time period of significance as well as the ecological site conditions. For Pecos NHP, the appropriate reference condition for some sites may be a period of historical significance rather that a pure reflection of ecological conditions. As these examples show, at historic sites, restoration projects may be approached from within a context of cultural resources and the site's fundamental resources and values rather than focusing on natural resource values.

This situation at Pecos NHP also illustrates the difficulty that managers can face in defining reference conditions in a historic area, particularly one with long or multiple periods of significance.

LBJWC 2011a). Ecological Site Descriptions are reports available from the NRCS that provide information about site characteristics and plant communities. These descriptions are useful starting points for restoration planning because they provide an idea of what plant communities the site historically supported and what it is capable of supporting (NPS & LBJWC 2011a). Ecological Site Descriptions always provide what is considered the historic climax plant communities, and they also often provide information on characteristics of altered states and recommendations on how to move a community back to the historic condition through state and transition models. Because climax conditions may not have occurred in the park, especially during the period of historic significances in a cultural site, some Ecological Site Descriptions can only be used in a more generalized manner to guide restoration efforts.

When reference ecosystems are not available, the reference condition is more conceptual. Historical information, including historic and aerial photographs and descriptions of the region's vegetation, can help frame reference conditions. The reference can consist of descriptions of the pre-disturbance condition of the site itself, if known. In other situations, local and regional plant lists and herbarium specimens also can inform the development of reference conditions, as can wildlife habitat requirements when providing wildlife habitat is part of the conceptual planning for restoration (Figure 10).

Historical and cultural information plays a role in determining reference conditions, especially at cultural sites in which prairie ecosystems are an integral part. Reference descriptions for ecosystems of particular cultural value should identify the cultural practices that are critical in restoring, and later managing, that ecosystem. These practices may include plant and seed harvesting, managed grazing, and other uses. Beyond the cultural uses of the ecosystem, the interaction of people and the landscape is also important. Considerations include factors such as the ways the landscape was used historically and ways that restoration goals enhance that story. Additionally, interpretive objectives related to how visitors may perceive and experience the ecosystem throughout the process of restoration are important.



DAWNELLE MALONE

Figure 10. Habitat requirements for wildlife can inform reference conditions for restoration projects.

Finally, it is essential to incorporate expert opinion in the development of reference conditions for restoration projects. This is especially the case in situations where good reference sites are not available and/or the climax communities described for the relevant ecological sites may not have existed in the restoration site, particularly for the period of cultural significance at a specific NPS site. Expert opinion can both help identify the best sources of information upon which to base a reference condition and help craft the specific components of that reference condition.

The precision with which a reference condition can model successful restoration is highly variable depending on its specificity and appropriateness. In some cases, the reference condition can only provide a general description of the direction of ecosystem development (Clewell et al. 2005). In other situations, where excellent reference sites exist and when supplemented with additional information, the reference condition may have a great deal of specificity and detail. However, the reference condition must remain broad enough to allow for the acceptable range in variability that reasonably can be expected from restoration (Clewell et al. 2005). In

general, the concept of reference must be dynamic (Gann and Lamb 2006).

Reference Conditions in the Southern Plains

Identifying reference conditions was an integral part of planning restoration efforts in southern Plains parks. Because current conditions varied greatly in each park, and because local sources of information also varied, individual parks faced different challenges in crafting reference conditions. Each park utilized different sources of information depending on whether good reference sites existed and what other resources were available.

In NPS sites in the southern Plains, local patches of prairie in good condition could be used as reference sites where it existed. Sand Creek Massacre NHS was able to utilize the prairie in the area surrounding the monument.

The Bamberger Ranch, a 5,500-acre property that has undergone restoration since 1969, and the Lady Bird Johnson Wildflower Center served as reference sites for the restoration project in Lyndon B. Johnson NHP. However, there was still considerable uncertainty in determining the reference condition for Lyndon B. Johnson because no intact prairie exists from 1860s, the period of reference for the Johnson City Unit when Johnson's ancestors first arrived in the hill country.

Other parks, such as Washita Battlefield NHS and San Antonio Missions NHP, did not have good reference sites available and had to develop hypothetical reference conditions using Ecological Site Descriptions, historical information and expert opinion. At Washita Battlefield, park and surrounding lands have been significantly altered by agriculture. Except for the Rancho de las Cabras Unit, San Antonio Missions NHP is surrounded by urban lands. In these situations, historical documents, such as journals of explorers and settlers, may provide a general description of similar sites in the area.

Lessons Learned

- Establishing reference conditions prior to initiating restoration efforts is essential, as they help both define restoration goals and provide a benchmark to use in evaluation.
- Many sources of information can help inform reference conditions including physical reference sites, Ecological Site Descriptions, historic information and expert information. The best reference conditions may incorporate more than one source of information.
- Ecological Site Descriptions are especially useful in defining reference conditions because they are based on both site characteristics and plant communities. However, because the NRCS ecological sites may only include descriptions of historic climax plant communities, uncertainties may exist whether the site to be restored consisted of that climax community prior to degradation. For example, previous use at the site to be restored may have altered which plant communities that the site can support.
- Using adaptive management principles in utilizing reference conditions is just as important as adaptively managing the other parts of the restoration process.



Administration

Administration, including completing compliance, managing fiscal, physical and human resources, keeping an institutional history (documentation), coordinating with other divisions and overall park operations, and developing partnerships, is an integral part of an entire ecological restoration project (Table 9).

Administration in the Southern Plains

Because the PMIS projects that supported the prairie restoration projects on the southern Plains involved many parks, they provided many opportunities and challenges related to the administration of the project. In particular, the multipark aspect allowed many opportunities for collaboration and information-sharing, which strengthened each park's individual efforts. Additionally, it provided a great opportunity for capacity-building for restoration projects where resource management staff spread across many parks gained restoration expertise that could be shared with other parks and used on other projects. This capacity-building component of the project was particularly critical in the southern Plains given the small resource management staffs, and was an integral part of the overall project.

Physical and human resources were also shared between parks. For example, funds from the PMIS project for the second phase were utilized to hire student interns who assisted with a variety of projects in six park areas. For example, at Chickasaw NRA, interns assisted with site assessments in grassland sites to determine priority management areas for exotic plant species and control methods strategy development. At Fort Larned NHS, the interns identified native plants along the trail to the fort, developed interpretive materials, and assisted with the treatment of field bindweed (*Convolvulus arvensis*).

Phase I of the multipark restoration project enabled the parks to purchase equipment to share, including a seed stripper, screens for cleaning seeds, a drill seeder and a trailer to transport equipment. Sharing equipment meant that each park did not have to buy or rent expensive specialized equipment on their own, providing fiscal efficiency for prairie restoration efforts that individual parks would not have been able to provide independently.

Table 9. Summary of the components of Administration

Component	Description
Compliance	Includes NEPA and Section 106 of the National Historic Preservation Act of 1966. All compliance forms and consultations need to be completed prior to the commencement of restoration treatments. Also includes Endangered Species Act compliance if applicable.
Resources (fiscal, physical & human)	Includes all fiscal, manpower and physical (equipment and plant materials) resources needed for a restoration project. Restoration projects may require grant or PMIS project funds. Manpower needs may be met with permanent or seasonal staff, interns or volunteers. Physical resources include equipment that may need to be purchased, rented or borrowed, supplies such as herbicides and plant materials including seeds and plugs.
Institutional History	Includes all documentation necessary to create an institutional history of restoration efforts at the site. It includes monitoring reports, purchase requisitions for equipment, materials and supplies, restoration timelines, treatment plans, the conceptual plan, site assessment and reference condition, grant proposals and reports, annual reports and any other documentation that will help future managers understand what restoration treatments have been taken at the site, how conditions at the site changed as a result of restoration treatments and environmental factors and other information. Many reports and proposals can be re-purposed into project documentation. An understanding of a restoration site's environmental history itself can be a restoration tool.
Coordination & Partnerships	Includes the integration of restoration efforts with park operations and programs, and coordination with other park divisions and park partners. Partnerships such as with volunteer organizations, friends groups, schools and researchers may help park staff successfully conduct restoration projects.

This equipment continues to be shared among parks as they continue with restoration projects.

Compliance

Prairie restoration projects in NPS units must adhere to the requirements of the National Environmental Policy Act and Section 106 of the National Historic Preservation Act of 1966. All compliance screening forms, assessment effect forms, environmental assessments and Section 106 consultations need to be completed prior to commencing restoration treatments.

In order to utilize an adaptive management approach in prairie restoration projects, compliance needs to meet NEPA requirements, but also enable flexibility in order to adjust restoration actions in response to current conditions and changes due to factors such as drought, fire, grasshopper infestations and other variables that may influence restoration projects.

The prairie restoration projects in southern Plains parks did not impact any listed species under the Endangered Species Act, and compliance issues related to listed species are not addressed in this report.

Traditionally, Environmental Assessments (EAs) and other compliance documents for prairie restoration projects have been written with a great deal of specificity in terms of detailing exactly what treatments will occur at a specified time. For example, EAs have delineated what specific herbicide will be applied to control a specific exotic plant in what month of a multiyear project. However, such prescriptions in compliance documents constrain what treatments can be taken and don't allow managers to use adaptive management to adjust parameters of restoration efforts in response to changing conditions in the restoration site. In many ways, traditional compliance documents can be so specific that they don't allow managers to respond to changing conditions in a restoration project, and utilizing adaptive management principles may not be compatible with them.

An alternative to writing EAs with highly specific prescriptions and detail is to describe generalized desired conditions for prairie restorations within the EA and to recognize the uncertainty of highly specific prescriptions and accommodate those as part of an adaptive management process. This can be accomplished by using annual work plans that complement the EA and are consistent

with the general desired conditions of the EA. These work plans can then undergo park-level compliance to ensure their consistency with the EA, but enable the flexibility to accommodate the dynamic and uncertain conditions that are encountered when implementing the restoration.

This approach allows for strategic vegetation management and enables the use of alternative management strategies. For example, a park could use chemical or mechanical treatments or prescribed fire to control exotic plants under such an EA depending on the effectiveness of alternative treatments and other factors. Annual work plans may provide specific information on treatment strategies such as stating that a particular herbicide will be applied to an identified exotic species that may be particularly prevalent due to drought or another environmental condition. In this way, the EA will still be able to determine whether restoration actions may be detrimental to the landscape and ecosystem, but managers are able to take the most appropriate restoration actions given current conditions and environmental variables.

Lessons Learned

- EAs can be used to outline critical elements and generalized desired condition for prairie restoration projects and incorporate a built-in capacity for flexibility in order to enable adaptive management.
- EAs that include specific prescriptions for restoration treatments may not allow managers to adjust to changing conditions in restoration sites.
- Annual work plans prepared underneath an overall EA may enable managers to respond to environmental conditions while still determining whether restoration actions will have an adverse impact on the landscape.

Resources

A variety of resources, including fiscal, personnel or manpower, and equipment, are necessary for implementation of prairie restoration projects.

A park's ability to complete a prairie restoration project is directly tied to the budget available to hire staff to complete restoration activities, and to purchase seeds, herbicide and other needed materials. Some aspects of a prairie restoration project, such as staff time, may be supported via a park's base funding, but other components such as purchasing materials may require specific funds from a PMIS project or other grant source.

Having adequate personnel available to complete restoration activities is often a limiting factor for parks undertaking a restoration project. Many tasks, such as exotic species management and native seed collecting, are time- and/or personnel-intensive. Volunteers may be able to assist with some parts of the project, such as hand-pulling exotic plants or collecting native seeds. If burning, grazing or mowing is anticipated to be a part of site maintenance, it may require the availability of specialized personnel such as an NPS fire group.

In addition to having adequate manpower, parks also need to have staff trained or experienced in working on restoration projects in short and mixed-grass prairies. Partnerships with organizations, such as other land management agencies or universities, can sometimes address personnel needs and may



Resources needed for a prairie restoration project includes equipment, plant materials, staff and fiscal.

VIGNETTE: Capacity-Building

An integral component of the prairie restoration projects in southern Plains parks was capacity-building within the NPS to address the large backlog of needed restoration projects in the Intermountain Region. The capacity-building aspect of this project included individual National Park Service units acquiring and sharing equipment and building staff knowledge, skills and expertise. During the planning or initial phases of each park's restoration project, a team of resource managers from participating parks worked in concert with experts from the Lady Bird Johnson Wildflower Center. Using this approach, team members participated in planning of not only the restoration in their own parks, but in the planning for the other park projects as well. This approach promoted the development of internal expertise that can serve as a resource for future restoration efforts.



This seed stripper was shared by parks conducting prairie restoration projects in the southern Plains.

The prairie restoration in southern Plains parks project also funded three interns that were shared between the parks. The collaborative nature of this project enabled fiscal efficiencies in hiring intern staff that would not have been possible if each park worked independently.

Sharing equipment between the parks was another key attribute of the collaborative approach to prairie restoration projects in the southern Plains. Collectively, the parks had most of the equipment necessary for prairie restoration (two seed harvesters, a seed drill, mowing equipment, fire equipment, broadcast seeders and UTV with attached weed sprayer), some of which was purchased during Phase I of the project. Sharing this equipment was cost-effective and enabled individual parks to have access to equipment that they either would not have had the funds to purchase or rent.

help provide needed expertise to conduct restoration projects. Friends groups and civic organizations can be a source of volunteers to supplement staff efforts.

Restoration projects often require equipment such as herbicide sprayers and mowers, supplies such as herbicide, and plant materials including native seeds and/or native plant plugs. Some of these physical resources must be purchased, but equipment may be rented or borrowed from another park or from other nearby state or federal agencies. It may be possible to collect native seeds or grow seedlings in a greenhouse.

Institutional History (Documentation)

Keeping adequate documentation to create an institutional history of restoration efforts is an integral, but often overlooked, part of restoration projects. The impetus for keeping documentation is to not only meet requirements for PMIS funding and other grants, but also to create a historical record so that future managers will know what was previously done in a restoration site. Given that restoration projects in the complex short and mix-grass prairie ecosystems in the southern Plains span great lengths of time, proper documentation that builds an institutional history of restoration efforts will allow for continuity of treatments. An institutional

VIGNETTE: Personnel Changes

Prairie restoration projects in national park sites in the southern Plains have a long life-span. Park staff members who submit grant applications or PMIS projects to fund projects are often not the same individuals who will initiate restoration activities. Further, since restoration projects in short and mixed-grass prairies may ultimately last as long as decades, the staff members who begin revegetation treatments likely will not be the personnel who work on the projects' later phases. For example, the Natural Resource Chief at Chickasaw NRA participated in Phase I of the project, but had retired prior to the initiation of Phase II.

The long time frame required to secure funding and then complete a restoration project, combined with staff turnover in many NPS units, presents another challenge to completing restoration projects. Resource managers who are involved in the preliminary parts of a project may assist their successors by ensuring that the vision for park restoration fits with the park's purpose and significance. For example, at Washita Battlefield NHS, prairie restoration efforts were tied to the historic viewshed. In this way, prairie restoration projects become a part of the overall park operation. The importance of prairie restoration can be reflected in GMPs, comprehensive interpretive plans and other documents. Resource managers can also help future managers by keeping detailed records of restoration activities, monitoring reports and other documentation.

history will help prevent future resource managers from having to reinvent or re-initiate restoration efforts and enable them to better utilize adaptive management principles based on the knowledge and treatments applied by their predecessors.

Lack of proper documentation and the dearth of institutional history has been a missing link in many prairie restoration projects.

Keeping adequate documentation that builds an institutional history does not have to be complex nor be an extra time-consuming responsibility on an already overburdened resource management staff. Instead, integrating documentation into regular workflow by designing field data sheets and database applications for treatments and monitoring efforts will seamlessly provide a mechanism to record the history of restoration. Information about restoration treatments can also be noted during regular monitoring protocols.

Developing seasonal and annual work plans and timelines, and keeping track of expenditures and maintaining budget worksheets are other ways of keeping documentation that will help manage the restoration project on an ongoing basis, and will also provide critical information to future managers about the history of restoration efforts. In this way, keeping proper documentation itself becomes another restoration tool.

Managers can take advantage of existing documentation requirements for PMIS reports, grant reports, annual work plans for the division and/or resource management, performance planning, budget tracking and other reports as a way to track a prairie restoration project. Restoration specialists can also utilize these reporting requirements for grants as a tool for building a historical record of restoration activities by ensuring that copies of reports are kept with other restoration records, as part of both electronic and paper records management.

Institutional History in the Southern Plains

Lack of proper documentation and the dearth of institutional history has been a missing link in prairie restoration efforts in many parks. Staff turnover is common in NPS sites, and there may be a time lag of years between entering a PMIS project into the system and the project being funded.

In general, the knowledge of what work transpired in a prairie restoration project is not available to new managers who inherit responsibility for ongoing restoration projects. A common result of a lack of proper documentation/institutional history is that a new manager takes a project in a different direction. When that happens, restoration becomes a piecemeal process instead of being part of a comprehensive long-term project working towards defined goals and a vision. It also may preclude utilizing adaptive management to adjust restoration efforts based on learning from what happened in the past.

Some park managers have found relatively simple mechanisms to generate institutional histories of their restoration efforts. For example, staff at Bent's Old Fort NHS ensured that all timelines, purchase requisitions and other working documents that related to restoration projects were incorporated in the park's central files.

Likewise, PMIS accomplishments and completion reports can contribute significantly to creating an administrative record of restoration efforts. Managers who oversee prairie restoration efforts may also prepare simple annual reports as addenda to prairie restoration plans.

Coordination & Partnerships

Coordinating with other divisions and park operations, and with partners and collaborators, can add to the success of a prairie restoration project. Maintenance staff may be able to assist with treatments such as mechanical site preparation and/or herbicide applications. Fire Groups can conduct prescribed burns. Exotic Plant Management Teams can provide herbicides and manpower. In small parks, like many of the southern Plains sites, cross-divisional coordination is especially important because staff sizes are also small.

Coordinating with other divisions can also help ensure that restoration activities negatively impact park visitors as little as possible and that they do not conflict with other park operations. Involving interpretation with restoration projects can provide both

Lessons Learned

- There is a strong need for keeping documentation to provide institutional history on a prairie restoration project in order to give these difficult long-range projects the greatest odds for success.
- Institutional histories can help ensure that restoration efforts are not piecemeal and can take advantage of adaptive management principles by allowing future managers to adjust restoration treatments based on previous restoration efforts.
- Many alternatives exist that can provide information about restoration actions and that create an institutional history. Many of these alternatives are simple and not time-consuming.
- Ideally, a streamlined process can be developed so that the entire restoration process, from initial planning to the results of long-term monitoring, is documented in order to assist current and future restoration efforts.
- Institutional histories also help managers plan other restoration projects, serve as case histories of restoration efforts in NPS sites, help interpreters understand and communicate park stories, and become part of the administrative history of a site.

VIGNETTE: Butterfly Garden at Fort Larned NHS



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Restoration efforts at Fort Larned NHS took place in conjunction with a major project to build a new pedestrian bridge and visitor parking lot in 2013. A new pedestrian bridge and parking lot replaced a structurally-deficient bridge that visually detracted from the historic scene. The project was funded by the Federal Lands Transportation Program and also included revegetation of the parking lot that was removed.

In 2014, Steve Sterns, a volunteer-in-park who is also a teacher at Larned Middle School, spearheaded a project to build a butterfly garden in one of the new parking lot islands. The new lot had lacked natural aesthetics and interpretive content. The conversion of the 8.5 x 3 m (28 x 10 ft) area into a butterfly garden with a Conestoga wagon, flowering vines, decorative stones, and native and adapted flowering plants added a visual focus to the area while drawing attention to one of the ecological functions of native prairie. The goal of the garden is to attract monarch butterflies and other pollinators while providing habitat and nourishment for these vulnerable species.



Fort Larned Chief Ranger George Elmore, Steve Sterns and Park Ranger Ellen Jones at the Fort Larned butterfly garden.

Volunteer Sterns coordinated the efforts of students from the Larned Middle and High Schools, who designed the garden, propagated plants in their classrooms, and planted them in spring 2015. Student participation in the project was also facilitated by Ticket to Ride grants from the National Park Foundation that provided transportation to the historic site. Bent's Old Fort NHS provided educational materials through a Regional Pollinator Grant for use with this project.

Native species planted included coneflower (*Echinacea spp.*), blacked-eyed Susan (*Rudbeckia hirta*), purple prairie clover (*Dalea purpurea*), and common milkweed (*Asclepias syriaca*), whose seed was collected from the historic site. The pollinator garden is an important interpretive tool for Fort Larned since the surrounding prairie has been either converted to agricultural land or seeded to smooth brome (*Bromus inermis*). Although smooth brome visually suggests what the prairie may have looked like when the fort was in use, native species are largely absent today.

Steve Sterns not only led the student's involvement in the project, he also volunteered himself and obtained donations from local business and the community for garden-building materials. Altogether, Mr. Sterns and his students contributed more than a thousand volunteer hours to the project.

Fort Larned's butterfly garden is a good example of how restoration projects can be part of a project that meets other park objectives, such as providing for education. Additionally, the involvement of volunteers such as Steve Sterns can be critical to the success of any restoration effort.

VIGNETTE: Collaboration with USFWS Burn Team at Lyndon B. Johnson NHP



The mixed-grass prairie in the restoration site at Lyndon B. Johnson NHP needs periodic burning to control woody plant invasion and rejuvenate native grasses. However, the entire restoration site is only twelve acres, and the southern Plains Fire Group is based in Lake Meredith NRA, located hundreds of miles away. Therefore, the park has partnered with the US Fish and Wildlife Service at the nearby Balcones Canyonlands Wildlife Refuge to use their burn team, which has an experienced fire boss. The Balcones Canyonlands fire crew conducted a burn at Lyndon B. Johnson NHP in spring 2014. This partnership has given the USFWS crew more burn hours for their program and continued the existing collaboration for training collaboration between the two facilities' law enforcement personnel.



Indian ricegrass (*Sorghastrum nutans*) after the prescribed fire with Chief of Resource Management Dave Shafer.

important information and compelling stories for interpreters and help park visitors understand restoration objectives.

Developing partnerships with other agencies and organizations, and with volunteer groups can also assist with restoration projects in myriad ways.

Coordination & Partnerships in the Southern Plains

Coordination with other divisions within the parks conducting restoration projects and with other parks contributed significantly to the prairie restoration projects in the southern Plains. Partnerships with outside agencies and organizations also were important. For example, at Lake Meredith NRA, the Division of Maintenance helped move mowing and other heavy equipment on public roads, since no one in Division of Natural Resources had a Commercial Drivers License (CDL). At Lyndon B. Johnson NHP, the Division of Maintenance provided equipment and expertise to remove terraces in the restoration area in order to re-establish the natural hydrology at the site. US

Fish and Wildlife Service personnel from a nearby wildlife refuge conducted a prescribed burn.

Coordination and cooperation was inherent between parks using the capacity-building approach adopted for the prairie restoration projects in southern Plains parks. Staff, equipment and expertise were shared during the project. Interpark agreements and regular conference calls also assisted with information- and expertise-sharing.

Partnerships between NPS sites and groups and other agencies and organizations have also benefited prairie restoration efforts in the southern Plains. Planning workshops for five parks in Phase I of the project were held in conjunction with the Lady Bird Johnson Wildflower Center. Additionally, a partnership with Master Naturalists, a program of Texas Parks & Wildlife, is being formed for work in the restoration area at Lyndon B. Johnson NHP. Bent's Old Fort NHS partnered with Otero Junior College in La Junta, Colorado to grow plants for restoration projects in the college's greenhouse.

Within the NPS, the Southern Plains Fire Group helped with prescribed burns and mechanical mastication to reduce fuel loads when fires were prohibited in the later years of the projects because of drought conditions. The fire group also conducted mowing and mastication treatments at Lake Meredith NRA, Sand Creek Massacre NHS, and Washita Battlefield NHS. The EPMT (Exotic Plant Management Team) program provided herbicides to parks and work crews for specific treatments. Crews cut exotic trees, including tamarisk (*Tamarix spp.*) at Washita Battlefield NHS and Lake Meredith NRA, and Siberian elm (*Ulmus pumila*) at Washita Battlefield NHS. The EPMT also sprayed for Johnsongrass (*Sorghum halepense*) and yellow sweetclover (*Melilotus officinalis*) at Washita Battlefield NHS. The Fire Group and EPMT also consulted on various restoration projects including restoration treatment planning at Bent's Old Fort NHS, Sand Creek Massacre NHS, Pecos NHP, and Washita Battlefield NHS.

Lessons Learned

- Multiple park objectives can be met when prairie restoration efforts are integrated with other park projects.
- Coordinating restoration projects with other initiatives helps develop synergy among park divisions and helps highlight the interrelationships between natural and cultural resources.
- Developing partnerships with volunteers and service organizations can help park meet restoration goals.
- Volunteers may become stewards or champions for restoration projects and become important members of restoration teams.



NPS PHOTO

Restoration Implementation

Restoration treatments may begin once the conceptual plan and site assessment have been completed, the reference condition has been described, and necessary administrative requirements such as compliance have been completed. The overarching objectives of restoration treatments are to implement the vision outlined in the conceptual plan, while taking account of the site's current condition and reference condition. Each restoration project will be unique in regards to its complexity and what treatments will be warranted.

Implementation planning involves identifying and scheduling specific restoration treatments while maintaining flexibility through the use of adaptive management. Specific restoration treatments include site preparation, native seed acquisition and propagation, revegetation and passive restoration (Table 10). Not every potential restoration technique will be used in any restoration effort. Restoration treatments must be tailored for each site and based on information gathered during the restoration planning phase (Figure 8). Restoration treatments may also need modification due to administrative factors such as lack of manpower or specialized crews to complete prescribed actions. Treatments are also subject to modification based on climatic variables, such as drought, and events such as floods, fires, or severe weather events.

After restoration actions are implemented, they must be followed by management and maintenance treatments, which will be discussed in a subsequent chapter.

Implementation Planning

Planning restoration treatments, otherwise known as ecological restoration design, is an essential first step in the implementation phase of a restoration project (Figure 8). This process serves to identify what specific actions the restoration project requires in order to be successful. It is informed by and dependent upon the conceptual plan, site assessment and reference condition. Implementation planning also identifies what types of restoration treatments may not be necessary or may in fact negatively impact a site given its current condition and other characteristics. For example, revegetation treatments do not need to take place in all restoration projects, and in some circumstances, a mechanical site

Table 10. Implementation Planning

Component	When Needed	Constraints/Considerations	Possible Treatments
Site Preparation			
Mechanical Site Preparation	When site has been physically altered by furrowing, soil compaction, terracing or roads.	Use only when native species are not present or when site is so physically altered that functioning ecosystem cannot be developed.	Disking, leveling, road removal, etc.
Exotic Species Removal & Management	When exotic species of concern that would outcompete native species are present or in the seed bank.	Use the least amount and most target-specific herbicides possible. Clean mowing equipment when moving between areas.	Chemical application, mechanical treatments, manual treatments
Invasive Species Removal	When native brushy or shrubby species have invaded prairie.	Many woody species require timely stump treatment to prevent re-sprouting.	Pulling, cutting, shearing, chemical application
Holding Crops	Following mechanical site preparation and prior to revegetation treatments.	Only use for one season in order to prevent wind erosion or to shade out exotic species.	Seeding
Native Seed Acquisition			
Method of acquisition (Collection or Purchase?)	When revegetation treatments will be a part of restoration.	Availability of local native seeds to collect, cost of collection.	Collect or purchase seeds
Collect Seeds	When native seeds are needed for restoration activities.	Requires monitoring for seed ripeness. Takes a lot of manpower. Seeds must be dried and stored.	Hand collection, mechanical collection, use of volunteer groups
Propagate Seeds	When plugs or seedlings are needed for revegetation or to increase the amount of available seed for revegetation.	Cost. A lot of manpower and greenhouse availability needed to propagate. Alternatively, need to contract with grower.	n/a
Purchase Seeds	When native seeds are needed for restoration are not available for local collection.	Cost. Need to find good supplier.	n/a
Revegetation			
Seeding	When area needed to be revegetated.	Appropriation of adequate equipment.	Broadcast seeding, seed drilling, interseeding
Transplanting	In situations where seeding is not likely to be successful.	Transplants require initial irrigation.	Transplanting along with watering
Irrigation	When rainfall is inadequate during and following revegetation treatments.	How to get properly-timed supplemental water to site.	Flooding, sprinklers, water truck
Passive Restoration			
Passive Restoration	When native plant components are present and site is minimally invaded by exotic species.	Requires proper weather conditions. Minimal maintenance.	Chemical, mechanical, manual invasive control. Interseeding

preparation treatment to release a native seed bank or to establish a natural hydrology may be all that is required to move a site towards recovery.

Implementation planning links proposed restoration treatments to conditions in the restoration site, the project's conceptual plan and the site's reference condition (Table 10). For example, in areas without significant degradation to physical characteristics, mechanical site preparation may not be necessary. Invasive woody species may need to be removed in areas where they are invading prairie due to the absence of natural disturbances. Seeds may need to be purchased for revegetation in areas where it is not possible to collect local native seeds. The aim in implementation planning is to select appropriate actions that should move the site on a transition pathway towards the reference condition while maintaining what ecological integrity remains. In other words, restoration treatments are planned based on specific analysis of the site assessment and reference condition and within the context of the conceptual plan.

An analysis of whether passive restoration can be used as a strategy is also a part of implementation planning. Areas that have retained significant ecological integrity, including native vegetation, and have been minimally invaded by exotic plants may be good candidates for passive restoration that may be obtained using only maintenance and management treatments.

Adaptive management is an essential aspect of ecological restoration, and these principles need to be applied throughout both the planning and implementation stages. Given the complexity of prairie restoration projects and the large number of factors such as climate, drought, wildfire, and other conditions that can impact a restoration project, implementation design itself is an ongoing process to a degree. Therefore, implementation planning includes both initial and continuing designs as restoration efforts are adapted to changing conditions in the site.

Planning restoration implementation also includes identifying a timeline or schedule of restoration activities (Figure 11), although changing conditions likely will necessitate alterations to the schedule. Planning restoration treatments should include both short-term and long-term time frames, with the understanding that these plans are dynamic and flexible.

Developing a restoration timeline (Table 11) can assist with tracking of the many different

Table 11: Sample restoration implementation timeline for Bent's Old Fort NHS taken from from the Bent's Old Fort NHS Restoration Plan (NPS and Lady Bird Johnson Wildflower Center 2011a).

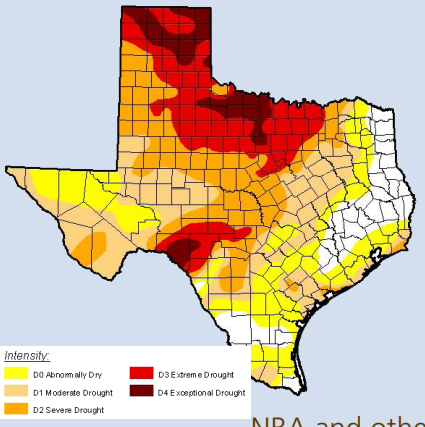
Year	Fall	Winter	Spring	Summer
Year 1	Seed harvest 1 PP	Seed sow* Seed testing: contract	Seed harvest 2 PP Herbicide: contract Mowing	Seed harvest 2 PP Herbicide: contract Mowing Seed drill instruction
Year 2	Seed havest 4PP Seed sow contract & 1 PP Exclosures etc. 1PP	Seed testing: contract	Seed harvest 2 PP Monitor invasives Invasive control 2 PP	Seed harvest 2 PP
Year 3				

* To improve success rate, sage needs to be mowed at time of installation to increase grass and forb advantage.

aspects of a restoration project and help plan for treatments that need to occur sequentially. Generally, restoration timelines identify seasons in which treatments will occur and may also include the amount of dedicated staff time that is needed. Multiyear timelines may be developed for restoration projects with the recognition that treatments in later years may be more likely to change than ones in the less distant future.

VIGNETTE: Adapting Restoration Implementation to Current Conditions

Good planning is necessary for prairie restoration projects, but positive responses to restoration treatments are highly dependent on factors such as weather conditions (e.g., drought, overabundance of precipitation, extreme temperature or other extreme weather events) and other variables that cannot be controlled by restoration managers. For example, parks in the southern Plains planned revegetation treatments between 2009 and 2014, but the area experienced extreme to exceptional drought conditions during this time period. Therefore, many parks had to alter their restoration timelines in response. For example, Washita Battlefield NHS delayed seeding treatments because of drought conditions, although it was prescribed in the first year in their restoration timeline. Germination following seeding treatments in other parks was likely impacted by the dry conditions. Drought-tolerant exotic species such as Russian thistle (*Salsola spp.*) increased in abundance in Lake Meredith NRA and other parks. Another example of how managers may adapt a restoration project to drought is having to use mowing treatments instead of prescribed burns to control exotic species.



US Drought Monitor for Texas (http://droughtmonitor.unl.edu/Home/StateDroughtMonitor.aspx?TX), accessed June 17, 2014 (Figure modified from Struthers and other 2016).

Additionally, managers may be able to take advantage of unexpected favorable conditions and alter their restoration plans accordingly. For example, staff at Sand Creek Massacre NHS did not plan to collect native seed, but took advantage of unexpectedly good years for seed set in blue grama grass (*Bouteloua gracilis*) to collect seeds of this species.

In reality, restoration projects almost never proceed exactly according to plan. Yet good planning remains essential because it enables managers to adapt to changing conditions at the site and gives a restoration project the best opportunity for success. The ability to respond to changing conditions for better or worse at the restoration site adds significantly to the ability of a project to produce desired results.

Lessons Learned

- Each restoration project is unique. Proposed treatments depend on conceptual planning, site assessment, reference conditions and current conditions at the site.
- Flexibility built into implementation planning allows managers to respond to current conditions using adaptive management.
- Implementation timelines can help structure restoration efforts, but like other aspects of an implementation plan, they are subject to revision due to changing conditions. The further into the future a proposed treatment is in a restoration timeline, the more likely that the implementation of that treatment will need to be adjusted.



Restoration site at Bent's Old Fort NHS.

Site Preparation

Site preparation treatments are generally the first type of restoration treatments conducted in a site. Site preparation consists of all modifications to a restoration site prior to revegetation treatments, including mechanical land preparation, exotic species removal and management, invasive[1] plant removal and planting of holding crops.

Mechanical Site Preparation

Mechanical site preparation in a prairie restoration site includes any modification to the physical characteristics of a restoration site by mechanical means. It includes removal of constructed features, such as roads or berms, that have altered the natural topography, changed the hydrology of the site, compacted the soil or created a hard pan. Mechanical land preparation is usually accomplished with equipment such as a disk harrow pulled by a tractor, or a rototiller depending on the size of the area to be treated. Removing features such as abandoned roads or berms generally requires the use of other heavy equipment. As much native topsoil that may remain in a site should be retained as possible during site preparation.

Understanding the previous uses of a site, including whether the site contained buildings or roads, had been used for agriculture or had other modifications that impacted its physical integrity, is essential in determining what kind of mechanical site preparation may be needed, if any. The objective of mechanical land preparation is to create or modify physical conditions to favor the recovery of a degraded, damaged or destroyed ecosystem.

Correct timing of the use of mechanical land preparation techniques is also important. Mechanical site preparation that takes place near the start of restoration implementation and prior to revegetation is more cost-effective and time efficient than later in a restoration project (Clewell et al. 2005). Some mechanical techniques are better suited to seasonal factors than others. For example, plowing or disking a field may be more effective when invasive species are dormant during the winter or before spring winds begin. In most of the southern Plains, it is best to plow and disk immediately before seeding, which is usually done in the late fall and early winter to allow

1. This report uses the term "invasive species" to designate species, usually woody or shrubby ones, that invade grassland habitats. These species may be either native or nonnative.

VIGNETTE: Mechanical Site Preparation at Bent's Old Fort NHS

Mechanical site preparation was used at Bent's Old Fort NHS to rectify uneven terrain resulting from a prairie dog town eradicated by plague. The site was plowed to even the ground surface, to level abandoned prairie dog mounds and make a level seed bed. The leveling of mounds also buried any remaining fleas, per the recommendation of the county health department.



The uneven terrain in the abandoned prairie dog town prior to mechanical site preparation.

Because of severe drought, the only plants that grew at the site in the year following site preparation were common bindweed (*Convolvulus arvensis*). Because the site previously had native grasses, the park made the decision not to plow. However, high winds blowing across the bare site caused severe wind erosion. To reduce wind erosion, the park used a custom tool used to create irrigation furrows perpendicular to the prevailing winds, which successfully reduced wind erosion with minimal soil disturbance.

VIGNETTE: Mechanical Site Preparation at Lyndon B. Johnson NHP

The restoration prairie at Lyndon B. Johnson NHP had been a pecan orchard during the mid-20th century. Two terraces had been installed across the prairie to assist in water retention for the orchard, but these terraces interrupted the natural hydrology of the site. The site has a very gentle slope to the Eastern Town Creek, a feeder to the Pedernales River. Removing berms returned the site to a more visually-consistent and ecologically-functioning prairie. These terraces were removed using a small tractor with a grader attachment in fall 2010 in order to minimize the impact on the area. Following terrace removal, the disturbed area was disked, then seeded with sideoats grama (*Bouteloua curtipendula*), Indiangrass (*Sorghum nutans*), purple threeawn (*Aristida purpurea*), and other native plants. After seeding, winter rains were followed by extreme drought the following two years. Spring forbs did well initially and there were obvious grass seedlings, but the drought had a significant impact on the establishment of native vegetation following mechanical site preparation.

native seeds to break germination with winter moisture.

Mechanical land preparation can reduce soil compaction. It can release the seed bank, which may consist of agricultural weeds or a native species depending on previous land use. It can improve water infiltration or be used to add amendments such as organic matter or missing mineral components to the soil. Mechanical land preparation is also typically necessary to remove furrows or terraces

and may be necessary to re-establish natural surface drainage systems and re-establish natural ground contours. Depending on the exotic species present, plowing can provide weed control without the use of herbicides.

These benefits of mechanical site preparation need to be balanced with potential negative consequences of breaking up the soil. Soil disturbance on the southern Plains, given the region's nearly constant winds and frequent prolonged droughts, can lead to severe instances of wind erosion. A large-scale example of this is the Dust Bowl in the 1930s (Figure 11).

Prairie restoration sites that have been plowed or disked are at risk of wind erosion, especially in semi-arid regions of Colorado, New Mexico, Texas and Oklahoma (Figure 12). Soil disturbance is generally a more effective prairie restoration technique in mixed-grass and tallgrass prairie ecosystems that receive more precipitation and experience less wind erosion. Therefore, on the southern Plains, restoration techniques that include soil disturbance are only utilized when absolutely necessary. It is especially important to not disturb sandy soils that are extremely susceptible to wind erosion, such as those at Sand Creek Massacre NHS.

If there is any native vegetation remaining in a site, plowing will disturb or kill it. Areas with existing forbs may be lightly disked to help control nonnative vegetation or to break up the soil in order to release an existing seed bank. Plowing an area with abundant native plants may cause more harm than leaving man-made features such as furrows in place.

One of the primary benefits of mechanical site preparation is the release of the native seed bank. However, in areas that previously have been dominated by nonnative plants or used for agriculture, any seed bank likely consists predominately of nonnative species. Some invasive nonnative plants, such as cheatgrass (*Bromus tectorum*) and Russian thistle (*Salsola spp.*), germinate before native species do. Plowing could give these exotic species a head start over natives if their seeds are present in the soil. However, in areas where native forb seeds are likely a major component of the seed bank, plowing can have significant positive contributions in the establishment of native prairie. In small sites, repeated plowing may be an option for exhausting a nonnative seed bank over a period of several germination cycles.



Figure 11. Dust storm in eastern Colorado in 1937 (Western History Collection, University of Oklahoma).

Careful site assessment during the planning phase of a restoration project will help identify whether mechanical land preparation will help meet restoration objectives. Mechanical site preparation can be a powerful tool to help native prairie in some situations, but may be equally disadvantageous in other areas.

Mechanical Site Preparation in the Southern Plains

Only two southern Plains parks, Lyndon B. Johnson NHP and Bent's Old Fort NHS, utilized mechanical site preparation in their restoration projects. Terraces from previous agricultural use were removed at Lyndon B. Johnson NHP. In other parks, disturbing the ground would have set back restoration efforts. For example, in the restoration site at



Figure 12. Wind erosion in an area without vegetation in Bent's Old Fort NHS.

Lessons Learned

- Mechanical site preparation generally has limited application in short and mixed-grass prairies in the southern Plains. The semi-arid environment with frequent drought and strong prevailing winds necessitates that the soil only be disturbed in situations where benefits exceed the risks of soil erosion and other potentially adverse impacts of disturbance.
- Mechanical site preparation is needed only in circumstances where the landscape must be recontoured for ecological function, or in areas of soil compaction that prevents the establishment of native vegetation.
- Plowing can be used for exotic species control in areas lacking native species. If native species are already present in the site to be restored, avoiding mechanical land preparation likely will be more beneficial to restoration efforts than using it to alter the land surface or to control exotic plants.
- Light disking that minimally disturbs the soil is a technique that can be used to release a native seed bank.

Washita Battlefield NHS, disking would have released a nonnative seed bank consisting of cheatgrass (*Bromus tectorum*), kochia (*Kochia scoparia*) and Russian thistle (*Salsola spp.*).

Exotic Plant and Animal Removal and Management

Removing or managing exotic plants and animals is often a part of site preparation for restoration projects in the southern Plains short and mixed-grass prairie. Removing exotic plants prior to revegetation treatments allows managers to use eradication or control techniques, such as mowing and some herbicide application techniques, that would be difficult or impossible to use after revegetating the site. If exotic animals such as wild (feral) hogs are present that may inhibit establishment of desired plants, removing them prior to revegetation also increases the odds of the restoration efforts being successful.

Depending on the specific characteristics and history of the site to be restored and on the exotic plant species present, control efforts may either aim to eradicate or reduce the prevalence of exotic vegetation. In many situations, complete eradication of exotic plants is not possible. Instead, managers may aim to keep the abundance of exotic species below a certain percentage of vegetation in the site, or continue to selectively control targeted species throughout the restoration project, including its management and maintenance phase.

Techniques for exotic plant management in a prairie restoration site include removal of exotic plants using mechanical, chemical and/or biologic treatments that kill plants. Abatement can take place via mowing, grazing, prescribed fire, removing seed heads before maturation or through other treatments that do not kill the plant but limit the exotic species' competitiveness and/or ability to reproduce.

Exotic plant management will be beneficial in nearly all restoration projects except in rare situations. For example, when an exotic species such as dandelion (*Taraxacum officinale*) that is relatively benign and has a low exotic plant impact is present in a restoration site, exotic plant control may be a low priority. Similarly, if removing exotic species would expose an area to significant wind erosion, it may be better to leave the plants in place and pursue other restoration methods.

Understanding the characteristics of exotic plant species that need to be controlled is important for successful treatment. Factors such as the species' competitiveness, mode of reproduction, frequency of sexual reproduction, number of seeds per plant, germination requirements, ease of control and the amount of control effort required (Hiebert

and Stubbendieck 1993) all impact how invasive an exotic plant is, what possible control actions may be effective, and the difficulty controlling the nonnative plant. Using an analytical approach that evaluates the potential of an exotic species' ability to alter native plant communities, such as the Handbook for Ranking Exotic Plants for Management and Control (Hiebert and Stubbendieck 1993), is helpful in understanding the impact that a nonnative species has on an ecosystem and for planning for effective control measures.

Like other restoration techniques, exotic plant management must be done in conjunction with other treatments and must be a part of a comprehensive and strategic restoration plan. With few exceptions, exotic plant removal by itself is unlikely to restore an ecosystem. For example, after seeding an area with native grasses, it may be possible to control cheatgrass (*Bromus tectorum*) with grazing in the early spring to give native grasses that germinate later a competitive advantage over cheatgrass. In other situations, it may be better to remove existing exotics prior to a planting because weedy exotic species such Russian thistle (*Salsola spp.*) may outcompete native perennial seedlings by shading them.

A critical aspect of controlling exotic species is the understanding that it requires a long-term commitment with consistent regular treatment, especially for invasive species. A single treatment may only have a short-term benefit as the treated area may become reinfested with exotics after one or more growing seasons. For example, seeds of some exotic species such as Johnsongrass (*Sorghum halepense*), exotic bromes such as cheatgrass (*Bromus tectorum*), and woolly mullein (*Verbascum thapsus*) may remain viable for decades, and removing these species from a restoration site once will have little benefit in an overall restoration project.

The goal of management for many invasive species is to implement a program of regular maintenance following an initial larger eradication or control effort. A maintenance program is necessary in order to prevent the species from re-establishing itself. Treating exotic species without a comprehensive plan that includes follow-up can be akin to playing "exotic whack-a-mole" as the treatments are piecemeal, superficial and result in only temporary improvements.

VIGNETTE: Feral Hogs

Feral or wild hogs are nonnative omnivores that are found in many areas of the southern Great Plains, such as Lyndon B. Johnson NHP and Chickasaw NRA. Feral hogs eat mostly plant material and invertebrates. They cause extensive damage through rooting, trampling and wallowing activities that disturb soils and vegetation. At Lyndon B. Johnson NHP, feral hogs root up areas within the restoration site. The park began contracting with a trapper in winter 2014/2015 to remove hogs from the park on an as needed basis.

The trapper uses a permanent pen with a gate that can be remotely triggered to drop when hogs are detected using a wildlife camera. During the first winter, the trapper removed approximately 60 animals.



STEVE HILLEBRAND/USFWS

Feral hog

While the trapping successfully removes animals, other pigs rapidly repopulate the area. Sows can have litters of up to 12 piglets twice a year. Feral pigs are considered nuisance wildlife in Texas.

VIGNETTE: Testing Exotic Control Techniques at Lake Meredith NRA

In the initial assessment, Lake Meredith's restoration site was found to consist of nearly a homogeneous growth of kochia (*Kochia scoparia*) and Russian thistle (*Salsola spp*.). Stands of these two exotic plants are representative of many disturbed or degraded sites in the recreation area, and park staff were uncertain which control techniques would be most successful under the environmental conditions at Lake Meredith. Therefore, the 4.2-acre restoration site was divided into three sections in order to conduct an experiment on treatments. One section was burned then left to regenerate on its own; one section was mowed then drill-seeded; and the third section was burned then drill-seeded. Of the three treatments, the mowed/seeded section responded best. Mowing and drill seeding is now the standard treatment for Lake Meredith. Periodic mowing with a mow-height of 4-6 inches takes place once exotic species have reached a near-mature height but before they set seed.

Although mowing is the preferred method of controlling exotic species in the recreation area, challenges exist in using this restoration technique. The park has the needed equipment, but Lake Meredith is a large park and travel from place-to-place requires the use of public roads. A CDL (commercial driver's license) is required to haul the tractor and mow deck on public roads, and the park has few staff with CDLs. Additionally, in order to effectively time mowing treatments, staff must be available to monitor the growth in areas with exotics.



The restoration site, showing the burn treatment area to the left and the mowed area to the right.



The area that was mowed and then seeded on the right has better grass and fewer weeds than the burned area on the left.

Methods for Exotic Species Control

Mechanical methods of exotic weedy species control include mowing, hoeing, light disking and hand-pulling for grass or herbaceous species. Woody exotics may be controlled using the same techniques as controlling native woody invasive species (see the following section). An advantage of hand treatments such as hoeing and hand-pulling is that the treatment is species-specific, and it may be especially useful for targeting a single species versus many species. Further, hand treatments may be completed by volunteer groups or conservation corps such as the

VIGNETTE: Johnsongrass (Sorghum halepense)

Johnsongrass (*Sorghum halepense*) is a highly invasive species that can outcompete native grasses in mixed-grass prairie ecosystems in southern Plains parks such as Lyndon B. Johnson NHP and Chickasaw NRA. The species reproduces both by seed and from rhizomatous roots, is alleopathic, grows well in disturbed sites, and has a high level of impact in natural areas (Texas Invasive Species Institute 2014). Using the Handbook for Ranking Exotic Plants for Management and Control (Hiebert and Stubbendieck 1993), the species is ranked high for its innate ability to become a pest. It is also difficult to control or eradicate, as it can resprout from roots and rhizomatous root fragments, and is well adapted to fire. Control efforts generally need to include a variety of techniques with appropriate timing and include repeated eradication efforts (NPS & LBJWC 2011b).



STEVE HILLEBRAND/USFWS

Johnsongrass

The restoration site in Chickasaw NRA, an abandoned agricultural field, was dominated by Johnsongrass and Japanese brome (*Bromus Japonicus*) during the site visit for the restoration workshop conducted by the Lady Bird Johnson Wildflower Center in 2008 (NPS & LBJWC 2011b). This field may have even been planted with Johnsongrass as pasture at one time (Struthers, et al. 2016a). Managers applied herbicide to Johnsongrass in this field sporadically between 2008 and 2012, and the field was planted once with an agricultural clover in 2011. Since 2014, efforts to control Johnsongrass have not occurred in the restoration site. In 2015, during a vegetation and soils rapid assessment for the Natural Resources Condition Assessment, this field was dominated by Johnsongrass (Struthers, et al. 2016a).

Treatment of Johnsongrass at Lyndon B. Johnson has been sporadic, and the species appears to be gaining in some areas. Of the southern Plains parks, Johnsongrass treatment has been most consistent at Washita Battlefield NHS. The park has been using an herbicide which effectively kills treated grass with the added qualitative benefit of increasing desirable native grasses. However, Johnsongrass pops up in other areas, so the overall park population does not appear to be decreasing.

Youth Conservation Corps with relatively little training and oversight. However, hand treatments are only most appropriate in small restoration areas or in larger areas with few of the target species that can be quickly surveyed and controlled by an exotics team. Additionally, hand-pulling and hoeing herbaceous weeds generally kills annual plants but may not kill perennials if root fragments remain. Hand-pulling some species such as kochia (*Kochia scoparia*) that bring up large root balls may cause soil disturbances that release exotic seed banks.

Grazing and mowing are effective techniques for controlling some exotic species. Grazing is effective in removing early annual species such as Kentucky bluegrass (*Poa pratensis*) and exotic bromes (*Bromus spp.*). Goats may control woody species.

Herbicide treatments generally kill exotic species, but herbicides need to be used carefully because most are not species-specific and may also kill native plants. It is difficult to target a single exotic species when using herbicides. Herbicides may be applied using hand sprayers, agricultural booms, and aerial application. The size of the treatment area may determine the appropriate application method.

Control of exotic plant species has been one of the greatest challenges of prairie restoration projects in southern Plains parks.

Prescribed fire can also be used to control certain exotic species, such as woody species that are invading grasslands. However, fire can promote the growth of other nonnative species. Other variables such as the intensity of burns, the timing of burns, and frequency of prescribed fires all impact whether fire will be effective as a treatment for the control of nonnative plants.

Biological control uses natural enemies of nonnative species including parasites, pathogens, predators, and competitors that may kill or harm exotic species. Biological control agents need to be species-specific and not harm native species. The tamarisk leaf beetle that feeds only on saltcedar trees is a good example of a biological control agent.



BOB RICHARD/USDA

Tamarisk leaf beetle

Understanding the specific characteristics of the exotic species that have infested a restoration site helps determine what control techniques will be effective. For example, King Ranch bluestem (*Bothriochloa ischaemum*) can be controlled by hot summer fires, but the species responds favorably to winter and spring burns. Woolly mullein (*Verbascum thapsus*) can be controlled by cutting off the seed heads, but many species require herbicide application to control.

As is the case with other restoration techniques, it is helpful to begin experimenting with treatment options in a small area to see what techniques are most effective, making adjustments as necessary using adaptive management. An additional consideration important for exotic species control is the necessity to maintain controlled areas in the years following the initial mitigation actions. An effective exotic species management plan will include identification of new areas to be treated and a plan for continued maintenance of previously-treated areas that takes into consideration necessary funding and staffing levels.

Exotic Species Control in the Southern Plains

Control of exotic plant species was one of the greatest challenges of the prairie restoration projects in southern Plains parks. The specific methods used to remove or manage exotic species depended on the species present, the density of the infestation, the size of the infested area, its site history and other variables. Herbicide application was the most commonly used technique to control exotic plants in restoration sites.

NPS sites in the Southern Plains Network have had some success controlling exotic species with hand treatments, although these treatments were not used in the restoration sites per se. At Capulin Volcano National Monument, hand treatment by removing flower stalks of the biennial species woolly mullein (*Verbascum thapsus*) before maturation drastically reduced the population based on

monitoring and observation data. However, populations have rebounded since treatment ended.

A large area in Lake Meredith NRA received aerial application of herbicide in 2011 to control saltcedar (*Tamarix spp.*) along the Canadian River. This project was a collaboration between Lake Meredith NRA and the Canadian River Municipal Water Authority to reduce water loss by evapotransportation.

Biological control of saltcedar (*Tamarix spp.*) has occurred in southern Plains parks. Tamarisk leaf beetles (*Diorhabda spp.*) were first released in west Texas in 2004. In 2012, a pilot project released beetles within Lake Meredith NRA. Tamarisk leaf beetles defoliate saltcedar, which may die after three years. Biological control of saltcedar by tamarisk leaf beetles may be cyclic, as beetle populations will naturally decline when few saltcedar trees are present.

Lessons Learned

- Controlling exotic species is a critical part of most restoration efforts.
- Exotic plant management in a restoration project is dependent on many variables, including previous uses of the site, nonnative species present, size of exotic infestation, available control methods and the goals of the restoration project.
- Adaptive management strategies are often necessary to determine the most effective technique(s) for eradicating or controlling exotic species.
- Once exotics treatment has commenced, it is necessary to sustain it. Otherwise, the species will likely re-invade, especially in open habitat before native plants get established.

A great deal of administrative oversight is required for use of biocontrol because once a biological control agent has been released into the environment, the action is irreversible.

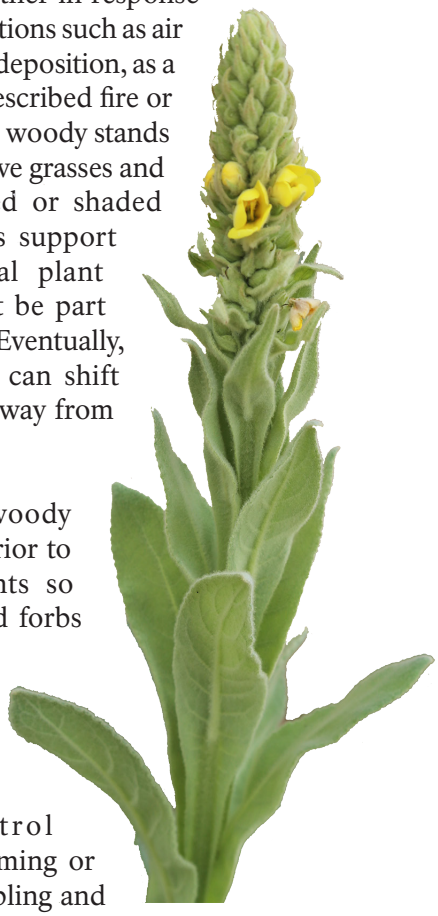
Invasive Plant Removal

Invasive native plant species sometimes are removed as part of a prairie restoration project. Native woody species such as juniper (*Juniperus virginiana, J. ashei*), honey mesquite (*Prosopis glandulosa*) and plum (*Prunus angustifolia, P. virginiana*) may invade prairie from neighboring woodlands or savannas. Historic land uses can shift conditions to allow woody encroachment that would not have occurred if the land had not been impacted by human use. While these native species may be desirable in some ecosystems, woody populations sometimes grow too extensive within grasslands, whether in response to environmental conditions such as air quality or atmospheric deposition, as a positive response to prescribed fire or from lack of fire. When woody stands become too dense, native grasses and forbs are outcompeted or shaded out while stand edges support or "nurse" additional plant species that might not be part of a grassland habitat. Eventually, woody encroachment can shift the plant community away from grassland systems.



King Ranch bluestem

Generally, invasive woody species are removed prior to revegetation treatments so that native grasses and forbs are not shaded out. Woody species may be removed either via mechanical and/or chemical treatments. Mechanical control methods include trimming or cutting down trees, sapling and shrubs by sawing,



Woolly mullein (*Verbascum thapsus*), an exotic species.

shearing or pulling. Saws are necessary to cut large trees, but smaller trees and brush may be cut near the ground surface with tree shears. Tree wrenches can remove saplings and shrubby species, including their taproots, without causing major soil disturbance.

Sawing works best on trees that do not re-sprout from roots or stumps. It is also used in combination with chemical treatment whereby freshly-cut stumps are treated with herbicide to kill them. Herbicide must be applied immediately after cutting or the treatment is less effective. Stumps that remain in a grassland restoration site can be problematic for years, precluding the use of tractors and equipment.

Saplings can be effectively removed using a tree wrench, which pulls out the root. This method works best when the soil is moist and results in minimal soil disturbance. A tree wrench effectively controls species that re-sprout from remaining roots, but this method is labor intensive.

Broad-scale chemical treatments on woody species are usually ineffective, cost-prohibitive and/or carry wide side effects. Aerial spraying will kill top-growth of woody species, but is indiscriminate as to species affected and will often not kill the root, enabling resprouting. Chemical drift of sprayed herbicide is of significant concern, as is killing of surrounding grass and forbs. Its use on cut stumps can be effective when immediately applied, but any delay in treatment (minutes) can reduce effectiveness.

Invasive Plant Removal in the Southern Plains

Encroachment of woody and brushy species into prairie restoration sites is a significant issue at Pecos NHP, San Antonio Missions NHP, Chickasaw NRA, Washita Battlefield NHS and Lake Meredith NRA. Therefore, restoration efforts at these parks may have included removal of woody and brushy species. At Washita Battlefield, Siberian elm (*Ulmus pumila*) saplings have been manually removed using a tree wrench.

Problematic species in the southern Plains include the native honey mesquite (*Prosopis glandulosa*), sand sage (*Artemisia filifolia*) and various junipers (*Juniperus spp.*) as well as the exotic species, Siberian elm and tamarisk (*Tamarix spp.*).

Lessons Learned

- Woody and brushy species removal typically precedes revegetation efforts. Periodic maintenance is also usually necessary to prevent woody species from re-invading a restoration site.
- The techniques used for invasive plant control (e.g., mechanical or chemical) depend on specific factors such as the size of trees or shrubs, size of the area to be treated, species characteristics, etc.

Holding Crops

Holding or cover crops are helpful in site preparation activities in some prairie restoration sites. Holding crops are used to prevent wind erosion in areas that otherwise would be bare ground and to keep exotic species from colonizing or dominating a field. A cover crop may also be planted for aesthetic reasons. For example, in an area of high visibility, it may be desirable to plant a species of annual wildflowers to provide visual interest for park visitors while other native species are becoming established.

Cover crops are useful in areas with no native seed bank. After disking or harrowing a field, a cover crop of an annual plant that does not reseed freely can help hold the soil, retain moisture and prepare the soil for later restoration efforts. Species that do not remain persistent in a site or interfere with native plant establishment may be appropriate for use as a cover species. Agricultural species such as proso millett (*Panicum miliaceum*) or sorghum (*Sorghum bicolor*) may serve as effective holding crops on the southern Plains. These two species also have the additional advantage of not needing much rainfall to germinate and are very drought tolerant. They are also both very inexpensive to purchase.

VIGNETTE: Brush Removal in the Rancho de las Cabras Unit, San Antonio Missions NHP

The Rancho unit is located 35 miles (58 km) southeast of San Antonio. It is a remnant of the extensive ranch lands that contained the herds of livestock for Mission Espada (Mitchell 2013). Vegetation data for the unit is limited and consists mostly of the vegetation map prepared in 2007 (Cogan 2007). The restoration site is an 11-acre shrubland, mapped as Honey Mesquite - Granjeno / Prickly-pear species - South Texas Ericameria Woodland, with mesquite (*Prosopis glandulosa*) trees of nearly uniform age, and several thornshrub species including hackberry (*Celtis pallida*) and Texas hogplum (*Colubrina texensis*), (Cogan 2007). Sheep and goats were kept there historically and cows grazed the area until the early 1990s when the NPS began management. Since that time, thorny brush has invaded the area and altered the habitat. The suppression of fire also was significant in the conversion of grasslands to shrubland (Cogan 2007). The goal of this restoration project is to return the site to an open grassland habitat reminiscent of the Mission period (Mitchell 2013). Native grasslands are the only Spanish colonial period landscape currently missing from the park (Mitchell 2013).



FROM COGAN (2007)

A stand of nearly uniform age mesquite from encroachment following fire suppression and grazing cessation.

Five acres of the site are being restored via mechanical site preparation with subsequent seeding. Invasive thornbrush and trees were removed by mastication (on-site grinding and chipping) and by chainsaw crews in 2013 and 2014. The park hired a Gryo-Trac mulching machine to masticate smaller brush, and crews sawed larger trees and treated the stumps with herbicide. The slash was piled around the site, providing cover for wildlife.

The cleared area was then disked to address soil compaction and to incorporate organic material into the soil. Hand-broadcast seeding was accompanied by raking to bring seeds in contact with the soil and took place in two subsequent years, using seed mixes purchased from Native American Seed Company, a small Texas-based business that specializes in native wildflower and grass seeds.

Irrigation was not possible, but a long rainy period followed seeding treatments. The site is now generally covered with vegetation, much of it early successional species that were released from the seed bank. It is hoped that more perennials will soon mature to outcompete weedier species

During the project, managers learned the trade-offs between masticating and sawing. Mastication is economical, but causes soil disturbances and doesn't allow for immediate treatment of stumps with herbicide. Chainsaw crews are expensive, require a lot of manpower and leave slash piles, but don't disturb the soil and can immediately apply herbicide to cut stumps to minimize sprouting.

VIGNETTE: Holding Crops and Restoration at Bent's Old Fort NHS

In 2013, Bents Old Fort NHS planted proso millett (*Panicum miliaceum*) as a holding crop at the site of the abandoned prairie dog town as part of an effort to reduce soil loss by wind erosion. The proso millett did not grow because irrigation water was not available, and the historic site was experiencing extreme drought at the time.



Wind erosion in the abandoned prairie dog town.

The failure of the proso millett cover crop is a good example of a restoration treatment that was unsuccessful because of environmental conditions. The park later altered their approach to control wind erosion and constructed furrows perpendicular to predominate wind direction to help slow wind erosion. See vignette on page 66 for more information.

Subsequent restoration treatments at the site included drill seeding of grasses the following fall. The site continues to be maintained by mowing, which may need to continue for a decade or more because grasses have been slow to germinate. In this site, mowing is preferable to herbicide because it allows native forbs to continue to increase, yet allows light to reach grass seedlings while they germinate and grow. Additional grass seeding treatments may also need to occur. The park may be able to transplant native grasses if volunteer assistance to water transplanted grasses becomes available.

Cover crops are generally used only for a single year, unless an area requires multiple mechanical site preparation treatments. They do best in areas where irrigation is possible, although proso millett may grow without irrigation, depending on rainfall amounts.

In other situations, a cover crop can be used as nurse plants to help native seedlings get established. For example, after mowing a holding crop at a high level, perhaps six inches, native grass seeds can be planted. After the annual holding crop dies, it acts similar to nurse plants by not using moisture, helping hold moisture in the soil and providing shelter for seeds and seedlings, without competing with them.

Use of cover crops in NPS sites in the southern Plains was limited. Unlike tall or mixed-grass prairie restoration sites, it is best to not plow an area of shortgrass prairie unless absolutely necessary because of the more arid and windy conditions. Additionally, without irrigation, holding crops may not grow in the southern Plains. Another consideration for park managers is that using a cover crop may give the impression to park visitors and/or neighbors that the NPS is farming park land, although interpretive and educational efforts may alleviate this concern.

Holding Crops in the Southern Plains

Among parks in the southern Plains, only Bents Old Fort NHS and Chickasaw NRA

used holding crops during their restoration efforts. The other parks did not have former agricultural areas lacking a native seed bank, did not use mechanical land preparation or did not have the ability to irrigate.

Bents Old Fort has utilized cover crops in restoration efforts since the mid 1990s. In 1997, park managers used sorghum as a cover crop in a 40-acre former agricultural field that had irrigation. The field was subsequently planted with native grass seeds and today is dominated by western wheatgrass (*Pascopyrum smithii*) and sideoats grama (*Bouteloua curtipendula*)

Chickasaw NRA utilized an agricultural clover as a cover crop prior to its restoration efforts. The restoration site is a former agricultural field that was dominated by Johnsongrass (*Sorghum halepense)*, and a local landowner was permitted to hay the field. The agricultural clover was very competitive as a cover crop and reduced the amount of Johnsongrass present during cultivation. However, Johnsongrass returned to dominate the field in subsequent seasons.

Lessons Learned

- Holding crops are more successful when irrigation is possible and are only used following mechanical site preparation such as plowing and disking.
- Holding crops are generally more useful in mixed- and tallgrass prairies than in the shortgrass steppes of the southern Plains.



NPS PHOTO

A native seed mix consisting of 56% western wheatgrass (*Pascopyrum smithii*), 22% sideoats grama (*Bouteloua curtipendula*), 5% little bluestem (*Schizachyrium scoparium*) and lessor amounts of other native grasses and forbs.

Native Seed Acquisition and Propagation

Native seed from local sources that is adapted to the local climate, geography, soils and other regional characteristics is crucial to successful prairie restoration. A majority of prairie restoration projects in the southern Plains required the use of native seed, either for direct seeding in the restoration area, or for propagation of native forbs or grasses to be transplanted as plugs into restoration sites.

Identifying what species of native seeds may be needed for restoration treatments and possible sources for collection and/or purchase occurs during the initial phase of restoration when the conceptual plan is developed, the site assessment takes place and the reference condition is defined.

Native seeds for use in restoration projects in NPS sites may be collected from park lands or on neighboring lands (with permission and/or agreements in place) or purchased commercially. A significant cost is generally associated with acquiring native seed. Resource managers must consider the most appropriate and cost effective way to obtain needed seed.

The USDA Natural Resources Conservation Service has many technical notes and other resources available related to collecting, storing and propagating native seeds. Additional information about collecting native seeds for restoration purposes is available from the Federal Highways Administration (Steinfeld et al. 2007) and the NPS (Buckley and Mataljak 2015 and Dorner 2002).

The intent of *Prairie Restoration in the Southern Plains* is to not replicate information about seed collection or propagation readily available elsewhere, but to focus on the application of seed acquisition and propagation techniques as they related to prairie restoration projects in southern Plains parks, including how managers may decide whether to purchase or collect native seeds for restoration purposes.

Since there were no threatened or endangered plant species in the restoration sites of the participating southern Plains parks, this report does not address seed collecting from a listed species.

Native Seed Acquisition

The sources of native seeds, as well as seed quality and viability, have significant impacts

on the success of revegetation efforts in restoration sites (Scianna et al. 2011). Guidelines for selecting seed sources focus on matching soil characteristics and climatic features (current and future) to that of a restoration site. Additionally, the quality and viability of seed used for restoration efforts is important because low seed viability can impede restoration efforts.

A hierarchical system of seed source preferences for restoration projects ranges from an ideal scenario of a local seed source with a close proximity to the restoration site (e.g., within a 80-km or 50-mi radius) combined with promising performance testing that indicate that the seeds will grow well in the restoration area's ecological site to the unacceptable condition of no seed origin data (Table 12) (Scianna et al. 2011).

Table 12. Hierarchal System of Seed Source Preference for Restoration Projects (Scianna et al. 2011)

Scenario	Description
Ideal	Local seed source & promising performance testing
Good	Non-local seed source & promising performance testing
Acceptable	Local seed source & no performance testing
Poor	Non-local seed source & no or performance testing
Unacceptable	No seed origin data

The decision to collect or purchase native seed for restoration purposes may be based on a number of factors, including availability of local seed for collection, availability of manpower to collect seed, expense of purchased seed, seed viability and other constraints (Table 13). Acquiring seed for restoration projects generally involves considerable expense as either a direct expenditure or an indirect cost for staff time required for seed collection. In parks where staff availability is limited, collecting seeds may not be an option because collection requires intensive use of manpower.

Native Seed Collecting and Propagation Resources on the Web

Many useful references, manuals and other guides to native seed collection and propagation are available on the Internet. Resources that are helpful in collecting species of native grasses and forbs that grow in short and mixed-grass prairies on the southern Plains include:

- Drying, Cleaning and Storing Prairie Seed (http://ionxchange.com/content/images/Drying_Brochure.pdf)
- An introduction to using native plants in restoration projects (https://www.nps.gov/plants/restore/pubs/intronatplant/intronatplant.pdf)
- Nursery Manual for Native Plants: A Guide for Tribal Nurseries (https://www.fs.fed.us/rm/pubs_other/wo_AgricHandbook730/wo_AgricHandbook727_133_151.pdf)
- Native Seed Propagation Methods (https://www.missouribotanicalgarden.org/Portals/0/Shaw%20Nature%20Reserve/PDFs/horticulture/Propagation.pdf)
- Collecting Native Seeds (https://www.fs.fed.us/wildflowers/Native_Plant_Materials/developing/collecting.shtml)
- Technical Protocol for the Collection, Study, and Conservation of Seeds from Native Plant Species for Seeds of Success (https://www.blm.gov/wo/st/en/prog/more/fish__wildlife_and/plants/seeds_of_success/protocol.html)

Websites accessed January 27, 2017.

Therefore, it may be necessary to purchase native seed for restoration efforts.

While collecting seed is more time intensive, it yields local seeds that usually are adapted to the ecological site of the restoration area. However, collected seeds may have lower viability and quality than purchased seed, which may require the use of greater quantities of seed. Seeds of some species targeted for restoration plantings may be unavailable commercially.

Each restoration project has unique needs for native seeds. Some projects may require seeds of only a few species, and others may need a more diverse seed mix. Sometimes, planting grass seeds may be sufficient, but other projects may require both grasses and forbs. In a small project, the amount of seed needed may be minimal, while larger restoration sites may require a great deal of seed. Therefore, planning for native seed acquisition, including the determination of whether to collect or purchase seeds, or to collect some species while purchasing other species, is an important part of restoration implementation design.

In park areas that may experience drier conditions resulting from climate change, it may be desirable to consider acquiring native seed materials from areas more arid than the restoration site, and/or seeds of native species that do well in more arid conditions in order to anticipate forecast conditions.

Native Seed Collection and Storage

Native seed collection and storage is a multistep process that includes identifying collection locales, monitoring them for flowering times and seed ripening, collecting seeds, and then cleaning, drying and storing the seed.

Ideally, seed is collected either inside park boundaries or within an 80-km (50-mile) radius of a park in order to select for native genotypes. Agreements should be in place with land managers or landowners if seed is to be collected from lands not under NPS management. Seeds should be collected in areas with good seed production in order to prevent depletion of the natural stands of the species being collected (Dorner 2002). Potential seed sources are identified during the site assessment.

Table 13. Factors Related to the Use of Purchased or Collected Native Seed in Prairie Restoration Projects

Factor	Collected Seed	Purchased Seed
Cost	Indirect costs for manpower for collecting, cleaning and testing	Direct costs for purchasing seeds
Manpower	High need for staff	Low need for staff
Local Source	Yes, if seed is collected from park lands or within 80 km (50 mi) of site	Ideally. Seeds from a local source may not be commercially available
Adapted to Ecological Site	Yes, if seeds are collected from similar sites	Ideally. Seeds adapted to the ecological site may not be commercially available
Viability	Viability of collected seed is often low	High

Identified collection areas should be visited while the target species are flowering and are more identifiable, and specific stands located with GPS. Monitoring for seed ripeness is essential for successful seed collection, as seeds must be collected when ripe. Some species may ripen and fall out of seed head within a day or two.

Native seeds may be collected either via mechanical means, with a combine harvester or brush stripper, or by hand. Generally, hand-collecting is only applicable when small quantities of seed or seeds from a specific individual species are needed. Mechanical collection is usually necessary when large amounts of seed are required. Because mechanical seed harvesters collect from all species present in the collection area, those areas should be relatively free of exotic species to ensure that seeds of exotic plants are not included in the collected seed.

The main machines used to collect native seeds are combine harvesters and seed strippers. Combines sever the grass stem and then separate seed from the seed head, and feed seed into a storage bin. Combining is a once-over treatment and the equipment cannot be used on rocky, uneven terrain (Rangeland Technology Equipment Council 2007).

Native Seed Collection Dos and Don'ts

This list of Dos and Don'ts for native seed collection is from *An Introduction to Using Native Plants in Restoration Projects* (Dorner 2002), prepared for Plant Conservation Alliance, Bureau of Land Management, US Department of Interior and the U.S. Environmental Protection Agency. The overarching principles for native seed collection are to collect the best possible seeds for a restoration project while protecting the native populations in the collection site (Dorner 2002).

- Do match the donor and restoration site conditions as much as possible: slope, aspect, hydrology, soil type, frost dates, temperature patterns, elevation, etc.
- Do collect in an area geographically near to planting site.
- Don't collect in sensitive areas.
- Do make sure none of the seeds collected are from rare species - contact the state Natural Heritage Program for more information about rare species in the area.
- Don't collect from ornamental plantings or near other exotics.
- Do avoid collecting in weed-infested areas.
- Do obtain permission from the landowner to collect seed on private land or the required permit(s) for public lands.
- Do try to collect dry seeds on a dry day. Wet fruits such as berries can be collected on wet or dry days.
- Do make sure to collect when seeds are mature. The seed should not dent under a fingernail and should detach easily from the plant.
- Do use paper bags or other "breathable" containers for dry seeds. Berries and fruits can be collected in plastic buckets.
- Do collect from large populations.
- Don't concentrate on one small area of the plant population, instead collect from a wider area.
- Do know the factors affecting seed viability of the species before collecting and processing them.
- Do collect a few seeds from many plants rather than many seeds from a few plants.
- Do collect from a wide range of plants: short or tall, scrawny or robust.
- Do leave at least 2/3 of the available seeds.
- Do communicate with other local collectors about where collections are taking place.
- Don't harm donor populations.
- Do immediately clean and dry seeds after collection or treat wet fruits appropriately.
- Do store cleaned, dried seeds in a paper envelope or a sealed plastic container with desiccant in a refrigerator until needed.

The best method to collect native grass seed is using a seed stripper. Seed strippers use circular brushes to strip seeds from seed heads and are effective with light chaffy seeds (Rangeland Technology Equipment Council 2007). Small seed strippers that can be pulled behind ATVs are suitable for use in many shortgrass prairie areas. In collection areas that have a good mix of native grasses, collecting seed once a week during the ripeness period is a good way to assure that the collected seed consists of early-, mid- and late-ripening seed.

VIGNETTE: Collecting Native Seeds at Bent's Old Fort NHS

The staff at Bent's Old Fort NHS have collected native seeds, on at least a small scale, for almost 15 years. Initially, the park used a small seed stripper borrowed from Capulin Volcano National Monument. Staff collected grass seeds in areas where there were good patches of single species such as alkali sacaton (*Sporobolus airoides*), blue grama (*Bouteloua gracilis*) and western wheatgrass (*Pascopyrum smithii*). Seeds were only collected from single species unless multiple species were ripe at the same time. Determining whether to collect from one or multiple species was made on a case-by-case basis, based on conditions in the field. Crews collected seeds of a particular species several times to get early-ripening seeds and late-ripened seeds for genetic diversity.



Alkali sacaton

After drying, seed was passed through a small seed sorter to separate it from stems, dirt and chaff. If the seed batch was small enough, it was hand-cleaned using a winnowing action and two shallow bowls. Hay and chaff collected with seeds was used as mulch because it contained native seeds of other species.



Collecting with a seed stripper.

Staff hand-collected seeds of species with large seeds, such as switchgrass (*Panicum virgatum*), Canada wildrye (*Elymus canadensis*), and sideoats grama (*Bouteloua curtipendula*).

Staff intermittently collected from April to November to obtain the widest number of species. Collectors spent a lot of time in the field locating and marking locations of forb species while they were flowering. They revisited sites to determine when the seeds were ready to be collected. However, it wasn't uncommon to lose seeds to local rodents just as they became ripe. Some seeds also ripened very quickly (within a few days) and others took longer. The park purchased small bags to put over the seed pods to try to protect them from rodents, but did not have the opportunity to test its effectiveness.

Record-keeping included noting species collected and flowering and ripening dates. These dates varied from year-to-year depending on temperature and rainfall. Even though the dates change annually, this information was used to assist in future collection projects.

Collecting seed by hand allows individual plants to be selected for collection. A variety of methods can be used to beat, cut or strip seeds from a plant, including a racket and hopper, sickles and clippers. Volunteers and volunteer groups typically are able to assist with hand collection, especially for larger seeds from forb species where handpicking is effective.

Once collected, native seeds need to be dried, cleaned and stored. Seeds may be dried using specialized equipment such as racks, or by spreading them out on sheets and simply allowing them to air-dry under low humidity conditions and good air circulation.

Prior to storing, seeds should be cleaned to separate them from chaff and other inert plant materials. Screens are very effective in helping clean and thresh seeds and for sorting seeds by size. Placing collected seed in the freezer for a short period may kill insects that may consume the seed.

Native seeds need to be stored in a cool, dark place with stable temperature and humidity. The general rule of thumb for storing seeds is that temperature in degrees Fahrenheit plus relative humidity should remain below the number 100. Changes in temperature and humidity reduce the viability of native seeds. Because viability is often low for native seeds locally collected and because storing seed reduces viability, it is best to plant seed in the same year it was collected.

It can be valuable for field-collected seed materials be tested for viability to assess the appropriate seeding rates when applying the material to the restoration site. Seed viability testing is usually available through extension services at local or state universities. Viability

VIGNETTE: Switchgrass (Panicum virgatum)

The use of hybrid plant material developed from native species can often be equally aggressive and problematic as some invasive, nonnative species. Switchgrass (*Panicum virgatum*) is a native warm-season grass with wide distribution in much of the United States. It grows in a variety of environmental and soil conditions, and a number of varietals have been developed with different traits such as for seed viability or drought resistance. "Alamo" switchgrass is a varietal released by the USDA Natural Resource Conservation Service (NRCS) James E. "Bud" Smith Plant Materials Center in Knox City, Texas in 1978 (USDA NRCS 2012). Alamo switchgrass has dense foliage and heavy seed production, and was selected for use as livestock and deer forage and for its biomass potential (USDA NRCS 2012).



LYNN BETTS/USDA NRCS

Switchgrass

In 2001, Alamo switchgrass was identified in the 12-acre restoration site in Lyndon B. Johnson NHP, apparently having been planted in previous restoration efforts (NPS & LBJWC 2011c). This species is so well adapted to the conditions in the Lyndon B. Johnson restoration site that the park is having to take steps to control it so the restoration site does not become a switchgrass monoculture. The Lyndon B. Johnson restoration plan has recommended removing Alamo switchgrass from the restoration site (NPS & LBJWC 2011c).

VIGNETTE: Vine mesquite (Panicum obtusum)

Vine mesquite (*Panicum obtusum*), a native, warm-season grass native on the southern Plains, is a low-growing grass that is part of a climax community in mixed-grass prairie (Griffith 1991). Including vine mesquite would be desirable in many restoration projects in southern Plains parks. However the seeds of the species are not available commercially.

Because the species is so low-growing and grows in areas with taller grasses, it is not possible to collect it using a seed stripper, meaning that seeds must be hand-collected. However, seeds of vine mesquite are only abundant every few years, and the seed has low viability. It is more effective to establish this plant in restoration sites via transplanting from plugs grown from seed in a greenhouse. The species reproduces by rhizomes and stolons, and can spread from small areas or patches once they are established. But once it gets established, it may be able to spread in a restoration site.



WESTERN NEW MEXICO UNIVERSITY DEPARTMENT OF NATURAL SCIENCES AND THE DALE A. ZIMMERMAN HERBARIUM

Vine mesquite

testing does add an extra cost to a project, but can be far less expensive than having to reseed a restoration area.

Propagation

Seeds may be propagated either for plugs to transplant into a restoration site as seedlings, or be grown to increase the amount of seed available for seeding treatments. Greenhouse facilities are needed for propagation of species needed for prairie restoration projects. Since many parks do not have greenhouse facilities, they may need to work in partnership with other park units that have greenhouses or perhaps with a nearby college or university. The NPS and Natural Resources Conservation Service (NRCS) Plant Material Centers have a cooperative program to develop plant materials for use in park restoration projects. However, utilizing NRCS Plant Material Centers takes multiple years to increase seed quantity and involves a significant cost to the park, both of which must be factored into the budget for any restoration project. These costs may be prohibitive for small parks.

Whether species get established better via seedlings or from seeds depends on the individual species and the unique characteristics of the restoration site. For example, in restoration sites that still have some perennial native species present, it may be more effective to transplant some species in "islands" or small areas within the site. Once plants in the islands get established, they may be able to reseed the area or spread on their own. Alternatively, some species do not grow well from seeds and it may be easier to establish them in a restoration site via transplanting.

Growing native plants in a greenhouse is very time intensive and requires expertise and understanding of the germination and growing requirements of each species.

Native Seed Purchasing

Native seeds must be purchased when it is not possible to collect them locally, or when another factor prohibits local collection, such as the desired species not growing or having only limited occurrence in or near the park.

Additionally, it may not be possible to collect seeds if collecting them would endanger an existing population or if the native stand needs all the seeds that it produces. Further, seed collecting, including locating and monitoring potential collection sites, is time intensive and a park may not have the budget or staff to collect seed for restoration projects. A park also may not be able to collect seed for restoration purposes if equipment such as a seed stripper is not available.

Important considerations when purchasing seed include knowing the seed origin (where the seed material was originally collected from), seed source (where the seed material was grown out) and the genotype or varietal of the species. A varietal, or cultivar, is below a subspecies in taxonomic rank, and represents a genotype that has different traits and is adapted to different climatic and soil conditions. A number of different cultivars may exist for some species, especially grass species that have wide distribution. Many of these cultivars were developed for agricultural or horticultural purposes and are not appropriate for use in prairie restoration sites because their selected trait for robust growth may throw a restored prairie out of balance by outcompeting desired native species.

As a general rule, local seed (e.g., within a 160-km or 100-mi radius of a restoration site) is essential so that it is adapted to local conditions and also helps maintain genetic diversity. It is especially important to obtain local seeds for plants from the lily or yucca families that are pollinated from other plants within a very short distance. It is less critical to obtain local seed for wind-pollinated species such as native grasses, as long as the seed is for plants adapted to local conditions. For example, little bluestem (*Schizachyrium scoparium*) grows in a wide variety of habitats throughout much of North America. However, seed from plants from the Texas Gulf Coast likely would not germinate or do well in restoration sites on the shortgrass steppe because the soils, climate and overall environment are completely different. On the other hand, little bluestem seeds from northwest Texas would likely perform well in a restoration site in eastern New Mexico or Colorado.

The seed label for purchased seed should list the species, origin of the seed, a lot number which will allow the grower to track the seeds, the net weight of pure live seed in the bag along with other information (Englert 2007). Net weight of pure live seed is calculated by the grower by subtracting the percentage of weed seed and inert material from the gross weight of the material in the lot. The total of pure live seed, other crop, inert matter and weed seed should always equal 100%.

Knowing these parameters of purchased seed can help managers understand how planting the purchased seed may impact a restoration site. If purchased seed has low purity, a manager may decide to not plant the seed in the site. A manager may decide to not purchase seed from a lot that contains noxious weed seeds. Because native plant seed purity is quite variable, the quantity purchased is best based on a pure live seed weight basis.

Although parks may have to purchase most of the seed required for restoration efforts, seeds of some species that managers would like to get established in a restoration effort may not be available commercially. Generally, seeds of major species are available, but seeds of species that make up smaller proportions (5% or less) of native plant communities may not be available commercially. In those situations, managers may have to consider finding a way to collect the seed or use seeds of other species that are available commercially.

Native Seed Acquisition and Propagation in the Southern Plains

Seed collection, propagation and purchasing was a major expense incurred during the PMIS-supported prairie restoration projects in southern Plains parks. Most parks used purchased seeds grown within the bioregion in their restoration projects, but some parks were able to collect and/or propagate native seeds to at least a minor degree.

Bent's Old Fort NHS and Sand Creek Massacre NHS collaborated on seed collection since the two parks are very close to one another. They both were also able to collect seed from the nearby Comanche National Grassland. Lake Meredith NRA also collected some native seed

for restoration purposes, and Fort Larned NHS collected a smaller quantity of seeds for use in its butterfly garden.

Parks in the southern Plains had access to shared equipment for seed collection and cleaning. A seed stripper that can be pulled behind an ATV was purchased with funds from Phase I of the PMIS project. A seed sorter (Figure 13) stored at Bent's Old Fort NHS was also available for other parks to use.

Greenhouses are necessary for propagation, but most parks in the southern Plains lack greenhouse facilities to propagate native plants, limiting their ability to grow plants for restoration efforts on their own. Capulin Volcano National Monument has a greenhouse and can collaborate with other NPS sites on propagating plants for restoration efforts. Bent's Old Fort NHS has an agreement with Otero Junior College for greenhouse use, and recently purchased a small greenhouse to grow plants for restoration projects.

A limited number of seed companies offer seed ideally suited for restoration. These companies often have seed for a specific species from several locations, allowing the purchaser to choose well-adapted genotypes. They also can make custom mixes separated by size for use in drill-seeding. Such seed mixes may be more expensive but usually will perform better in restoration projects. Native American Seed in Junction, Texas, is an example of a native seed company that provides only seeds from the southern Plains bioregion.



Figure 13. A seed sorter

Bent's Old Fort NHS purchased seed for six of the main shortgrass and mixed-grass species. These species have wide ranges from Canada to Mexico, and it was possible to purchase seed specific to the southern Plains bioregion. The historic site used ecological site information and reference conditions to determine what minor species to include in the seed mixes depending on availability, either via collecting or appropriately-identified commercially sources.

Lessons Learned

- When collecting or propagating native seeds, it is essential to understand the characteristics of the species in order to have the greatest odds of success.
- Acquiring native seeds and plugs for restoration projects requires considerable expense, and may involve significant manpower.
- A great deal of information about seed collecting and propagation is available from online sources.
- Given the expense and complexity of obtaining plant materials, small pilot efforts may help managers learn what species and revegetation techniques do best in the site to be restored.



NPS PHOTO

A seed drill

Revegetation

Revegetation consists of treatments taken after site preparation with the objective of re-establishing native vegetation. Revegetation efforts can encompass planting seeds of native species, seedlings propagated in greenhouses or salvaged native plants. Revegetation treatments may involve one or more native species and sometimes occurs in stages. For example, initial revegetation efforts may consist of planting grass seeds followed by later plantings of forb seeds.

Identifying species to include in revegetation efforts takes place during conceptual planning and site assessment. Determining whether to use seeding, transplanting or both as revegetation techniques depends on factors such as the size of the restoration site, whether desired species germinate well from seed or become better established via transplants, cost, the prevalence of exotic species in the restoration site and other characteristics of both the restoration site and the desired native species.

Additional specific information on planting and transplanting native species is available from other sources, such as the USDA Natural Resources Conservation Service, other federal land management agencies, universities, and from various native plant organizations. The intent of this report is not to duplicate information readily available in other places, but to focus on revegetation applications in shortgrass and mixed-grass prairies of the southern Plains.

Seeding

Precision seeding is usually the preferred method for planting seeds in a prairie restoration site. Precision seeding involves placing seeds at specified depths and spacing, generally using a seed drill or other mechanical device. Other seeding techniques that may have at least limited application in prairie restoration sites include broadcast seeding, hydroseeding or dispersing seed balls (Table 14).

When planning seeding treatments, it is important to be aware that different species have different seed depth requirements. Some species require light to germinate, some should be planted 1/4 inch deep and some much deeper. Seeds of some species should be planted separately because they have different germination requirements.

Table 14. Seeding Techniques

Technique	Applications	Notes
Precision Seeding	Seed drills are deal for seeding large areas and for interseeding	Seed drills are the preferred method in most prairie restoration projects
Broadcast Seeding	Limited application in prairie restoration projects	Raking or other technique to bring seed into contact with the soil is needed
Seed Balls	Applicable if seeds are collected from similar sites	Seeds adapted to ecological site may not be commercially available
Hydroseeding	Limited application in prairie restoration projects	Seeds from a local source may not be commercially available

A seed drill places seeds in the soil via a furrowing-type action, then covers them and smooths the surface. Seed drills plant seeds at specified depths, with some having adjustable planting depths. Because agricultural seed drills may plant seeds deeper than ideal depths for native species, it is preferable to use seeders designed for prairie restoration. Small units that can be pulled behind an ATV also can be used in areas too steep or rugged for agriculture seed drills, although these small units are inefficient to use in large restoration sites (Figure 14).

Using a seed drill is also very effective for interseeding in areas that have retained some native species because they cause minimal ground disturbance. For example, grass seeds can be planted in an area that has retained some native forbs using a seed drill.

In most prairie restoration sites, manual broadcast seeding will generally be ineffective because the broadcast seed will not come in direct contact with the soil which helps the seed retain enough moisture necessary for germination. Therefore, if hand-seeding is used, it should be combined with raking or another technique so that the seed touches the soil. Slope stability/erosion control mats are also used when small areas have been hand-seeded. They retain ground moisture and provide shade. In general, hand-seeding has very limited application for prairie restoration projects except in small areas that have bare soil. For example, Bent's Old Fort NHS hand-seeded and used mats in small areas of grassland that had been disturbed during construction of trails and a shade structure (Figure 15).



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Figure 14. The Dew Drop Drill is an example of a small seed drill that can be pulled behind an ATV.

Seed balls are mixtures of native seed and soil materials that usually include clay that may be dispersed by hand. Seeds balls are available commercially and can also be prepared from seeds collected from a local area. The soil and compost around the seed ball may aid in germination and protect the seed from predation. While using seed balls is most likely preferable to broadcasting bare seed, using seed balls may have limited restoration application, except as a way to involve the public or to incorporate an interpretive element. Seed balls can be made or dispersed by school or volunteer groups and/or park visitors allowing direct involvement in restoring degraded grasslands.

Hydroseeding uses a slurry of seed and mulch and may have limited application in restoring areas of prairie that have been impacted by construction or other activities. A tacking agent assists with erosion control and the mulch aids with moisture retention from rain or snow, which may promote germination.

When implementing revegetation treatments that involve planting seeds, managers generally consider the timing of plantings, the composition of seed mixes and whether to utilize multiple plantings. Seeding treatments are usually timed to when moisture is available and to meet the germination requirements of species in the seed mix. Seeding in prairie

restoration projects in the southern Plains generally occurs in late fall and early winter and may take place as late as January. Seeding just prior to a heavy snowfall can provide both early water for germination and press the seeds into the soil for seed-soil contact. The timing of seeding treatments may also be influenced by whether a cover crop was used, drought conditions or other factors related to the current condition and desired conditions of the site.

Seed mixes typically consist of a number of species that are appropriate for the restoration site depending on its Ecological Site Description and reference conditions (Figure 16). Multiple plantings are planned for many restoration projects. In some situations, it may be desirable to initially plant only grasses and introduce forb seeds later. For example, when restoring a former agricultural field, it may be necessary to continue to control agricultural weeds with herbicide after seeding with native grasses so that the site is not bare and subject to wind erosion during the restoration process. Since forbs and other broad-leaved species would be impacted by herbicides used to control agricultural weeds, forb seeds may need to be interseeded later using a seed drill. Forb interseeding needs to occur before the grasses fill in enough to outcompete the forbs. Once forbs are planted, mowing to control weeds is the only control method available.

The composition of seed mixtures depends on seed species availability, seed quality, germination rate and times, budget, current condition, reference condition and the project's conceptual planning including restoration goals. Seed mix compositions for subsequent seedings may be adjusted on the basis of the success of previous treatments, environmental factors or other changes resulting from ongoing adaptive management of the restoration site.



Figure 15. Broadcast seeding by hand and using erosion control mats can be effective in small restoration sites such as at Bent's Old Fort NHS.

Transplanting

An important revegetation technique in some prairie sites consists of transplanting plugs grown from seed in a greenhouse, plants collected in the local area and salvaged plants. Because transplanting plants is labor-intensive and expensive, transplanting is usually used in smaller restoration sites, or to plant "islands" with diameters of a few meters (feet) with species such as forbs that do not germinate well from seed. Planting in islands may be a way to establish certain species in a restoration site so that the species may later expand throughout the area.

Managers also use transplants in restoration sites when seed of desirable perennial grass and forb species is not available in sufficient quantities for seeding treatments.

Transplanting plugs of native grasses and wildflowers (Figure 17) may also be



Figure 16. A seed mix used at Bent's Old Fort NHS.

appropriate in high visibility areas, such as next to visitor centers, parking lots and trails, especially in areas that have been impacted from construction and maintenance projects.

Managers need to carefully consider the timing of transplanting efforts, just as they would for seeding treatments. Transplanting is often done in the early part of the growing season or when water from rain is more likely to be available. And similar to other aspects of a prairie restoration project, it may be helpful to use a small area of a restoration site to experiment to determine which species do best and the preferential times for planting.

While transplanting can be a highly effective restoration technique, most new transplants require significant monitoring and watering for the plants to become established. Seedlings are generally watered immediately after they are planted, and depending on the species, supplemental water may be needed for months or even more than a year. Volunteers may be able to assist with supplemental watering.

If successful, transplanting revegetates an area more quickly than seeding treatments, which often takes a longer time period to become successful.

Irrigation

Providing irrigation or supplemental water, if possible, can significantly increase the odds of success in a restoration project. Proper amounts of water can aid in seed germination and seedling survival and greatly improves the survivability of transplants. Depending on characteristics of the restoration site, species planted, and amount of precipitation in the weeks and months following revegetation treatments, the length of time that supplemental water may need to be provided can be variable.

Small restoration sites in frontcountry locations may be watered by hand or with sprinklers. Water tanks, especially ones that may be pulled by a tractor or ATV, may be needed to provide water in some areas. Former agricultural fields that are being converted to native grasslands may still have irrigation systems that may be used to aid the restoration initiative.

In most larger areas, it may not be possible to provide supplemental water in a restoration site. In that case, much of the site's response to revegetation treatment is dependent on weather conditions. In the semi-arid southern Plains, especially in areas of shortgrass steppe, in most years, moisture from precipitation is not sufficient for abundant germination from seeding treatments. Perhaps as few as one



Figure 17. Buffalo grass (*Bouteloua dactyloides*) plugs grown by seed for restoration efforts at Bent's Old Fort NHS.

VIGNETTE: Restoration Along the Acequia Trail in San Antonio Missions NHP

The Acequia Trail is part of an urban trail system in the city of San Antonio. The Acequia Trail follows a historic acequia, or water ditch, and is on a narrow strip of land between the San Antonio River and a four-lane road. The vegetation in the area consists of approximately 50% exotic plants, especially Johnsongrass (*Sorghum halepense*) and bastard cabbage (*Rapistrum rugosum*).

The goal of the restoration project is to restore the area to a more natural open grassland. Cultural resources in the area prevents the use of mechanical restoration treatments, so herbicide application is the primary technique being used. Areas of bare ground in the restoration site are being hand-seeded with seed mixes purchased from Native American Seed Company, a small business that specializes in native wildflower and grass seeds native to the bioregion. San Antonio Missions NHP has used three different seed mixes in their restoration efforts: a prairie seed mix, a riparian seed mix and a pollinator mix. Revegetation efforts through seeding will continue along with periodic mowing to meet both ecological and safety concerns, until exotic species are eradicated.



The San Juan Acequia. The riparian seed mix contains species that help stabilize stream banks and provide other ecological services.

in every ten years is wet enough for a site to respond.

Managers can also use other techniques that may help hold moisture in the soil, such as straw, mulch or temporary fencing to help catch blowing snow.

Being able to provide supplemental water greatly increases the odds of successful germination following a seeding treatment. However, even if irrigation is not possible, seeding efforts may provide future benefits as they will contribute to building the native seed bank.

Site Protection

Protecting a restoration site following revegetation treatments may help them be effective. Using fences and cages around revegetation areas along with signage about the restoration site may keep animals and people from disturbing seedlings and newly transplanted plugs, and help prevent soil compaction. Generally, site protection may be needed in a restoration site until new vegetation is well-established.

Revegetation in the Southern Plains

Most of the southern Plains parks involved in prairie restoration projects conducted revegetation treatments. Seeding treatments using seed drills was the most common revegetation technique used. For example, Lake Meredith NRA seeded with purchased seed sourced from the Texas Panhandle. The seed mix contained big bluestem (A*ndropogon gerardii*), sideoats grama (*Bouteloua gracilis*), little bluestem (*Schizachyrium scoparium*) and buffalograss (*Bouteloua dactyloides*) among other species.

VIGNETTE: Revegetation at Sand Creek Massacre NHS

Managers at Sand Creek NHS initiated restoration work in a five-acre site in the southwest corner of section 25 along the site boundary fence in 2009. The area was a monoculture of Russian thistle (*Salsola spp*.) from tumbleweeds accumulating in the fence corner over many years. Managers began by mowing tumbleweed to a mow height of five inches. Park staff seeded the area that fall in anticipation of a wet winter. However, a dry period in southeastern Colorado began in 2009, and nothing germinated. Seeding treatments in 2010 and 2011 were also unsuccessful. The area was so dry and was impacted by blowing sand that even Russian thistle did not grow, resulting in a lack of vegetation.

In 2012, the park installed plastic fencing in the boundary fence in an attempt to reduce wind impact and collect snow to add moisture to the site. However, the fencing tore, requiring major cleanup. In 2013, park staff planted red three-awn (*Aristida purpurea*) seed collected from another area of the park. However, the seeding treatment was not successful due to the fine blowing sand that inhibited grass growth. The area remained free of vegetation.

In 2014, with the help of the Exotic Plant Management Team, the park transplanted native grass plugs collected elsewhere within the historic site. Transplanted grasses included little bluestem (*Schizachyrium scoparium*), blowout grass (*Redfieldia flexuosa*), sideoat grama (*Bouteloua curtipendula*), blue grama (*Bouteloua gracilis*) and alkali sacaton (*Sporobolus airoides*). The grasses were dug up using a shovel, placed in plastic pots and then watered. The potted grass plugs were then planted in the restoration site. The transplants were watered every day for the first week and then every other day for another week after transplanting. The area was seeded again with native grasses in fall 2014 and 2015.



Transplanting enabled restoration efforts to succeed where seeding treatments were not effective because of blowing sand in the restoration site.

The grass plugs survived, creating an area where wind speed was reduced and snow moisture was stored. A wet winter in 2014-2015 most likely assisted with transplant survival and seed germination, and the area had very good grass growth in 2015 and 2016. The survival of the grass plugs is helping the new seed to germinate and seedlings to survive. Transplanted plants also have set seed. The five-acre restoration site is now self-sustaining and requires no further seeding treatments.

Chickasaw NRA, Sand Creek Massacre NHS, Bent's Old Fort NHS, Lyndon B. Johnson NHP, Washita Battlefield NHS, and San Antonio Missions NHP also seeded during their restoration efforts. Parks shared seed drills purchased during Phase I of the project.

Most parks purchased seed from suppliers who were able to provide varietals appropriate for their restoration sites. Not having staff experienced in collecting and drying native seeds, limited available manpower and/or few areas in which seeds of desired species could be collected limited most park's ability to use seed collected in the local area for their restoration efforts.

The extreme to exceptional drought conditions in much of the southern Plains from 2010 through 2014 greatly impacted the prairie restoration efforts in the eight parks that participated in Phase II of the project. Many parks did not see responses to seeding treatments and, in fact, some restoration sites had bare ground during this time period. Additionally, some parks such as Lake Meredith NRA experienced a sharp increase in the abundance of drought-tolerant exotic plant species such as Russian thistle (*Salsola spp.*) and kochia (*Kochia scoparia*) (Struthers and others 2016).

Even under ideal conditions, it may not be possible to discern the success of a seeding treatment in the first year or two. Germination rates in the initial year after seeding may be very low; for example, only 5% of buffalo grass (*Bouteloua dactyloides*) may germinate during the first season. In general, at least three years is required to determine whether a seeding treatment was effective. Additional plantings using a seed drill in subsequent years may be successful, especially if managers continue to control nonnative plants in the site. Monitoring is also an important component in determining the success of revegetation treatments.

Only a few parks in the southern Plains were able to incorporate transplanting during restoration efforts. Bent's Old Fort NHS planted buffalo grass plugs in a small area and Sand Creek Massacre NHS transplanted grasses from another area of the historic site to the restoration area where seeding had not been successful due to drought conditions and blowing sand. Both transplanting efforts involved supplemental watering that helped the plants get established. Both were successful at revegetating the intended areas.

The ability to provide supplemental water or irrigation can greatly help revegetation efforts, especially in the semi-arid southern Plains where sufficient precipitation is not available in most years for revegetation efforts.



Alkali sacaton (*Sporobolus airoides*)

Lessons Learned

- Precision seeding using a seed drill is the preferred technique in restoration projects in the short and mixed-grass prairie.
- Seeding treatments are the least expensive revegetation technique. Unless supplemental water is available or seeding is followed by above average precipitation, an immediate response to the treatment may not be visible. However, seeding treatments will add to the native seed bank.
- It may take three years or longer for revegetation efforts via seeding to be successful, and/or may require multiple seeding treatments.
- The success of revegetation treatments is significantly dependent on available moisture. Treatments that occur during dry years or droughts are much less likely to be successful than those in wet periods. The availability of irrigation or supplemental watering will greatly assist revegetation efforts.
- If seeding treatments are not immediately effective, managers may need to mow or take other actions to control exotic plant species in the restoration site until revegetation efforts are successful.
- Transplanting seedlings grown in a greenhouse or salvaged wild plants offers a more rapid method of revegetation; however, it has a greater manpower requirement and cost. Supplemental water is also key in getting transplants established, and volunteers may be able to assist with watering efforts.
- Monitoring is essential to help evaluate the success of revegetation treatments.



DAVID ZETTNER

Passive Restoration

Passive restoration, or the facilitation of natural restoration, takes place when minimal restoration treatments are utilized to meet restoration goals. For example, a site may be able to recover ecological function after a site preparation treatment such as exotic species eradication or physical site preparation takes place. Passive restoration encompasses the aspects of ecological recovery that can develop naturally without intentional intervention (Clewell et al. 2005).

Passive restoration is less of a specific restoration treatment than a vigilance to ensure that barriers to natural processes do not impede the ability of a restoration site to ecologically function. In areas with adequate ecological integrity where passive restoration may be appropriate, managers may not need to conduct active revegetation treatments, instead utilizing a mixture of site preparation actions, along with regular maintenance and management of the restoration site.

Utilizing the ability of an ecosystem to heal on its own is, in itself, a powerful restoration tool. In fact, further intervention in a restoration site by conducting revegetation treatments may alter the natural trajectory of the ecosystem. Therefore, by consciously identifying passive restoration as a possible methodology, managers can ensure that revegetation and other activities do not take place when they may not be actually needed.

Passive restoration is only appropriate in some sites to be restored. Areas without natural seed banks, that do not have desirable native species growing in them, and that have been significantly altered by previous land use are generally not good candidates for passive restoration.

On the other hand, an area that has a good native seed bank that may be released by light mechanical land preparation, such as disking or removing exotic species that shade out native prairie species, may do well on its own after releasing the seed bank. Likewise, if the hydrology of a site has been altered, restoring the natural hydrology may be enough to tip the balance so that the site restores its natural function without further treatments.

In other situations, re-introducing natural disturbances such as fire or grazing may allow

VIGNETTE: Passive Restoration Following Tamarisk Removal in Bent's Old Fort NHS

In 2006, the NPS completed a 10-year project to remove tamarisk (*Tamarix ramosissima*) from 350 acres within the historic site. Tamarisk infestations in riparian areas are responsible for significant water consumption. The aggressive species outcompetes native species and its thick growth shades out species that would grow in the understory of native cottonwoods and willows. The park completed the control project using chainsaws and applying herbicide to cut stumps, and the slash was then burned.



Native wildflowers on the bank of the Arkansas River thriving after removal of tamarisk.

After tamarisk was removed and the area was opened up to sunlight, exotic plants such as Canada thistle (*Cirsium arvense*), tall whitetop (*Lepidium latifolium*) and other weeds grew in its place. Park staff immediately controlled these aggressive exotics in order to allow native species to compete and eventually dominate. Once these exotic species were controlled, native species then began to establish themselves from the native seed bank through passive restoration. Native vegetation reestablished itself in approximately 90% of the area that previously been covered by tamarisk thickets without further treatment. Although this particular restoration project was in a riparian area instead of a drier prairie grassland, it illustrates the principle of passive restoration that occurs by facilitating conditions for native species to thrive. Once that happens, they can re-establish themselves and undergo natural succession on their own.

native species to thrive. Evaluating whether it is possible to meet restoration goals by maintenance and management treatments versus revegetation is important part of site assessment and implementation planning.

Additionally, understanding the possible causes of current conditions in a site may help managers understand whether they can utilize the passive approach to restoration. For example, a restoration site may be dominated by exotic species such as Russian thistle (*Salsola spp.*) during a drought period when the same species would be outcompeted by native species during periods of normal precipitation. The type of treatments applied will depend on the overall site restoration goal(s) and the variables (such as the types of exotic plants present) that have created the need to implement restoration. Prescribed burning may help control some exotic species and stimulate the growth of native grasses.

The type of treatments applied will depend on the overall site restoration goal(s) and on the variables (such as the type of exotic plants present) that have created the need to implement restoration.

Passive Restoration in the Southern Plains

The prairie restoration projects in the southern Plains only incorporated passive restoration to a very limited extent. Most of the project's restoration sites needed active restoration because of the level of degradation present in the sites. Sand Creek Massacre NHS, a park where most of the grasslands have experienced few previous impacts and have relatively few exotic plant species, has utilized passive restoration with success. During the



Figure 18. In the abandoned prairie dog town at Sand Creek Massacre NHS, exotic species like Russian thistle (*Salsola spp.*) are now limited to areas around burrows.

drought in southeastern Colorado between 2010 and 2013, a 100-acre area that had been a site of a prairie dog town that was destroyed by plague had little to no vegetation growing in it. Park managers considered plowing to release the seed bank, but after evaluating the impact of climatic conditions, they decided to see if the site would restore itself after the drought ended. In 2014, after the area received adequate rainfall, the site was dominated by red threeawn (*Aristida longispica*), a native species. In subsequent years, the vegetation in the area consisted of mostly native grasses and forbs. The exotics in the area are mostly concentrated around former burrow sites where the topsoil was covered by mineral soil brought to the surface by prairie dogs. The area is now going through natural succession and is resilient enough to deter further spread of exotic species.

Knowing the history and previous use of a site may help managers determine whether passive restoration may be successful. For example, both Sand Creek Massacre and Bent's Old Fort had prairie dog towns that were eradicated because of plague and were bare of vegetation during the severe drought years. Native vegetation at the Sand Creek site was able to recover naturally because the site had not been plowed. However, the Bent's Old Fort abandoned prairie dog town was previously an agricultural field, and will continue to need treatments in order to restore native plant communities.

Lessons Learned

- Passive restoration is applicable in areas where a restoration site has retained much of its biotic integrity, but needs to have conditions that will facilitate natural restoration processes.
- The passive restoration approach may be used after site preparation treatments or along with maintenance and management actions such as prescribed burns.
- It is essential that managers actively monitor sites where passive restoration is being used and be vigilant for exotic plant infestations.



A prescribed fire
Bent's Old Fort NHS

Maintenance and Management

Maintenance and management of a restoration site takes place after implementation. The goal of maintenance and management activities is to continue to support the recovery of native vegetation and processes in the restoration site. Ideally, maintenance and management will stimulate growth of native species, control exotic species and aid in the continuation of natural processes. Removing exotic plants from a restoration site will usually stimulate growth of native species due to reduced competition.

Many types of maintenance and management activities, such as herbicide application, hand-control of exotics, mowing, grazing, prescribed fire and mastication (Table 15), may require multiple or periodic treatments. These activities need to be planned and scheduled in much the same way as restoration implementation treatments. Treatments to help the site attain what was defined in the restoration vision need to be identified, scheduled and budgeted—all while allowing for flexibility for adaptive management and changing environmental conditions.

Maintenance and management treatments must be specifically designed for each site, based on the conceptual plan, site assessment, reference condition and restoration treatments used. Planned maintenance treatments may need to be modified due to climatic variables, such as drought, lack of staff available to complete prescribed actions or other factors.

It is important that restoration projects are planned with an understanding of the need for continued maintenance and management. Without adequate post-revegetation treatments, native vegetation may not become established or thrive in a site because of competition from nonnative species or lack of stimulation from natural disturbances such as fire. Therefore, this ongoing maintenance of a restoration site is an integral component of any restoration project.

Maintenance and management treatments may have positive impacts on a restoration site depending on timing or other variables. For example, some exotic species such as King Ranch bluestem (*Bothriochloa ischaemum*) respond differently to fire depending on the season. A hot summer fire controls King Ranch bluestem, while winter and summer burns stimulate its growth (Simmons et al. 2007).

Table 15. Maintenance and Management Planning

Treatment	Control of Exotic Species		Stimulate Growth of Native Species	
	Pro	Con	Pro	Con
Herbicide Application	Cost effective for labor	Use requires licensing, cost of chemical and technical knowledgeable of herbicide application	Reduces competition from nonnative species	Most herbicides are not species-specific so surrounding natives are also suppressed
Hand-Control of Exotics	Can be done with volunteers, ensures death of plant, does not effect surrounding plants	Labor-intensive, may cause soil disturbance, need to pull taproot of some species for effective control	Reduces competition from nonnative species, has low impact on surrounding native plants	If soil is disturbed, it can release exotic seedbank, native plants may be trampled during treatments
Mowing	Can be a substitute for fire or grazing, is cost- and time-efficient, breaks or suppresses seed cycle of annual exotic plants	Requires proper timing and equipment, non-selective so impacts natives, equipment must be cleaned between areas to prevent contamination	Warm-season grasses respond well if mow-height is adequate, reduces competition from nonnative species	Requires high mow-height to preserve native bunchgrasses
Grazing	Different livestock (cattle, sheep, goats) target different issues	Requires knowledgeable and accommodating handler, requires fencing and water, livestock must have clean digestive system to prevent contamination, compliance issues, requires careful timing	Mimics missing natural grazing disturbance of prairies, reduces competition, cropping can stimulate native grasses	Requires careful timing, overgrazing may cause additional harm, possibility of soil compaction
Prescribed Fire	Reduces biomass, if properly timed, can break seed cycle of exotic plants	Opens up bare ground for exotic invasion, hot fires scar soil and promote exotics, weather dependent, large labor cost, neighboring landowner issues	Efficient for large areas, reduces litter and decadence, stimulates native grass to outcompete exotics, recycles nutrients	Not efficient for small areas, opens up bare ground to erosion and invasion, neighboring landowner issues, uncertain fire return intervals
Mastication	Reduces woody species, adequate substitute for fire and grazing	Requires specialized equipment, woody species may resprout resulting in greater biomass, cannot be used in areas with steep or rough terrain	Reduces woody invasion, shading, and competition	Requires specialized equipment, woody species may resprout resulting in greater biomass, large concentrations of woody debris, cannot be used in areas with steep or rough terrain

Some treatments may control exotic species or stimulate growth of native species depending on timing and other circumstances. Grazing during the early spring when cheatgrass (*Bromus tectorum*) is the only grass growing may help control it, while grazing later in the season would not impact the exotic grass, as it would then be dormant. But light grazing during the summer may alternatively stimulate the growth of native grasses. In general, each maintenance and management technique will have pros and cons in restoration sites for the control exotic species or the stimulation of native species growth or both (Table 15).

Therefore, maintenance and management treatments have to be applied carefully and judiciously in order to promote the desired benefits in the restoration site, as the same treatment may have positive or negative outcomes depending on the species involved, the season, and climatic conditions.

Herbicide Application

It may be necessary to continue to control exotic plant species with herbicide treatments following revegetation, or as part of a passive restoration strategy. When using herbicide, every effort must be made to not kill desired native vegetation while reducing the abundance of nonnative plants. It may be necessary to

spray herbicides when native species are dormant, such as spraying for cheatgrass before native species green up in the spring. If a restoration site has been seeded with native grasses but contains nonnative forbs, the use of an herbicide that only targets broad-leafed species is appropriate. Hand-spraying areas with high concentrations of exotic plants is an alternative when nonnative plants are not uniformly distributed throughout a site.

Hand-Control of Exotics

Hand-control of exotic species by pulling, trimming or other methods may have limited application as a maintenance and management technique in a restoration site. Controlling exotic species by hand is labor-intensive, but it allows managers to control or remove only exotic plants while avoiding impacts to natives. Because it requires a great amount of manpower, its use may be limited to small areas or in situations when a volunteer group may be able to assist.

Mowing

Mowing is a maintenance and monitoring treatment that can either be used to control exotic species, stimulate growth in native species or both.

Mowing is one of the best ways to control exotic forb species, especially Russian thistle (*Salsola spp.*) and kochia (*Kochia scoparia*) following revegetation treatments. Mowing can reduce the competitiveness of exotic plants and prevent exotic forbs from setting seed. It also helps prevent native grass seedlings from being shaded out by taller nonnative species. Invasions by woody shrub species may also be controlled with mowing.

In situations when it is not possible to use prescribed fire, either due to drought or when fire conditions aren't appropriate, mowing can be used as a surrogate for wildfire as it removes decadent plant materials. Mowing can also serve as a proxy for grazing. Mowing can stimulate grass growth as long as it isn't too frequent or if the mow height is not too low.

Mowing may be used selectively in a restoration area. Instead of mowing the entire area, treatments may be focused in areas with the greatest abundance of nonnative plants. Operators may choose to not mow in straight or complete rows in order to increase biodiversity in the site.

Mowing does not effectively control all exotic species. It does not work well for Johnsongrass (*Sorghum halepense*) or King Ranch bluestem (*Bothriochloa ischaemum*). Johnsongrass can only be controlled by herbicide application and King Ranch bluestem is stimulated by mowing. However, low mowing early in the season may prevent cheatgrass (*Bromus tectorum*) from being able to produce seeds.

Grazing

Conservation grazing is the use of livestock to assist in the stewardship of natural grasslands. Given that grazing by native bison (*Bison bison*) played a major role in the ecology of the shortgrass and mixed-grass prairie, incorporating grazing by domesticated livestock can be effective in maintaining a prairie restoration site.



Grazing with livestock cannot exactly replicate the natural disturbances caused by bison because of the inherent differences between the species. Bison graze predominantly on grasses and intensely graze an area but move frequently. Parks in the southern Plains are considering bringing back bison to prairie habitats, but the species requires significant management including fence repair and potential conflicts with park neighbors.

Parks usually find that having a grazing management plan, which may or may not be separate from a restoration plan, assists in administering grazing.

Grazing by cattle, sheep, and goats may be used in prairie restoration sites to control exotic species, stimulate growth of native grasses or control invasions of woody species. As with any other technique used in restoration, the use of livestock must be carefully and judiciously applied. It is especially important not to overgraze a site, as overgrazing likely will cause more harm than good to the ecosystem.

VIGNETTE: Mowing to Reduce Shrub Cover in Grasslands in Sand Creek Massacre NHP

Mowing has been successfully used to reduce the abundant cover of sand sagebrush (*Artemisia filifolia*), a native species of shrub, in grasslands in Sand Creek Massacre NHS. Vegetation in the park is a mosaic of sand sagebrush shrubland and shortgrass prairie bisected by a corridor of riparian vegetation. Sand sagebrush occupies the sandhills to the south and west of Big Sandy Creek and shortgrass prairie generally characterizes the loamier north and east sides (Neid et al. 2007). The sand sagebrush communities generally are found on well-drained sandy soils in areas of ancient dune systems and floodplains. Cover of sand sagebrush is thought to have increased with continual grazing prior to establishment of the historic site. Overall, the site contains an overabundance of early successional forbs and annual plants relative to the site historical climax plant communities (Roath et al. 2008).

Mowing has been a preferred method of treatment to reduce sand sagebrush in the park because of the very sandy soils. Mowing has successfully reduced the cover of sand sage, allowing existing native grasses and forbs to grow and multiply during the approximately four years required for sand sage to again dominate the area. Should a wildland fire burn through the park, the reduction in decadent sand sage will prevent a hotter fire, which in turn will be a benefit to the habitat.



An area within Sand Creek Massacre NHS showing an area that has received mowing treatments versus an unmowed area.

Prescribed burns could control sagebrush, but would also remove ground litter, which would cause a high risk of erosion given the sandy soils. Alternately, chemical treatment also could remove the sage and may have a longer-lasting effect than mowing. However, it would also remove native forbs, an important element for pollinators in the shortgrass prairie, and the grasslands in the park already have a deficiency in late successional forb species.

Given these factors, mowing has been the primary management alternative to control sagebrush invasion of grasslands relative to other possible treatments such as prescribed fire or herbicide application. It reduces the sage volume but also retains the forbs as well as leaves cover for protection against erosion. But as managers continue to maintain grasslands in the park, the trade-offs of each treatment option need to be taken into consideration.

In addition to maintaining appropriate stocking level, several strategies can help ensure that livestock do not congregate in some areas and overgraze them, while not utilizing other areas. These include the use of water development, shade structures and fencing (Bailey 2004).

Like bison, cows are predominately grazers, but they eat a higher proportion of forbs than bison. Cattle are the type of livestock most commonly used in conservation grazing of native prairies. They do not move as much as bison, and like any animal, they will overgraze an area if allowed. Grazing by cattle does stimulate the growth of native species, but grazing by itself will not restore a prairie, nor maintain the health of a prairie ecosystem.

Sheep are docile and light-footed, and cause less soil compaction than cattle grazing. Sheep also crop grasses in a way that stimulates new growth. However, sheep will stay in one area and overgraze it unless management is in place to ensure that it doesn't happen.

Goats eat exotic plants that other livestock will not, and therefore, can be very useful for control of exotic species. Goats can also graze on steep terrains. They are also predominately browsers and will eat woody species, which may be helpful in controlling shrub infestations.

Grazing by horses has very limited application for restoration purposes. Horses are very selective in their foraging habits, preferring areas with new growth for example. They also intensively use localized areas, which can expose bare ground, which is susceptible to erosion and/or invasion by exotic plants. Additionally, a horse's biting style causes them to clip plants very close to the ground, which impedes plant regrowth.

The pros and cons of grazing must be assessed before using the technique used in a restoration project. With the potential for harm via overgrazing, it is especially important to carefully assess the technique before implementing a grazing program. Park managers will need to work with a contractor who understands the objectives of conservation grazing and will work towards meeting both the park's and the contractor's objectives and restoration goals. The contractor's ability and commitment to ensure that overgrazing does not occur is especially important.



Grazing can be used to control exotic species. Exotic bromes in the grazed area to the left of the fence are controlled relative to their growth in the ungrazed area right of the fence.

Managers must also carefully consider the specific objectives of grazing treatments. For example, grazing to control exotic bromes such as cheatgrass (*Bromus tectorum*) is very different than an effort aimed at controlling woody species. Cattle or sheep grazing an area intently in the early spring would be useful in the former, whereas, goats would be necessary to achieve the latter.

Conservation Grazing in the Southern Plains

Southern Plains parks have not implemented conservation grazing in prairie restoration projects to date. However, in the future, there is interest in using this maintenance technique in restoration areas (Figure 19).

Considerations for future grazing in restoration sites include the importance of having a knowledgeable grazing contractor in order to ensure that it is a mutually-beneficial partnership. The most important factors when planning grazing treatments are to include targeting the right stocking levels, protections



Figure 19. Bent's Old Fort NHS maintains a small number of livestock primarily for interpretive purposes. The park proposes to periodically use these animals for exotic plant treatment when this use does not conflict with the interpretive goals for these animals. This use may include temporary electric fencing in areas where grazing would be beneficial as well as temporary exclusion of animals from areas actively being restored.

against overgrazing and to have treatment objectives that match the animals used and the timing of grazing treatments. Contractors must be responsible for removing animals when instructed so that restoration areas are not overgrazed.

Prescribed Fire

Fire has had a dominant role in shaping the Great Plains and maintaining the health and functioning of grasslands (e.g., Joern and Keeler 1995), but its relative significance to grazing in the shortgrass prairie, where conditions are more arid, is less understood than for tallgrass prairie (Scheintaub et al. 2009). Specifically, the role of fire as a primary determinant of grassland structure likely decreases strongly from tallgrass prairie to shortgrass steppe as a result of the gradient in productivity and fuel (Kucera 1981, Oesterheld et al. 1999, Scheintaub et al. 2009). Therefore, fire probably plays a lesser role in maintaining a healthy prairie in the shortgrass steppe than other drivers such as herbivory and climate variation (Struthers et al. 2015).

Nonetheless, fire is an important natural disturbance in prairie ecosystems, as it removes accumulated litter and decadence from aboveground growth (Figure 20), recycles nutrients, and controls invasions of woody plants (Scheintaub et al. 2009). Prescribed fire can also remove fuels buildup that creates a risk of an unacceptable wildfire and removes excessive dead biomass, especially from exotic plants, that can limit native plant vigor, productivity or recovery.

On the other hand, shortgrass steppe has minimal litter accumulation (Burke et al. 1998). Additionally, Scheintaub et al. (2009) reported a positive relationship between litter and productivity in shortgrass systems, suggesting that litter may facilitate, or at least not inhibit, productivity as it does in tallgrass prairie. However, Scheintaub et al. (2009) also suggest that further research is needed on the relationship between litter and productivity in shortgrass ecosystems.

The incidence of fire in the shortgrass prairie has decreased significantly since the 1800s because of suppression and reduction in fuels due to heavy livestock grazing (Ford and McPherson, 1996 and 1999).

Today, the absence of fire is generally thought to have contributed to fuel accumulation in some areas, especially where there has been encroachment of woody plants. Therefore, when fires do occur, it is possible that fires now burn at a greater severity than they did historically, especially where shrubs are present (Struthers et al. 2015). Whether fire has a positive, neutral or negative benefit on grassland condition depends on several factors (season, frequency, potential for exotic plant response, etc.) that will need to be carefully considered before using prescribed fire as part of a prairie restoration program. The inherent uncertainty of using fire as a prairie restoration management tool generally also warrants that it be undertaken under an adaptive management



Figure 20. Decadent grass, containing dead or dying plant material.

VIGNETTE: Changing Conditions for Use of Prescribed Fire at Bent's Old Fort NHS

Prescribed fire can be an appropriate tool to achieve management goals in a prairie restoration site for a variety of reasons. Fire is useful when vegetation, particularly grasses, has lost vigor and become decadent, or fuel buildup poses a risk of a wildfire. Fire also is effective when excessive dead standing biomass, particularly from exotic plants, is high enough to preclude effective light penetration for native plants or otherwise limits native plant vigor or recovery. Prescribed fire may also be beneficial when litter accumulation exceeds that expected for a given ecological site.







Whether these set of conditions exist on the ground in a restoration area or other prairie site is a result of changing climatic or environmental conditions. Droughts, floods and other events can determine whether fire may be able to meet management objectives. These dynamic conditions can cause challenges to managers trying to plan and schedule fire and other treatments.

For example, when a site in Bent's Old Fort NHS was visited for a site assessment in late 2014, it had a great deal of dead vegetation, making it a good locale for a prescribed burn. However, a flood along the Arkansas River is spring 2015 removed much of the dead vegetation, eliminating much of the impetus for a burn (top left).

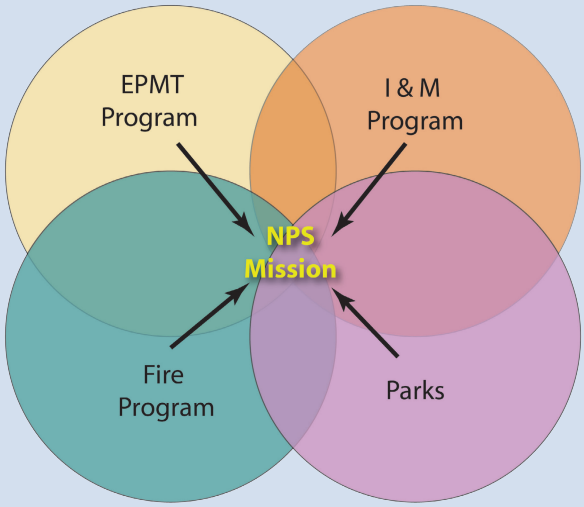
Whether an area has been experiencing drought conditions also may impact whether it is appropriate for a prescribed burn. One site would have benefited from a prescribed fire in 2011 (middle left), but in 2015, the vegetation is so low that there is not enough fuel to carry a fire (lower left). These two photos were taken before and after the most intensive period of the drought that impacted southeastern Colorado in the early 2010s.

framework that includes monitoring of the response to the fire.

The historic fire return interval for the southern Plains is poorly known at best, given the lack of trees on which to conduct tree ring studies. Because fire return intervals are mostly unknown for prairie ecosystems, there is considerable disagreement on what the

VIGNETTE: Collaborative Framework for Resource Management in the Southern Plains

Preserving park resources unimpaired for the benefit of future generations is the responsibility of all NPS divisions, programs and sites. The Inventory and Monitoring Division, the Biological Resource Division's Exotic Plant Management Teams and the Fire and Aviation Division all collaborate with parks to better assess and manage natural resources. Although each program may have its own programmatic goals, considerable overlap exists in their goals and efforts. Traditionally these groups have worked independently, but parks in the southern Plains are working collaboratively to use the best science possible to aid in prairie restoration projects.



The inventory and monitoring program, exotic plant program, fire program and parks all contribute to, but overlap, in their efforts to meet the NPS mission.

Working collaboratively provides increased efficiency when there is redundancy. For examples, the Southern Plains Fire Group and the Southern Plains Inventory and Monitoring Network (SOPN) consolidated vegetation monitoring and was able to cut costs, reduce administrative overlap and increase information sharing. Additionally, a collaborative approach improves the quality of information provided to parks, and leads to consensus on park management issues.

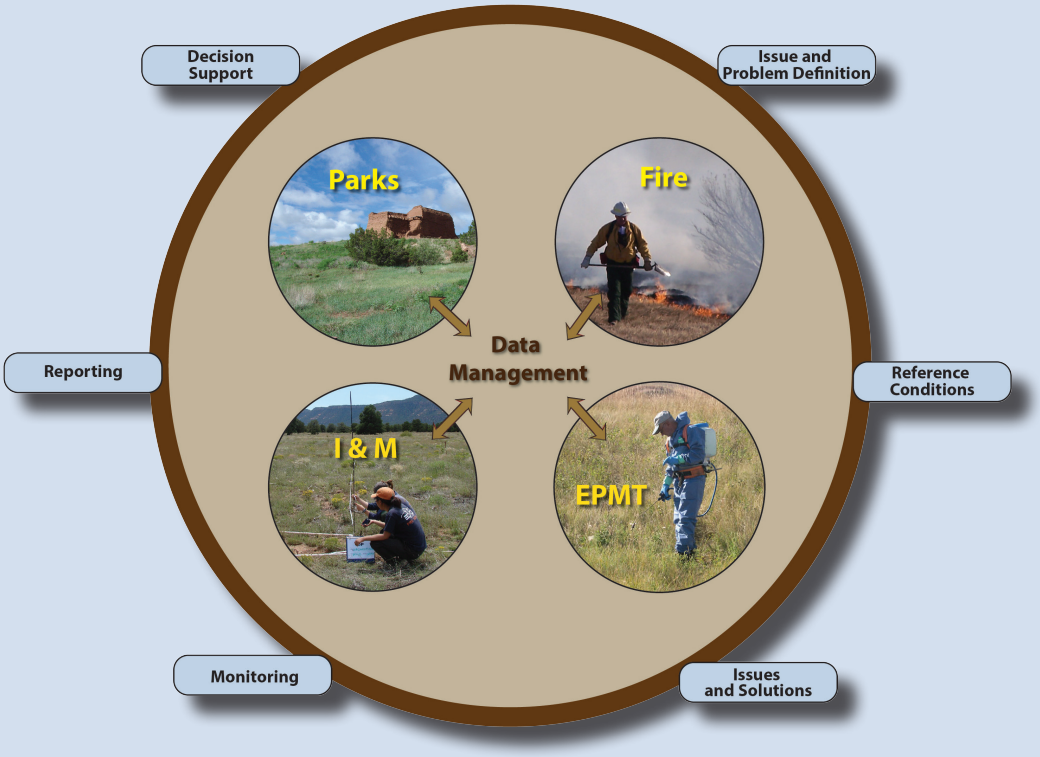
The 11 parks in the Southern Plains Network are beginning to utilize a collaborate framework with the Southwest Exotic Plant Management Team (EPMT), Southern Plains Fire Group and the SOPN on natural resource issues and solutions. This collaboration is part of a larger network of collaboration between neighboring I&M networks, the Southwest EPMT and the Sonoran and Chihuahuan Deserts Zone of the U.S. Fish & Wildlife Service. This collaborative framework closely parallels the principles of adaptive management.

Each partner within the collaborative framework has specific roles and responsibilities. Parks have an explicit responsibility for and are accountable for management of park lands and they have the final authority for making decisions that typically occur at the park level, even though all partners may provide input. The Southern Plains Fire Group has a primary role in developing and implementing burn plans. The EPMT has a responsibility and is accountable for the exotic plant treatments and restoration. The SOPN is responsible for the scientific integrity and defensibility of monitoring and likely would play a stronger role in developing sampling designs and field monitoring efforts.

The issues and solutions that the collaborative team may center on preventing the degradation of a potentially threatened resource, while in other cases, the

VIGNETTE: Collaborative Framework for Resource Management in the Southern Plains (continued)

team may have an emphasis on restoring an already degraded resource, such as a grassland site. The prairie restoration projects in the southern Plains were an important interdisciplinary effort that built relationships between the partners, leading to the development of the collaborative framework.



The collaborative framework seek solutions to natural resource issues in the parks, by:

(1) Identifying and defining potential issues,
(2) expanding upon the broad desired conditions contained within General Management Plans to more measurable desired resource states,
(3) discussion and implementation of management solutions and treatments,
(4) monitoring the effectiveness of those solutions and treatments,
(5) interpreting and reporting the results of our efforts, and
(6) providing parks with the best information possible in support of management decisions.

The process will use reference conditions to evaluate the effectiveness of resource management progress and will assess resources in a variety of relevant contexts to help the parks better understand the resource condition, especially those relative to the park's fundamental resource values.

Monitoring, including effectiveness monitoring, will be an integral part of this work and will take place in conjunction with treatments initiated through the collaborative framework. Reporting of data would take place on an annual basis and at a multiyear scale, and include comparisons of condition relative to reference or target conditions.

The collaborative approach is also consistent with the general principles of sound decision making, further helping to preserve park resources at risk.



Prescribed fires can help control exotic species and stimulate growth of native grasses.

historical intervals were and what they should be.

Because prescribed fire can be an important tool used to manage and maintain a prairie restoration site, an alternative to using a presumed fire return interval is scheduling fire treatments only when conditions warrant. In other words, instead of having a prescription for fire based on a set interval of time, resource conditions may better dictate when prescribed fire is the preferred management tool. An approach based on the condition of resources and the role that fire played in influencing that condition is consistent with park's fire management plans, but clarifies the use of fire to achieve resource management goals in the context of vegetation management.

Small prescribed fires conducted for specific ecological objectives are most effective in prairie restoration sites.

The use of fire, like that of other management treatments in restoration sites, is dependent on the currents conditions, restoration goals and the principles of adaptive management. For example, fire may be the preferred method to remove dead biomass, but drought conditions may preclude the use of fire, forcing managers to adapt alternative strategies. As with mowing, grazing and other maintenance and management treatments, fire is the preferred treatment method in some situations but not others.

The timing of burns is also critical in determining what the impact will be. Hot summer fires have different impacts on native and exotic species than cooler winter fires.

Parks that use prescribed fire also need to be prepared to conduct follow-up treatments on exotic plants that may come in burned areas. Infestations of nonnative annual species such as Russian thistle (*Salsola spp.*) and kochia (*Kochia scoparia*) may occur following prescribed fires, especially during dry periods. Because of the need for follow-up control of exotic plants, small prescribed burns may be easier for parks to manage.

Prescribed Fire in the Southern Plains

The use of prescribed fire during the prairie restoration projects between 2008 and 2015 was greatly limited by the extreme to exceptional drought in most of the southern Plains during that interval. Only Lake Meredith NRA and Lyndon B. Johnson NHP were able to conduct any burns in their restoration sites. Chickasaw NRA also conducted burns to control invasions of woody plants, primarily eastern red cedar (*Juniperus virginiana*).

Seven of the parks who participated in the prairie restoration projects are part of the Southern Plains Fire Group, which is based out of Lake Meredith NRA. Lyndon B. Johnson NHP and San Antonio Missions NHP are both part of the Big Thicket Fire Group, but Lyndon B. Johnson NHP has partnered with the nearby Balcones Canyonlands National Wildlife Refuge to assist with burns on their 12-acre restoration prairie.

Parks with Fire Management Plans in place can utilize prescribed burns in their restoration sites as needed to meet resource objectives. Integration of fire program and prairie restoration objectives enables the planning of prescribed fires that can aid in the maintenance of prairie restoration sites, although this approach can be more challenging from a planning perspective.

VIGNETTE: Planning for Prescribed Fire at Washita Battlefield NHS

Grasslands dominate most of 326 acres in Washita Battlefield NHS and prescribed fire would help to meet resource objectives in these grasslands. While burning all these acres at once would be cost-effective, small prescribed burns are preferable in many ways, especially because of the park's small natural resource staff and the probable need for follow-up management for control of exotic species (especially given the prevalence of exotic grasses in the historic site).



MATT LAVIN/WIKIMEDIA COMMONS

Japanese brome

Two areas of the park are priority for prescribed fire. One area would be a spring burn conducted to test for control of Japanese brome (*Bromus japonicus*) and cheatgrass (*Bromus tectorum*), both among the most prevalent exotic plants growing in the historic site. This burn would be carefully timed for when these exotic grasses are about to set seed and there is enough thatch to carry a fire. The other area consists of the fields south of the Washita River that were seeded ten to 15 years ago. Grasses in this site have become decadent and need to be burned because the thatch is too thick and inhibits regeneration.

These small fires would be conducted for two different restoration maintenance purposes: to control of exotic species and to stimulate growth of native species. Not only do small acreage fires make post-burn management easier, they also enable managers to experiment in order to determine the most effective treatments and allow for adaptive management. It also allows evaluation of prescribed burns in conjunction with other possible management and maintenance treatments.

Prairies are dynamic ecosystems, and in some situations, natural disturbances such as fire have been disrupted. The absence of fire and other disturbances may have allowed encroachment of woody species in some park grasslands. In these situations, parks may decide to take management actions such as prescribed burns in order to maintain a cultural or historical landscape.

Mastication

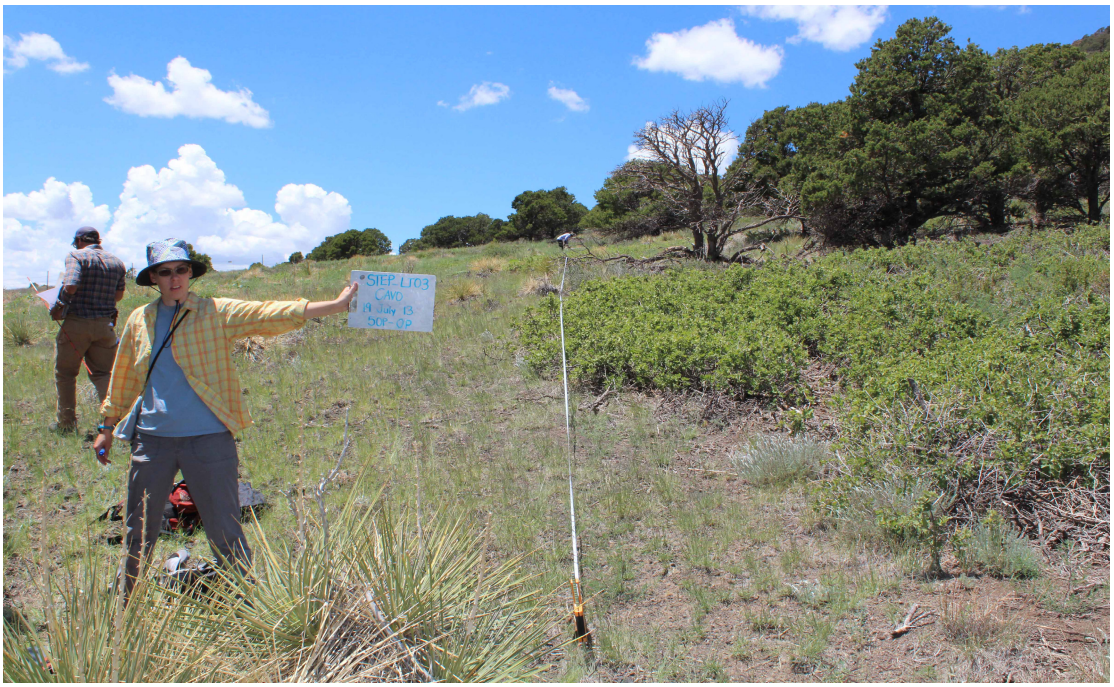
Mastication is a treatment that involves the chipping and shredding of shrubs and small diameter trees on-site and is a maintenance and management option that can be used in lieu of fire to treat encroachment of woody vegetation. In prairie restoration sites, mastication may be used when it is not possible to conduct prescribed burns to suppress shrub and tree invasion due to factors such as drought conditions or if the site is not otherwise suitable for prescribed fires.

There is no natural analogue to mastication, as natural disturbances do not create litter made of woody debris. Additionally, the equipment used during a mastication treatment may cause ground disturbances, damage grasses and forbs and may create locales where exotic plants may become established. It also may not be possible to use the mastication equipment in areas with steep slopes. However, mastication

may be preferable to mechanical thinning and burning of slash piles that may sterilize the soil underneath piles due to high heat. It is also more expensive than prescribed fire, but may be a beneficial management option in some restoration sites that are impacted by encroachment of brush or trees.

Lessons Learned

- Maintenance and management treatments are often necessary in a restoration project to ensure that conditions remain favorable for the establishment and continuing vigor of native plant communities.
- Exotic species infestations may be controlled by herbicide application, hand control, mowing, grazing or prescribed fire.
- Mowing is one of the best ways to control exotic forb species. Management mowing in a restoration site can be done selectively and can be used in lieu of prescribed fire or grazing when necessary.
- When conducting grazing treatments, it is important to work with a knowledgeable contractor who understands the conservation goals for the restoration site in order to establish a mutually-beneficial partnership.
- Stocking levels, livestock species and rotations are critical factors in determining the success of conservation grazing treatments and may require development of a grazing management plan that incorporates restoration objectives and goals.
- Small prescribed fires in prairie restoration projects allow managers to be more effective in conducting post-burn treatments (especially exotic species control), monitoring and evaluation and utilize adaptive management in maintenance of prairie restoration sites.
- Prescribed burns conducted for ecological purposes are more effective in prairie restoration projects than those scheduled on the basis of poorly-known fire return intervals.
- Fire plays an important role in maintaining the health and vigor of grasslands, but prescribed fire, like that of other treatments, should be applied judiciously.
- Mastication may be used to control encroachment of shrubs and small trees.



Monitoring park resources can provide a valuable foundation for effective park planning.

Monitoring

Monitoring is an integral part of a restoration effort because it helps managers understand the current conditions of the restoration site, evaluate the effectiveness of applied restoration treatments, and adapt management strategies to changing conditions. Monitoring data are also an open and transparent way of guaranteeing that the funds used for restoration activities were well spent.

Monitoring techniques observe changes in soil and vegetation communities in the restoration site that occur prior to, during and after restoration treatments. Not only does monitoring provide information on the current condition of a restoration site, it also provides insight into trend; e.g., whether conditions in the site are improving, remaining static or declining, and into the causes of those changes. Monitoring of reference sites may also be valuable in understanding the condition of a restoration site since some changes in condition may be a result of a climatic factor such as drought.

Monitoring throughout all phases of a restoration project (Figure 8), from conceptual planning through restoration implementation and the post-treatment assessment phase, allows managers to utilize adaptive management principles to adjust restoration treatments to changing conditions.

Monitoring is an important but often overlooked aspect of a restoration project.

Managers may utilize different monitoring strategies (Table 16). The simplest technique is photographic monitoring. A rapid assessment is a qualitative evaluation of an ecological site using soil, hydrologic and biological indicators. Formal monitoring involves making qualitative and quantitative observations and measurement that assess the type, abundance and condition of vegetation in the site along with other physical parameters, such as soil characteristics. Formal monitoring of restoration sites may also take place as part of other monitoring efforts, such as fire effects monitoring or protocols implemented by NPS inventory and monitoring networks such as SOPN. Formal monitoring programs may also be implemented in restoration sites that are designed to specifically measure the effectiveness of applied restoration treatments.

Table 16. Types of monitoring that may be used to document changes in a restoration site

Type	Description	Advantages	Limitations
Photographic Monitoring	Repeated photographs from a photo point or points taken at repeated intervals.	Inexpensive and simple. Can provide a long-term record that can characterize qualitative changes in a restoration site.	Does not provide quantitative information. May be difficult to identify specific species or vegetation types.
Rapid Assessment	A fast survey utilizing indicators for plant and soil attributes to provide information on the ecological integrity of a site.	Provides a comprehensive qualitative assessment of a restoration site at a single point in time. Provides information about vegetation, soils and hydrology.	Must be completed by a trained ecologist. Provides only qualitative information.
Effectiveness Monitoring	Specific monitoring to evaluate restoration treatments.	Provides direct information on potential results of restoration treatments.	Only measures attributes impacted by restoration treatments.
Long-term Monitoring	Monitoring using protocols or plans of study that produce valid repeatable measures over time.	Scientifically rigorous, repeatable, provides in-depth quantitative information. Provide measurable trend information.	Expensive, requires specialized and experienced staff.

Photographic Monitoring

Photographic monitoring involves taking photos from established points. These repeat photographs allow visual comparison of changes in vegetation and other conditions in a restoration site (Figure 21). Photo points are usually defined by a stake in the ground or other landmark that will be easily identifiable in subsequent years. Additionally, the photo monitoring protocol may define whether the photos are to be taken in particular direction or in many directions. Other specific parameters such as time of day and camera settings may help ensure that the photographs show the same information as closely as possible. Photographic monitoring is best when it occurs at periodic intervals such as on the same date each year, or at another standardized interval (such as quarterly). For best results, photographic monitoring takes place on at least an annual basis.

Photographic monitoring may be combined with detailed notes and climate information



Figure 21. Repeat photographs from grasslands monitoring in Washita Battlefield NHS. Although the photographs were taken within weeks of another in subsequent years, the transect had thicker grass and more forbs growing in 2016 (right) than in 2014 (left).

from nearby weather stations to help characterize any changes evident in the repeat photographs.

Photographic monitoring can provide information about the vegetative cover, and presence of invasive woody species, and possibly information on the number and types of forbs growing in the restoration site. If photographic monitoring is to be used to determine the presence or absence of grass species that were seeded during revegetation treatments, photographs should be taken when seed heads are ripe and grass species are easily identifiable.

Photographic monitoring is inexpensive and easy to implement. Simple protocols may be developed for photographic monitoring that can be followed by staff or volunteers with little training. A well-curated file of repeat photographs can provide a powerful long-term source of information about a restoration site that can be easily understood by resource managers and other park managers. Repeat photos may be able to show a trend in condition of a site. Repeat photographs are also useful to illustrate restoration practices as part of a park's interpretive or educational programs.

Rapid Assessment Monitoring

A rapid assessment utilizes qualitative observations during a fast survey of a grassland area using indicators for both plant and soil components (Pellant et al. 2005). These indicators provide information on the integrity of the soil, vegetation, hydrology and ecological processes in grassland ecosystems.

Grasslands rapid assessments examine three interrelated attributes: soil/site stability, hydrologic function and biotic integrity (Pellant et al. 2005) (Table 17). Soil/site stability is the capacity of an area to limit redistribution of soil resources by wind and water erosion. Hydrologic function is the ability of an area to capture, store and safely release water from precipitation, snowmelt and run-off, and to maintain this capacity. And biologic integrity is the capacity of the biological community to support ecological processes within the site's normal variability, and to perpetuate these functions (Pellant et al. 2005 and Struthers et al. 2016b).

Table 17. Indicators and measures used to assess the restoration site at Lyndon B. Johnson NHP during a 2014 rapid assessment

Indicator	Measure
Soil/Site Stability and Hydrologic Function	Rills
	Water Flow Patterns
	Pedestals and/or terracettes
	Bare ground
	Gullies
	Wind-scoured, blowout and/or depositional areas
	Litter Movement
	Soil surface resistance to erosion
	Soil surface loss or degradation
	Compaction layer
Biotic Integrity	Landscape-scale Diversity
	Local Species Composition
	General Life Cycles Relative to Disturbance
	Relative proportion of functional groups (e.g., graminoid, forbs, shrubs, etc.)
	Relative proportion of cool-season and warm-season species

Modified from Struthers et al. (2016b). Methods used in the 2014 rapid assessment for a Natural Resources Condition Assessment were based on Pellant et al. (2005).

Qualitative measures used in rapid assessment can provide land managers and natural resource specialists with good communication tools (Pellant et al. 2005). Indicators are used as an index of an attribute like hydrologic function that is usually too difficult, time-consuming or expensive to measure. Taken together, multiple indicators provide a good surrogate for grasslands health in a restoration site.

When qualitative measures are used in association with quantitative monitoring and inventory information (when available), they can be used to provide an important snapshot of the condition of a restoration site.

Effectiveness Monitoring

Effectiveness monitoring is a targeted type of monitoring designed explicitly to determine how successful a restoration project ultimately is, and may include evaluation of specific treatments such as seeding or prescribed burns,

especially relative to a project's conceptual plan and restoration goals (Machmer and Steeger 2002).

It includes monitoring key indicators of the system's response to restoration activities. This type of monitoring is an especially important part of adaptive management as it provides information that can help managers adjust restoration strategies as needed to attain project goals and objectives. Effectiveness monitoring can also provide information used to meet reporting requirements for restoration projects, plan and prepare funding proposals future restoration treatments and communicate the results of restoration efforts in interpretive or educational media.

Effectiveness monitoring may collect information relative to a variety of restoration treatments, including site preparation, revegetation and maintenance treatments such as prescribed burns. Managers may want to monitor the hydrology of a site after terrace removal or monitor for abundance and diversity of exotic plants after control efforts for nonnative plants. Monitoring for any changes in the presence and abundance of plant species included in revegetation treatments may yield information about the success of seeding and transplanting efforts over time.

Protocols ranging from the simple to complex may be put into place for conducting specific types of effectiveness monitoring and may consist of qualitative or quantitative data gathering.

Fire effects monitoring takes place before and after burn treatments in a restoration site and is designed to document and analyze short- and long-term effects of fire on vegetation. Sites are also monitored at one, two, five and ten year intervals after a burn. In the southern Plains, fire effects monitoring includes assessment of vegetation composition and abundance, fuel loads, litter and duff depth and burn severity. The data allow resource managers and scientists to compare pre- and post-burn vegetation composition and fuel loadings and assess whether burn objectives were met, and to track long-term ecosystem changes due to fire.

In some cases, long-term monitoring such as that under the SOPN grassland protocol, can provide information about the effectiveness of restoration treatments, although its main objective is assessment of larger-scale ecological attributes such as biodiversity.

Long-term Monitoring

Long-term monitoring uses established protocols to document changes over periods of time, ranging from years to decades or longer. The goal of long-term monitoring is to assess the overall health of an ecosystem.

The SOPN utilizes the *Grassland Monitoring Protocol and Standard Operating Procedure*s in collaboration with the Southern Plains Fire Group to monitor permanent grassland transects in each park (Folts-Zettner et al. 2011). Each 50-meter transect consists of five nested 2x1 meter plots. During a transect visit, a field crew measures 1) species composition and cover in each plot, 2) surface type and cover in each plot, 3) shrub density within 10 meters of the transect center-point, and 4) point-line intercept cover along the transect. Status and trends in species composition and community structure are examined in relation to environmental variables (i.e., long-term management actions, climate and atmospheric deposition).

SOPN initiated this protocol in 2010, and transects are visited two out of every three years. Since the goal of these permanent plots is to assess the overall health of park grasslands, transects may or may not be in areas that have received restoration treatments. Transects within restoration sites can provide important information on the condition of a restoration site, and provide important quantitative information on trends in vegetative cover and species composition, including native and nonnative species, and ground strata (bare soil, litter, rock).

Grasslands monitoring can be complemented by other long-term monitoring in park areas. For example, SOPN also monitors for exotic plants along high-priority vectors, such as

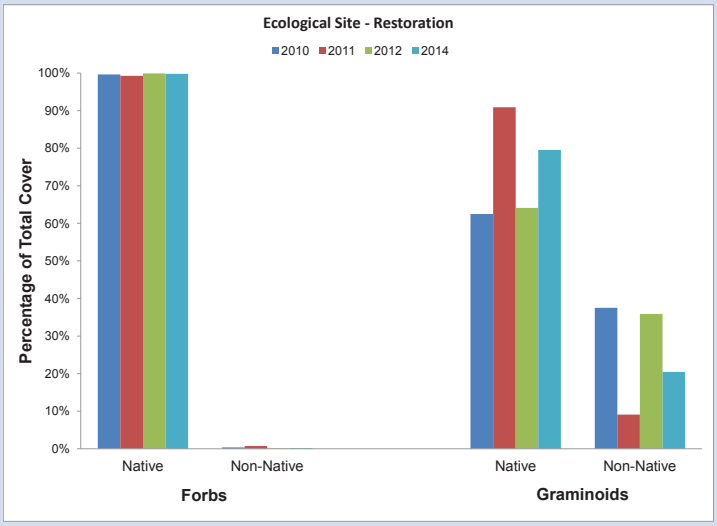
VIGNETTE: Grasslands Rapid Assessment for Natural Resources Condition Assessment at Lyndon B. Johnson NHP

As the only grasslands in at least a semi-natural condition in Lyndon B. Johnson NHP, the restoration prairie was the focus of grasslands assessment for the Natural Resource Condition Assessment (NRCA) conducted by the NPS and cooperators in 2014 (Struthers et al. 2016b). NRCAs evaluate current conditions for a subset of natural resources and resource indicators in national park units, providing a credible, snapshot-in-time evaluation of selected natural resources and indicators.

The rapid assessment conducted by Biologist Tomye Folts-Zettner for the NRCA is a good example how monitoring conducted for other programs can provide important information about a restoration project. The assessment, which incorporated findings from long-term monitoring of two transects using the SOPN grasslands protocol, used two indicators: soil/site stability and hydrology, and biotic integrity (Struthers et al. 2016b). The first indicator included ten measures and the overall condition of soil/site stability and hydrology was good, as nine of the measures had the highest rating.

Table 4.9.4-2. The number and percentage of native and exotic species of each life form found on Lyndon B. Johnson NHP during the 2010-2012 and 2014 grassland monitoring sampling.

Life Form	Native	Exotic	Total	Percent Native
Grass	41	12	53	77%
Forb	108	6	114	95%
Subshrub	1	0	1	100%
Tree	5	0	5	100%
Vine	15	0	15	100%
TOTAL	170	18	188	90%



The assessment also found that 95% of forbs growing in the restoration site were native species. However, grasses were only 77% native. From Struthers et al. (2016b).

Five measures were used to assess biotic integrity. Landscape-scale diversity, local species composition, relative proportion of functional groups, and relative proportion of cool-season and warm-season species were found to be in good condition. General life cycles, relative to disturbance, were in moderate to good condition. Given the disturbances at the site, including terrace removal and the prolonged drought, this finding was not considered to be surprising. Overall, the assessment of the restoration site determined that it was in good condition with an improving trend.

roads and trails. These vectors may be in or near restoration sites and exotics monitoring may provide information on the status of exotic plants in a restoration area.

Monitoring of Restoration Sites in the Southern Plains

Field crews from the Southern Plains Inventory and Monitoring Network conduct regular monitoring of grassland transects in eight of the nine parks that conducted prairie restoration projects. San Antonio Missions NHP is in the Gulf Coast Network and utilizes monitoring protocols developed by the Lady Bird Johnson Wildflower Center.

SOPN grassland plots in any individual park may or may not be in an area that has received restoration treatments. Transects in restoration sites can provide important information about the site's responses to restoration treatments. Transects that are not within restoration sites but are in areas with similar soils and vegetation, or in similar ecological sites, can act like a control for a restoration site.

SOPN has permanent plots in restoration sites in Bent's Old Fort NHS, Chickasaw NRA, and Lyndon B. Johnson NHP. Plots in similar grassland areas with similar soils and vegetation are in Fort Larned NHS, Lake Meredith NRA, Pecos NHP, Sand Creek Massacre NHS and Washita Battlefield NHS.

Throughout this project, the SOPN has also been available to park staffs to assist by providing training in monitoring protocols and with data analysis.

In addition to conducting monitoring in restoration sites, whether it be photographic monitoring, rapid assessments, long-term monitoring or effects monitoring, it is important for managers to regularly observe conditions in the restoration site. These observations can help adjust management of the site in order to respond to changes that may occur over short intervals of time. For example, visits to a restoration site in the days or weeks following a seeding or transplanting treatment may reveal that the seedlings or transplants may need supplemental water in order to become established. Such observations may also reveal incipient invasions of exotic plant species or other threats to the ecological integrity of a restoration site.

Lessons Learned

- Regular monitoring is an essential part of a prairie restoration project, and it requires commitment and dedicated resources to ensure that it occurs. Standardized data collected through monitoring can inform treatment strategies through adaptive management and can be used to provide evidence of the value of restoration activities.
- Communicating with managers of NPS programs, such as I & M networks and fire effects, who conduct monitoring may allow synergies with other monitoring programs. Using a monitoring protocol in a restoration site is a way to add to the knowledge base of park conditions as a whole.
- I & M networks may be able to provide training in monitoring protocols and can help with data analysis.
- Photographic monitoring is the simplest type of monitoring and staff from other park divisions or volunteers may be able to assist with repeat photography.



Bent's Old Fort NHS

Interpretation

Interpretation, or the communication of information in way to promote understanding of the significance and meanings of park resources, is a fundamental part of the NPS mission. As such, it is an essential component in any resource management project, such as prairie restoration. Successful interpretation can help restoration specialists meet restoration goals by promoting understanding of the importance of native grasslands, and this understanding can deepen people's understanding of the value of restoring degraded shortgrass and mixed-grass sites in the southern Plains.

The prairie restoration projects undertaken by the nine parks will not only help restore biological function of the impacted grasslands, but also help restore cultural landscapes, which is vital to the significance of these parks. Three national historical parks (Lyndon B. Johnson, Pecos and San Antonio Missions) and four national historic sites (Bent's Old Fort, Fort Larned, Sand Creek Massacre and Washita Battlefield) participated in the prairie restoration projects. The prairie landscape is an integral part of each of these parks' stories, whether it is representing the prairie that travelers on the Santa Fe Trail encountered at Bent's Old Fort and Fort Larned, or recreating the lush grasslands that enticed President Johnson's family to settle in the hill country.

Interpretive Themes

Interpretive efforts related to the prairie restoration projects in the southern Plains focused on two major thematic areas:

- The importance of native vegetation (grasses and forbs) and the role they served historically and their relationship to the cultural significance of a site or park.
- The relationship of native and exotic grasses as it relates to wildlife and the value of preventing degradation of grassland ecosystems.

Native prairie is an important resource in all parks that took place in the prairie restoration projects, including sites with cultural emphasis. The accuracy of an historical site includes the biotic integrity and visual scene, and both are necessary for cultural interpretation. The presence of exotic plants and animals, encroachment of woody vegetation into what were grasslands during the period(s) of cultural significance for the site and surface

disturbances such as roads, ditches or levees all can detract from the accurate representation and effective interpretation of a park's story and the public understanding of it. For example, the enabling legislation for Washita Battlefield NHS directs the National Park Service to maintain the landscape as closely as possible to its appearance at the time of the battle in 1868. Exotic tamarisk has been removed from the Washita River (Foote 2003), and removing exotic grasses from the prairie in most of the rest of the historic site will also help preserve the battlefield's historical character, meeting both interpretive and management goals.

Interpretation is an integral component of a prairie restoration project.

Restored prairie can accurately depict the scene of settlers, Native Americans, and explorers of the early- to mid-1800s and can help articulate why this grassland landscape seemed so intimidating and lonesome to some, and beautiful and full of opportunity to other people.

Native species are essential to the biologic health of grasslands. Nonnative grasses displace native grasses and degrade wildlife habitat because wildlife native to the shortgrass and mixed-grass prairie rely on native plants for food and cover. Many native grasses are bunch grasses, but many invasive grasses are sod-forming. Sod eliminates the patches of bare ground that are necessary habitat for many grassland birds and invertebrates. Healthy grassland ecosystems need native grass species in order to function appropriately. Effective restoration fills plant niches with native species and minimizes the probability of exotic plant invasion.

Interpretation about the importance of native versus nonnative grasses can help park visitors understand essential characteristics of prairie ecosystems that may not be readily apparent. The interrelationships between wildlife and native plants, the importance the underground root systems to the resilience of the ecosystem and the importance of native forbs to pollinators may not be understood by visitors who do not have a pre-existing knowledge about prairie ecology.

Effective communication of these two interpretive themes can both deepen the public's understanding and appreciation of a park's natural and cultural history, and also help build support for prairie restoration. This support can range from that for a specific restoration project to broader stewardship for the shortgrass and mixed-grass prairie ecosystems. Visitors who are informed about and who understand the purpose and methods of prairie restoration are more likely to view disturbances caused by restoration activities in a positive manner.

Interpretive Media

Interpretation about restoration projects can take place via publications, waysides and signs, exhibits, websites, videos and in ranger programs. Collaboration between interpretive and resource management staff on interpretive and education materials is often beneficial as interpreters can serve as communication specialists and resource managers have in-depth knowledge of restoration sites and the restoration process.

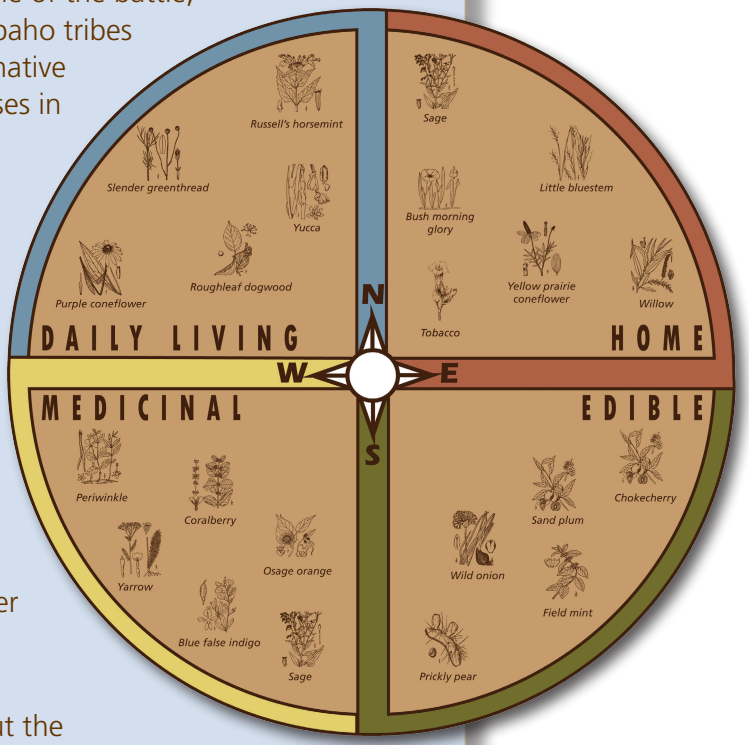
Interpretive publications can include brochures, resource briefs, site bulletins and other material designed to be distributed in print form or downloaded from the Internet as PDFs (Figure 22). Publications such as brochures are useful to reach audiences both on- and off-site, and can include a moderate level of detail about restoration topics. They can be effective in communicating both specific information about a restoration site or broader concepts.

Interpretive signage reaches park visitors in or near restoration sites. Waysides usually are permanent exhibits placed near visitor centers and viewpoints or other points of interests that provide information and that illustrate the scene, including the location's features and events. Like other interpretive media, waysides communicate specific message within the park's overall primary interpretive themes. Temporary signs and media developed for use in bulletin boards can provide specific information about restoration efforts, especially short-duration ones that may impact park visitors such as prescribed fires, exotic plant treatments and other activities.

VIGNETTE: Native Garden at Washita Battlefield NHS

A native ethnobotanical garden was developed at Washita Battlefield NHS between 2009 - 2011 in cooperation with the Cheyenne and Arapaho Tribes as part of the prairie restoration project there. This garden serves to demonstrate the results of the long-term restoration efforts in the park, and also to help interpret the role of native plants in the context of their importance to native peoples.

At the Washita site, the physical resource (cultural and natural landscape) and the intangible resources (emotions, memory, and sense of connection) possess a high degree of integrity. The park's enabling legislation calls for both the preservation of the site as closely as possible to that of the time of the battle, and for opportunities for the Cheyenne and Arapaho tribes to be involved in park education programs. The native garden help the park attain both of these purposes in the enabling legislation.



The design of the garden is a medicine wheel and includes 21 plant and tree species significant to the Cheyenne and Arapaho tribes for spiritual and practical uses. These uses are arranged into four separate categories: Daily Living, Home, Edible, and Medicinal. The medicine wheel holds spiritual significance to many American Indian tribes and is used for healing rituals and as a source for peace and clarity. The ultimate vision for the Washita Battlefield Native Garden is to have the Cheyenne and Arapaho tribes continue to prosper spiritually and physically from its crop.

Tribal leaders also value the native garden as an educational tool that can educate everyone about the environment and the beauty of Cheyenne and Arapaho and other native people.

Interpretive and educational materials about the native garden are available in the park, and also online, including multimedia programs. The garden is a powerful interpretive tool for both the park's natural and cultural resources, and it promotes stewardship of the southern Plains' native prairies.



The Native Garden is a collaborative project between the NPS and the Cheyenne & Arapaho Tribes Language Program.

Both permanent and temporary exhibits provide opportunities to promote stewardship of restoration sites.

Websites, multimedia content and social media content are often aimed at audiences off-site. Well-designed websites, multimedia programs and videos have the potential to reach wide audiences and can communicate both the general concepts of prairie restoration and specific restoration projects.

Interpretive gardens can be another important tool to convey information about the concepts or efforts of restoration projects. Such gardens can take on a variety of thematic areas whether they have an ecological or cultural context, or both. Interpretive gardens require significant investment to establish and also need regular upkeep, but are very effective in promoting appreciation of native vegetation and understanding of prairie ecosystems. Development and maintenance of interpretive gardens can often be conducted in cooperation with interpretive staff and/or volunteers.

Audiences for interpretive media can include park visitors, neighbors, educational groups, park partners and cooperators and internal audiences made up of park staffs. Interpretive media are most effective if they are targeted for specific audiences and contain the right amount of information presented in meaningful language appropriate for the audience.

Another important target audience for outreach about restoration projects in the southern Plains is other federal, state and private land managers. Prairie restoration in shortgrass and mixed-grass systems is an emerging field. Sharing results and management practices developed in this project in public presentations and at scientific meetings and articles in peer-reviewed journal articles can help further the practice of this field.

Interpretation in the Southern Plains

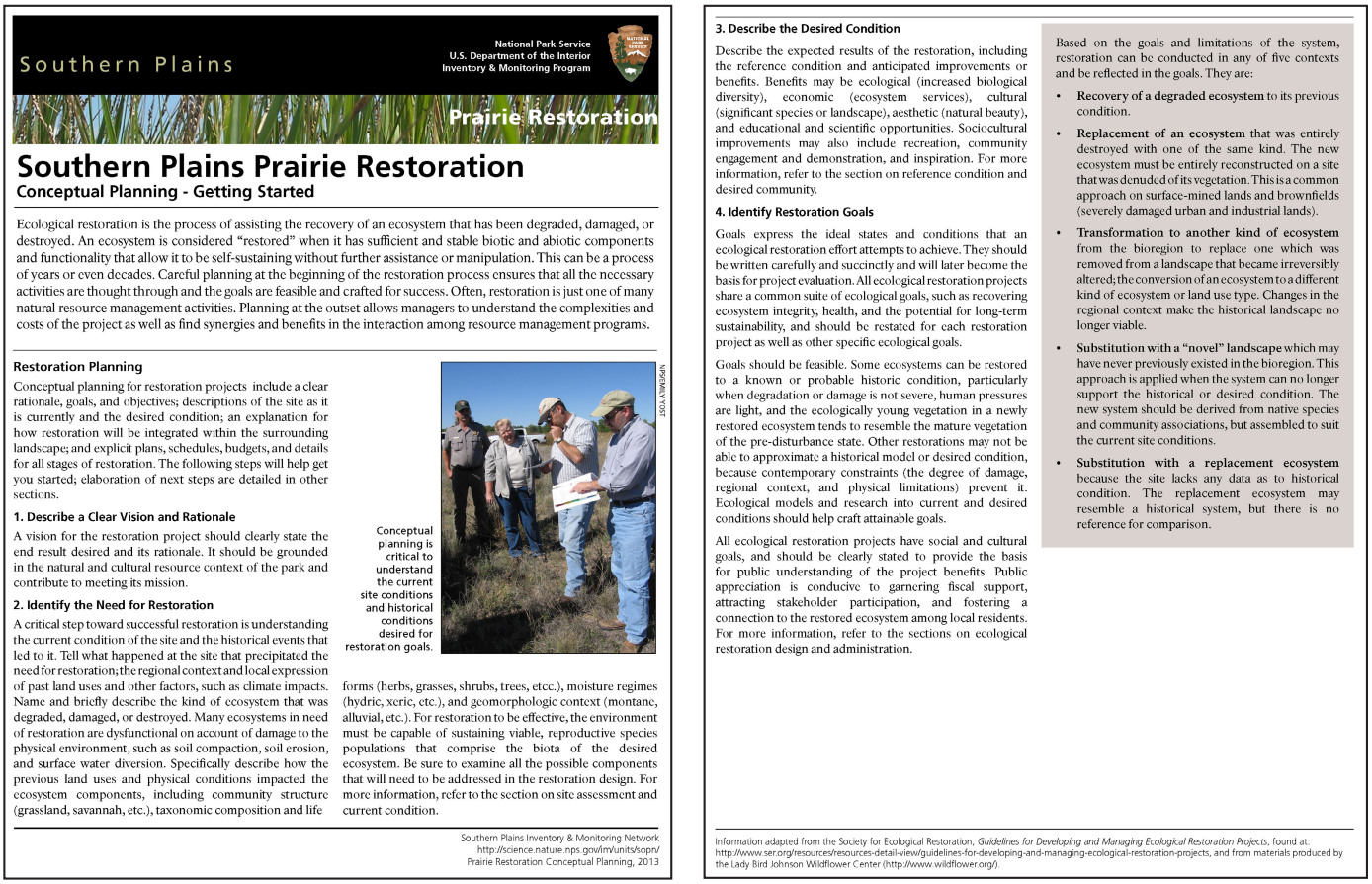
Interpretation was an integral part of the prairie restoration projects in the nine southern Plains parks. Interpretive efforts included both project-wide projects and park-specific ones. SOPN, in conjunction with the partner parks, produced a series of resource briefs or brochures about prairie restoration. These briefs overviewed the project, including the specific projects that planned for each park, and also covered specific topics such as conceptual planning (Figure 22) or reference conditions. These brochures were distributed in the parks and available for download from the Internet.

Interpretive and educational information about the park restoration project and about the prairie restoration project was available online through NPS websites and the Learning Center of the American Southwest. The Learning Center of the American Southwest was a partnership started in 2008 that was dedicated to science and education about the unique resources of the American Southwest through.

The Science of the American Southwest website (www.nps.gov/subjects/swscience/index.htm) promotes understanding and preservation the unique resources of park sites in the American Southwest through science and education. It delivers information about the natural and cultural resources of the region and about scientific activities underway. The primary focus is to present the results of research and monitoring to land managers, students, researchers, policy makers, and the interested public, and to promote mission-oriented research within the region.

Interpretive gardens of varying size and complexity have been established or expanded at Fort Larned NHS (see vignette page 55), Lyndon B. Johnson NHP, Washita Battlefield NHS (see vignette page 121), and Lake Meredith NRA. Interpretive gardens can provide opportunities to learn plant identification along with information about plant ecology and plant traditional uses.

Several parks also installed species identification signage for use along trails. These labels can be changed throughout the growing seasons, and can help park visitors learn about the native prairie vegetation.



Southern Plains

National Park Service
U.S. Department of the Interior
Inventory & Monitoring Program

Prairie Restoration

Southern Plains Prairie Restoration

Conceptual Planning - Getting Started

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. An ecosystem is considered "restored" when it has sufficient and stable biotic and abiotic components and functionality that allow it to be self-sustaining without further assistance or manipulation. This can be a process of years or even decades. Careful planning at the beginning of the restoration process ensures that all the necessary activities are thought through and the goals are feasible and crafted for success. Often, restoration is just one of many natural resource management activities. Planning at the outset allows managers to understand the complexities and costs of the project as well as find synergies and benefits in the interaction among resource management programs.

Restoration Planning

Conceptual planning for restoration projects include a clear rationale, goals, and objectives; descriptions of the site as it is currently and the desired condition; an explanation for how restoration will be integrated within the surrounding landscape; and explicit plans, schedules, budgets, and details for all stages of restoration. The following steps will help get you started; elaboration of next steps are detailed in other sections.

1. Describe a Clear Vision and Rationale

A vision for the restoration project should clearly state the end result desired and its rationale. It should be grounded in the natural and cultural resource context of the park and contribute to meeting its mission.

2. Identify the Need for Restoration

A critical step toward successful restoration is understanding the current condition of the site and the historical events that led to it. Tell what happened at the site that precipitated the need for restoration; the regional context and local expression of past land uses and other factors, such as climate impacts. Name and briefly describe the kind of ecosystem that was degraded, damaged, or destroyed. Many ecosystems in need of restoration are dysfunctional on account of damage to the physical environment, such as soil compaction, soil erosion, and surface water diversion. Specifically describe how the previous land uses and physical conditions impacted the ecosystem components, including community structure (grassland, savannah, etc.), taxonomic composition and life forms (herbs, grasses, shrubs, trees, etcc.), moisture regimes (hydric, xeric, etc.), and geomorphologic context (montane, alluvial, etc.). For restoration to be effective, the environment must be capable of sustaining viable, reproductive species populations that comprise the biota of the desired ecosystem. Be sure to examine all the possible components that will need to be addressed in the restoration design. For more information, refer to the section on site assessment and current condition.

Conceptual planning is critical to understand the current site conditions and historical conditions desired for restoration goals.

NPS/MATT FOSS

Southern Plains Inventory & Monitoring Network
http://science.nature.nps.gov/im/units/sopn/
Prairie Restoration Conceptual Planning, 2013

3. Describe the Desired Condition

Describe the expected results of the restoration, including the reference condition and anticipated improvements or benefits. Benefits may be ecological (increased biological diversity), economic (ecosystem services), cultural (significant species or landscape), aesthetic (natural beauty), and educational and scientific opportunities. Sociocultural improvements may also include recreation, community engagement and demonstration, and inspiration. For more information, refer to the section on reference condition and desired community.

4. Identify Restoration Goals

Goals express the ideal states and conditions that an ecological restoration effort attempts to achieve. They should be written carefully and succinctly and will later become the basis for project evaluation. All ecological restoration projects share a common suite of ecological goals, such as recovering ecosystem integrity, health, and the potential for long-term sustainability, and should be restated for each restoration project as well as other specific ecological goals.

Goals should be feasible. Some ecosystems can be restored to a known or probable historic condition, particularly when degradation or damage is not severe, human pressures are light, and the ecologically young vegetation in a newly restored ecosystem tends to resemble the mature vegetation of the pre-disturbance state. Other restorations may not be able to approximate a historical model or desired condition, because contemporary constraints (the degree of damage, regional context, and physical limitations) prevent it. Ecological models and research into current and desired conditions should help craft attainable goals.

All ecological restoration projects have social and cultural goals, and should be clearly stated to provide the basis for public understanding of the project benefits. Public appreciation is conducive to garnering fiscal support, attracting stakeholder participation, and fostering a connection to the restored ecosystem among local residents. For more information, refer to the sections on ecological restoration design and administration.

Based on the goals and limitations of the system, restoration can be conducted in any of five contexts and be reflected in the goals. They are:

- **Recovery of a degraded ecosystem** to its previous condition.
- **Replacement of an ecosystem** that was entirely destroyed with one of the same kind. The new ecosystem must be entirely reconstructed on a site that was denuded of its vegetation. This is a common approach on surface-mined lands and brownfields (severely damaged urban and industrial lands).
- **Transformation to another kind of ecosystem** from the bioregion to replace one which was removed from a landscape that became irreversibly altered; the conversion of an ecosystem to a different kind of ecosystem or land use type. Changes in the regional context make the historical landscape no longer viable.
- **Substitution with a "novel" landscape** which may have never previously existed in the bioregion. This approach is applied when the system can no longer support the historical or desired condition. The new system should be derived from native species and community associations, but assembled to suit the current site conditions.
- **Substitution with a replacement ecosystem** because the site lacks any data as to historical condition. The replacement ecosystem may resemble a historical system, but there is no reference for comparison.

Information adapted from the Society for Ecological Restoration, *Guidelines for Developing and Managing Ecological Restoration Projects*, found at: http://www.ser.org/resources/resources-detail-view/guidelines-for-developing-and-managing-ecological-restoration-projects, and from materials produced by the Lady Bird Johnson Wildflower Center (http://www.wildflower.org/).

Figure 22. An example of a resource brief prepared for the prairie restoration project in southern Plains parks.

Lessons Learned

- Interpretation can help visitors understand the purpose of prairie restoration, which makes it more likely that they view disturbances from restoration treatments as positive instead of negative.
- Interpretation makes a restoration project more holistic and can help connect natural and cultural resources.
- Interpretation can increase understanding about the importance of grasslands and the reasons behind prairie restoration projects.
- Audiences for interpretation includes not only park visitors, but internal audience and park neighbors and cooperators.



Switchgrass (*Panicum virgatum*) (far left) and blue grama (*Bouteloua gracilis*) at Bent's Old Fort NHS.

Conclusions

The nine southern Plains parks that participated in prairie restoration projects in this multipark project made significant progress towards restoring the health of their short and mixed-grasses ecosystems. However, like in all restoration projects, there were also setbacks, and not every park was able to meet all its goals. Progress in some cases was inhibited by the extreme drought that impacted many parks (Figure 23), especially during the later stages of the project. Further, park projects were sometimes challenged by personnel changes, lack of available staff to complete restoration treatments and/or new park initiatives.

The restoration projects in the participating parks were pilot projects in some ways, and these projects gave the parks important opportunities to test prairie restoration techniques in shortgrass and mixed-grass ecosystems. Participating parks gained important insights about the restoration process and how it applies in NPS units on the southern Great Plains. These lessons learned were presented in each chapter in this report and are summarized in Table 18. Another important outcome of these pilot restoration projects is the increased capacity to conduct prairie restoration projects in southern Plains parks. Staff in southern Plains parks gained experience planning and implementing restoration treatments and learned about how each park's unique ecosystems responded to restoration treatments. Equipment such as seed strippers and seed drills were also acquired for parks to share. These gains lay the groundwork for continuing efforts to restore ecosystem health in the restoration sites and for planning and implementing future restoration projects.

While parks were not able to meet every goal identified at the start of the multipark project in 2008, parks were able to participate in conceptual planning for restoration efforts, along with conducting site assessments and defining reference conditions. The extensive planning that took place in the parks was not only applicable to restoration treatments implemented to date, but they also build an important framework from which to base continuing restoration efforts. Insights gained during the planning process will continue to

Restoration projects are always at the mercy of natural processes. Droughts, floods, and fires may all may all alter planned treatments and restoration timelines.

Table 18. Selected Lessons Learned during the Prairie Restoration Projects on the Southern Plains

Component	Description
Conceptual Planning *p. 24*	• Comprehensive conceptual planning ensures that a restoration plan is suitable for the site, identifies the need for restoration and has goals that are in concert with the site's purpose and fundamental values. • Linking prairie restoration to a park's significance and its cultural resources and placing it within the ecological history of the area can benefit a prairie restoration project by making it more effective while promoting a better understanding of the importance of healthy grasslands within NPS sites, including cultural sites where there are important links between natural and cultural resources.
Site Assessment *p. 29*	• Information sharing between park units greatly increases the capacity to conduct comprehensive site assessments and identify implementation strategies, as collaborative teams are likely to include specialists with different areas of expertise. Because prairie restoration is inherently complex, this pooling of resources is crucial. • On-site assessments by multidisciplinary teams are the preferred method to conduct site assessments for restoration projects.
Reference Conditions *p. 36*	• Establishing reference conditions prior to initiating restoration efforts is essential as they both help define restoration goals and provide a benchmark to use in evaluation. • Many sources of information can help inform reference conditions, including physical reference sites, Ecological Site Descriptions, historic information and expert information. The best reference conditions may incorporate more than one source of information.
Administration (Compliance) *p. 39*	• EAs can be used to outline critical elements and generalized desired condition for prairie restoration projects and incorporate a built-in capacity for flexibility in order to enable adaptive management.
Administration (Institutional History) *p. 42*	• Institutional histories can help ensure that restoration efforts are not piecemeal and can take advantage of adaptive management principles by allowing future managers to adjust restoration treatments based on previous restoration efforts. • Institutional histories also help managers plan other restoration projects, serve as case histories of restoration efforts in NPS sites, assist interpreters understand and communicate park stories and become part of the administrative history of a site.
Administration (Partnerships) *p. 45*	• Multiple park objectives can be met when prairie restoration efforts are integrated with other park projects. • Coordinating restoration projects with other initiatives helps develop synergy among park divisions and helps highlight the interrelationships between natural and cultural resources.
Restoration Implementation *p. 51*	• Each restoration project is unique and proposed treatments depend on conceptual planning, site assessment, reference conditions and current conditions at the site. • Flexibility built into implementation planning allows managers to respond to current conditions using adaptive management.
Site Preparation (Mechanical Site Preparation) *p. 56*	• Mechanical site preparation generally has limited application in short and mixed-grass prairies in the southern Plains. The semi-arid environment with frequent drought and prevailing winds necessitate that the soil only be disturbed in situations where benefits exceed the risks of soil erosion and other potentially adverse impacts of disturbance.
Site Preparation (Exotic Plant and Animal Removal and Management) *p. 61*	• Controlling exotic species is a critical part of most restoration efforts. • Once exotics treatment has commenced, it is necessary to sustain it. Otherwise, the species will likely re-invade, especially in open habitat before native plants get established.
Site Preparation (Invasive Plant Removal) *p. 62*	• Woody and brushy species removal typically precedes revegetation efforts. Periodic maintenance is also usually necessary to prevent woody species from re-invading a restoration site.
Site Preparation (Holding Crops) *p. 65*	• Holding crops are more successful when irrigation is possible and are only used following mechanical site preparation such as plowing and disking.
Native Seed Acquisition and Propagation *p. 75*	• Acquiring native seeds and plugs for restoration projects requires considerable expense and may involve significant manpower.

Table 18. Continued. Selected Lessons Learned during the Prairie Restoration Projects on the Southern Plains

Component	Description
Revegetation *p. 84*	• It may take three years or longer for revegetation efforts via seeding to be successful and/or may require multiple seeding treatments. • The success of revegetation treatments is significantly dependent on available moisture. Treatments that occur during dry years or droughts are much less likely to be successful than those in wet periods. The availability of irrigation or supplemental watering will greatly assist revegetation efforts.
Passive Restoration *p. 87*	• Passive restoration is applicable in areas where the restoration site has retained much of its biotic integrity, but needs to have conditions that will facilitate natural restoration processes.
Maintenance and Management ***p. 100***	• Maintenance and management treatments are often necessary in a restoration project to ensure that conditions remain favorable for the establishment and continuing vigor of native plant communities. • Mowing is one of the best ways to control exotic forb species. Management mowing in a restoration site can be done selectively and can be used in lieu of prescribed fire or grazing when necessary. • When conducting grazing treatments, it is important to work with a knowledgeable contractor who understands the conservation goals for the restoration site in order to establish a mutually-beneficial partnership. • Fire plays an important role in maintaining the health and vigor of grasslands, but prescribed fire, like that of other treatments, should be applied judiciously.
Monitoring *p. 106*	• Regular monitoring is an essential part of a prairie restoration project and it requires commitment and dedicated resources to ensure that it occurs. Standardized data collected through monitoring can inform treatment strategies through adaptive management and can be used to provide evidence of the value of restoration activities.
Interpretation *p. 111*	• Interpretation can help visitors understand the purpose of prairie restoration which makes it more likely that they view disturbances from restoration treatments as positive instead of negative. • Audiences for interpretation includes not only park visitors, but internal audience and park neighbors and cooperators.

Page numbers give the location of the full set of lessons learned for each component of a restoration process.

be used in natural resource management in the participating parks. For example, Pecos NHP developed reference conditions for their restoration work using a holistic management approach of integrating natural and cultural resources. Reference conditions were also placed in the context of the long period of human occupation at Pecos, and the fact that grasslands and woodlands probably changed over the centuries due to combined natural and human factors and may change in the future as a result of climate and other factors.

Parks also gained experience implementing restoration treatments, including site preparation, exotic species control and revegetation. For example, both Bent's Old Fort NHS and Lyndon B. Johnson NHP successfully applied mechanical site preparation treatments that restored natural contours to the land surface and/or restored natural hydrology. Sand Creek Massacre NHS transplanted native grasses to stabilize a site that was undergoing active wind erosion that precluded germination from seeding treatments. Sand Creek Massacre also used



Figure 23. The Bent's Old Fort restoration site in July 2011 under drought conditions with field bindweed (*Convolvulus arvensis*) and a lot of bare ground.

mowing to help control shrub encroachment into native grasslands. Lake Meredith NRA tested two different exotic plant control methods (prescribed fire and mowing) to determine that mowing was the more successful technique to use in restoration areas in the park. San Antonio Missions NHP made progress restoring two sites, including the grasslands in the Rancho de las Cabras Unit by controlling invasive woody species. The presence of cultural resources adjacent to the San Juan Acequia limited what methods the park could use to control exotic plants, but they were able to make progress in restoring native species with a combination of herbicide application and seeding native species by hand.

Prairie restoration has a longer time scale than a park's administrative cycle. Restoration projects are long-term investments with peaks and valleys throughout the process.

Bent's Old Fort's ecological restoration efforts predated this project, and they were able to provide guidance to other parks and also probably made the most progress in their restoration program, although their efforts were challenged by extreme drought conditions (Figure 23). Staff at Bent's Old Fort were able to collect native seeds, propagate plugs from those seeds in collaboration with the greenhouse at the neighboring community college and complete several seeding treatments. Bent's Old Fort previously also had successfully restored riparian areas that had been infested with exotic tamarisk (*Tamarix spp.*).



Washita Battlefield NHS.

Parks also faced significant challenges in meeting restoration goals. The abandoned agricultural fields in Chickasaw NRA that need to be restored to native grasslands are heavily infested with Johnsongrass (*Sorghum halepense*), an invasive species that is exceptionally difficult to control. Washita Battlefield and Fort Larned NHS are challenged by large areas dominated by exotic bromes.

This project also facilitated important advances in interpretation of natural resources and prairie ecosystems, including in some parks that have primarily a cultural significance. For example, both Fort Larned and Washita Battlefield NHS constructed demonstration gardens using native plants. Washita Battlefield's Native Garden also provided an opportunity for the Cheyenne and Arapaho tribes play to a role in the park's educational programs, as indicated in the park's enabling legislation.

Lessons Learned

Complex resource management initiatives such as prairie restoration projects in shortgrass and mixed-grass ecosystems generally provide opportunities for refining techniques and for learning from both successes and failures within a project's planning or implementation. The collaborative process in the multipark prairie restoration projects in southern Plains parks provided further opportunities for information-sharing and learning from restoration efforts. In addition to the concrete steps taken in each park to restore prairie sites, these lessons learned are among the significant outcomes of this project. (See Table 18 for selected lessons learned; full lists of lessons learned are in each chapter). Resource managers may be able to utilize these lessons learned when planning restoration projects in the future to increase the odds of successful outcomes.

Administrative functions and issues were areas in particular where insights gained from these restoration efforts may benefit future resource

managers. For example, Environmental Assessments that outline broad desired conditions can be used in conjunction with annual work plans to allow flexibility to respond to current conditions while using adaptive management. Maintaining an institutional history can provide continuity in restoration efforts that may span many years to even decades. And forming partnerships with other land management agencies, nongovernmental agencies and volunteer groups may enable parks to meet additional restoration objectives that may not have otherwise been obtainable.

In addition to lessons learned specific to individual components of the overall restoration process such as conceptual planning, site assessment, site preparation, revegetation and monitoring, several overarching lessons learned became apparent:

- Although it is extremely important to plan all aspects of the restoration process, restoration projects are always at the mercy of natural processes and conditions. Droughts, floods, wildfires, and other natural events add uncertainty to planned restoration treatments and impact the site's responses to them. The type and timing of restoration treatments may need to be adjusted based on current or expected future conditions at the site. For example, a park may choose to postpone a revegetation treatment during a period of prolonged drought or extreme temperature. Alternatively, a seeding treatment may be exceptionally successful if it is followed by an unusually wet season. The response of a restoration site is always a combination of the applied treatments, the current environmental conditions and its past history and use. Therefore, comprehensive planning that includes assessment of the site, its history and defining reference conditions is an important framework for all restoration efforts.

- Prairie restoration projects generally take many years, a time scale much longer than the National Park Service's administrative cycles for planning, budgeting, compliance and work planning. Therefore, managers who enter prairie restoration projects need to have the expectation that it is long-term investment and that there will be highs and lows along the way. The manager who initiates planning for a restoration project will likely be different than the manager who initiates treatments and may also be different than the personnel who are responsible for long-term monitoring of the site. Using a comprehensive planning process and keeping documentation throughout the restoration project will help future managers take actions that may implement the restoration vision and may give the overall project its greatest chance of success. Additionally, the condition of a restoration site may appear to be of significant concern during drought periods or immediately after a site preparation treatment, but the overall health of the site may be improving. Regular monitoring and evaluation of the site's responses to restoration treatments may help characterize the condition of the restoration site over time and the effectiveness of restoration treatments.



W. LOTT

Indian blanket wildflowers (*Gaillardia pulchella*)

Most parks with prairie habitats will likely need to consider restoration at some point. Using the collaborative framework among NPS disciplines and using lessons learned from previous parks will make new projects more successful.

Collaborative Framework

Another significant outcome of this multipark prairie restoration effort is the collaborative framework for multidisciplinary and multiprogram cooperation of major resource management projects like restoration (see vignette on p. 108-109). The overlap between NPS programs, such as inventory and monitoring programs, fire programs and exotic plant management teams, along with park units became especially apparent during the planning and implementation of the restoration projects in the nine participating parks. The projects themselves also provided important opportunities for these programs and the parks to work together.

Most parks that have prairie habitats will most likely need to consider undertaking at least some type of restoration project at some point. Given that multiple NPS programs have responsibilities that are applicable to restoration projects and have experience conducting treatments that are used in restoration efforts, collaboration between parks and relevant programs may contribute to a project's success. Taking advantage of the NPS' collective knowledge, skills and abilities in restoration applications and the various experiences, expertise and wisdom of different park service programs may result in more effective prairie restoration projects that increase ecosystem health in shortgrass and mixed-grass systems in southern Plains parks.

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