National Park Service
Badlands National Park, South Dakota
Fire Monitoring Plan

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INTRODUCTION

Badlands National Park (BADL) is located in southwestern South Dakota. The park encompasses 242,756 acres; 64,144 acres are designated as Wilderness. The park is characterized by barren canyons, peaks, and ridges--known as badlands--intermixed with large areas of mixed-grass prairie providing habitat for large numbers of wildlife and plant species. Recent vegetation mapping shows two dominant land cover types (Von Loh et al., 1999). Sparsely vegetated badlands cover 45% of the park and a western wheatgrass alliance covers 37%. No other type covers even 5 percent of the park. Western wheatgrass (*Pascopyrum smithii*) mixed-grass prairie is believed to be the pre-settlement vegetation for the area but the exact composition of the communities before settlement is unknown. Kuchler (1964) described the potential vegetation for the BADL area as wheatgrass-needlegrass prairie.

Large and small-scale disturbances shaped the landscape of BADL and surrounding areas. Disturbances included seasonal bison grazing, extended wet and dry periods, soil disturbance (buffalo wallows and prairie dog towns) and fire. These disturbances continue in BADL today. Fires started both by lightning and Native Americans maintained the prairies and kept shrubs and trees limited to wetter areas or areas of broken topography until the area was settled in the 1880s. Fire suppression, overgrazing and plowing for farming broke up the areas of continuous fuels and significantly reduced the number of fires and acres burned. The lack of trees with fire scars make interpreting fire history for the area difficult. Wendtland and Dodd (1990) considered historical accounts and fire scar data from the edges of the Black Hills. They estimated fire return intervals from as short as 5 years in level to gently rolling topography to 15-30 years in more broken topography at Scotts Bluff National Monument, Nebraska.

Collins and Gibson (1990) documented the need for an interaction of four different disturbance types to maintain diverse community structure in mixed-grass prairie. The interaction of drought, grazing, fire and soil disturbance--both buffalo wallows and prairie dog towns--alters community structure. In the absence of any one of these disturbances, species richness (the number of species per unit area), evenness (the distribution between dominance among species) and patch structure (the association of species at various spatial scales) may change. The absence of fire tends to increase woody species and reduce species richness and patch structure. The absence of grazing by large ungulates and/or soil disturbance reduces species diversity and decreases community heterogeneity. Management actions that include all disturbance types should be considered to maintain diverse community structure.

Prescribed and wildland fire for resource benefits (wildland fire use fires) will be used to maintain and restore the fire adapted ecosystems at Badlands. National Park Service (NPS) **Reference Manual 18** states, “Monitoring is a critical component of fire management and the Fire Monitoring Plan is important to identify why monitoring will be done, what will be monitored, how it will be monitored, where it will be done, and how often it will be completed.” Monitoring of these fires is mandated in **Director’s Order #18: Wildland Fire Management** issued in 1998. Section 5.2, *Fire Management Plans* (no. 10) states, “Include procedure for short and long term monitoring to document that overall program objectives are being met and undesired effects are not occurring”. Section 5.8 directly addresses *Prescribed Fire Monitoring*:

a) Fire effects monitoring must be done to evaluate the degree to which objectives are accomplished.

b) Long-term monitoring is required to document that overall programmatic objectives are being met and undesired effects are not occurring.
c) Evaluation of fire effects data is the joint responsibility of fire management and natural resource management personnel.

There are three main communities at Badlands that will initially be monitored: (1) Western Wheatgrass Mixed-grass Prairie, (2) Non-native Grasslands, and (3) Woody Draws. Much of the park has not burned since its establishment in 1939. Fire will initially be used to restore these communities to more native conditions and then will be used in maintaining systems by burning within the predicted range of return intervals. A more complete discussion of fire effects and management follows.

DESCRIPTION OF THE ECOLOGICAL MODEL

I. NORTHERN GREAT PLAINS MIXED-GRASS PRAIRIE

The vegetation of BADL is mixed-grass prairie. Mixed-grass prairie is characterized as having a mixture of mid-height and shortgrasses as well as a mixture of grasses with different photosynthetic pathway types (C_3: cool-season and C_4: warm-season) (Singh et al. 1983). This diversity of species found on the Northern Great Plains is a result of great and repeated migrations of species that responded to changes in climate during periods of glaciation (Weaver and Albertson 1956, Wells 1970). One of the unique traits of the Northern Great Plains mixed-grass prairie is the dominance of cool-season grasses (Singh et al. 1983). A complex disturbance regime of biotic and abiotic disturbances (including periodic drought, grazing, fire, and soil disturbances) have interacted to form and continue to maintain grasslands of the Northern Great Plains (Anderson 1990, Collins and Gibson 1990). These disturbances also interact with climate, topography, soils, and competition among plant species to influence grassland composition (Fig. 1) (Wells 1970, Wright and Bailey 1980, Collins and Gibson 1990).

Although cool-season species tend to dominate northern mixed-grass prairies, warm-season species co-dominate on more xeric sites since these species are generally better adapted to warm, dry conditions (Singh et al. 1983). Light to moderate grazing also favors warm-season species while heavy grazing can shift composition toward warm-season shortgrasses like buffalograss (*Buchloe dactyloides*) and blue grama (*Bouteloua gracilis*) (Weaver and Albertson 1956, Ode et al. 1980, Singh et al. 1983). Native ungulates generally favor graminoids over forbs which may lead to increases in occurrence of forb species (Krueger 1986). Annual forbs colonize small-scale soil disturbances such as prairie dog mounds or buffalo wallows (Collins and Gibson 1990).

Historically, fire was a frequent and large-scale disturbance on northern mixed-grass prairies and continues to be a tool that managers use. Historic fire frequencies are very difficult to determine largely due to a lack of trees on the plains to record fire scars (Wright and Bailey 1980). Most fire frequency estimates have been based on accounts of early settlers or known fire frequencies needed to prevent woody plant encroachment into grasslands. Mean fire return intervals have been estimated at 4 to 9 years for the sandhills of north-central Nebraska (Steinauer and Bragg 1987), 10 to 12 years for the forest-prairie ecotone of the Black Hills of South Dakota (Brown and Sieg 1999), and 15 to 30 years for the broken topography of Scotts Bluff National Monument, Nebraska (Wendtland and Dodd 1990).

Ignition sources for fires in presettlement times are believed to be mainly lightning and both intentional and unintentional ignition by American Indians. A study of lightning-ignited fires in the Northern Great Plains over the past five decades indicates that nearly 75% of lightning-ignited fires occurred during July and August and lightning-ignited fires were recorded every month from April to September (Higgins 1984). It is presumed that this pattern has not changed significantly for at least a few centuries. Historical documents and accounts of early settlers suggest that there were two seasonal periods for fires ignited by American Indians, one during the spring with a peak in April and one during the fall with a peak in October (Higgins 1986).

Effects of fire can vary depending on the season burn occurred, time since last burned, grazing history, precipitation before and after burn, vegetation composition, fire intensity and severity, and topography (Anderson 1990, Collins and Gibson 1990). Fire can influence both plant community productivity and structure. Productivity may be increased following fire as a result of reduction in the litter layer and grazing may have similar effects (Anderson 1990). In mixed-grass prairie, with both warm- and cool-season species, season of burn can strongly affect species composition. Generally, spring and fall burns favor warm-season grasses while summer burns tend to favor cool-season grasses (Steuter 1987, Howe 1994).

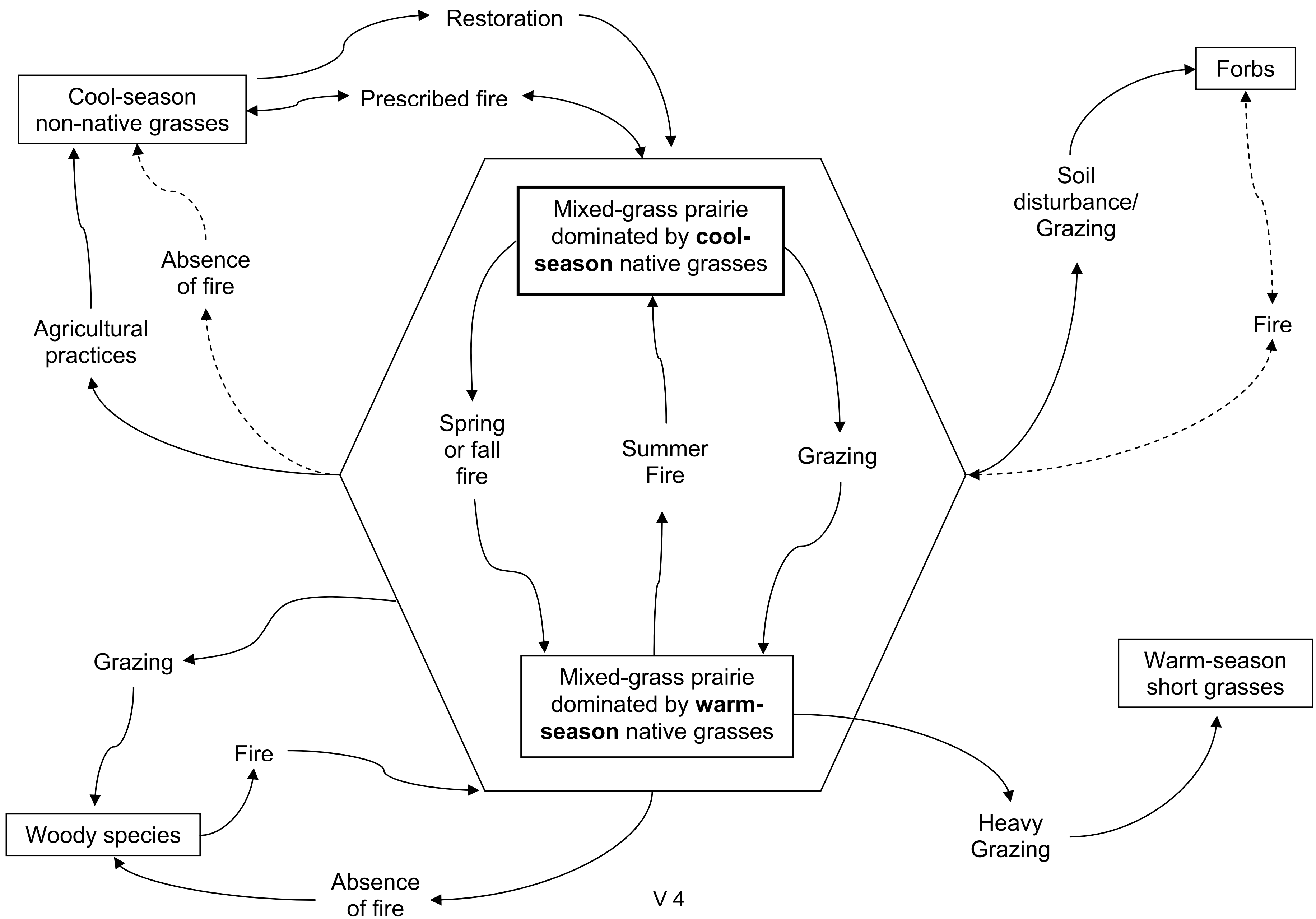
II. VEGETATION OF BADLANDS NATIONAL PARK

Kuchler (1964) described the potential vegetation for the BADL area as wheatgrass-needlegrass prairie and wheatgrass-grama-buffalograss prairie. A vegetation survey was conducted in the park in 1983, but the wheatgrass-grama-buffalograss type was not located. It was suggested that this vegetation type, observed in the early 1960s, was the result of drought and overgrazing and had shifted to the wheatgrass-needlegrass type since the earlier survey (Stubbendieck and Willson 1986).

The wheatgrass-needlegrass type is dominated by western wheatgrass, blue grama, needle-and-thread (*Stipa comata*), and green needlegrass (*Stipa viridula*) (Kuchler 1964). Other graminoids present include slender wheatgrass (*Elymus trachycaulus*), sedges (*Carex* spp.), Junegrass (*Koeleria macrantha*), little bluestem (*Schizachyrium scoparium*), buffalograss, and prairie sandreed (*Calamovilfa longifolia*). The non-native grasses smooth brome (*Bromus inermis*), crested wheatgrass (*Agropyron cristatum*), and Kentucky bluegrass (*Poa pratensis*) are common in some areas of the park. Common forbs are pussytoes (*Antennaria* spp.), heath aster (*Aster ericoides*), sagewort (*Artemisia* spp.), purple coneflower (*Echinacea angustifolia*), goldenrod (*Solidago* spp.), and the non-natives yellow sweetclover (*Melilotus officinalis*), and Canada thistle (*Cirsium arvense*). Shrub species like leadplant (*Amorpha canescens*), wild rose (*Rosa* spp.), yucca (*Yucca glauca*), and prickly pear (*Opuntia* spp.) are common in the grassland areas.

Shrublands and woodlands are a minor component of the park and are generally associated with draws and floodplains. Rocky Mountain juniper (*Juniperus scopulorum*), ponderosa pine (*Pinus ponderosa*), green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), plains cottonwood (*Populus deltoides*), willow (*Salix* spp.), silver sagebrush (*Artemisia cana*), skunkbush sumac (*Rhus aromatica*), chokecherry (*Prunus virginiana*), and American plum (*Prunus americana*) are generally found in these areas.

Figure 1. The Northern Great Plains mixed-grass prairie is characterized as having a mixture of mid-height and shortgrasses with different photosynthetic pathway types (cool- and warm-season). Cool-season grasses are dominant. A complex disturbance regime of biotic and abiotic disturbances (including periodic drought, grazing, fire, and soil disturbances) have interacted to form and continue to maintain grasslands of the Northern Great Plains. These disturbances also interact with climate, topography, soils, and competition among plant species to influence grassland composition.



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MONITORING TYPES

Park resource management staff selected three plant communities as the current priorities for short and long-term monitoring. These communities are based on the vegetation communities described by Von Loh et al. (1999). They were chosen by evaluation of acreage across the park, presence of rare species that would be impacted by fire, importance as habitat for a number of different animal species, estimated fire return intervals, known and unknown fire effects, and opportunities for non-native plant reduction. A description of other community types found and relative acreage can be found in Appendix G of the Fire Management Plan (FMP) or Von Loh et al. (1999). Each monitoring type has a "Desired Future Condition" statement developed by a team consisting of the park superintendent, resource management staff and the Northern Great Plains lead fire effects monitor. These are described in the Management Objectives section of this plan.

I. WESTERN WHEATGRASS MIXED-GRASS PRAIRIE

Western wheatgrass alliance covers 88,252 acres or 37% of the park area (Von Loh et al., 1999). Because of the extent of this community, it was one of the first to be monitored when Fire Monitoring Handbook (FMH) plots were installed at Badlands in 1996.

This community occurs in a wide a variety of habitats throughout the park. Sites are generally flat to moderately steep in slope and occur on all aspects. Associations of the type occupy clay, silt, loam and sandy soils of flats, swales, drainages, hills and slopes. (Von Loh et al., 1999) Elevations range from 2,400 to 4,000 feet. Soils are clayey, silty, claypan, and badlands overflow. Soil types are Blackpipe clay loam, Blackpipe-Norrest complex, Blackpipe-Wortman Complex, Cedarpass silty clay loam, Cedarpass-Denby complex, Cedarpass-Interior-Badlands, and Interior-Cedarpass-Denby (USDA-SCS, 1987). Stands of this type have moderate to complete herbaceous cover, between 40-100%. Western wheatgrass is strongly dominant in ungrazed stands, and less so in stands subjected to annual livestock grazing. Species dominance can vary locally within a stand, depending on soils and use factors (Von Loh et al., 1999). Dominant graminoids are western wheatgrass, blue grama, and green needlegrass (Table 1). Shrubs are plains prickly pear (*Opuntia polyacantha*), skunkbush sumac, sand sage (*Artemisia frigida*), and silver sagebrush (*Artemisia cana*). Forbs include heath aster, yarrow (*Achillea millefolium*), and Missouri goldenrod (*Solidago missouriensis*). Non-native species including Kentucky bluegrass, smooth brome, Japanese brome (*Bromus japonicus*), cheatgrass (*Bromus tectorum*), and yellow sweetclover occur but are a minor component of this monitoring type.

Table 1. Dominant species of western wheatgrass mixed-grass prairie monitoring type.

Species	Native	Season	Annual/ Perennial	Growth Habit
western wheatgrass	Yes	Cool	Perennial	Sod-forming/ Rhizomatous
blue grama	Yes	Warm	Perennial	Tufted
green needlegrass	Yes	Cool	Perennial	Bunchgrass

II. NON-NATIVE GRASSLANDS

Non-native grassland covers 5,100 acres or 2% of the park area (Von Loh et al., 1999). These areas include prairie that is composed of 50 - 80% non-native species. Many of these areas are associated with disturbances such as roadsides, abandoned farm fields, and areas that were seeded with non-native grasses to "improve" the range for grazing. Certain areas with high disturbance include: areas adjacent to park roads and facilities, abandoned agricultural fields along the northern park boundary, and Sheep Mountain, Cuny, and Stronghold Tables. These areas historically supported western wheatgrass mixed prairie (Von Loh et al., 1999). Elevation ranges from 2,400 to 4,000 feet. Non-native grasslands occur on clayey, silty, claypan, and badlands overflow soils. Soil types are Blackpipe clay loam, Blackpipe-Norrest complex, Blackpipe-Wortman Complex, Cedarpass silty clay loam, Cedarpass-Denby complex, Cedarpass-Interior-Badlands, and Interior-Cedarpass-Denby (USDA-SCS, 1987).

Stands typically have moderate herbaceous cover, ranging from 40-90% and very dense litter over the ground surface. Areas tend to be dominated by one non-native grass species, often planted. Species often found dominating these sites include smooth brome, crested wheatgrass, or Kentucky bluegrass (Table 2). Other non-native species associated with these areas include Japanese brome, cheatgrass, alfalfa (*Medicago sativa*), yellow sweetclover, and common mullein (*Verbascum thapsus*). At the edge and occasionally interspersed are western wheatgrass, needle-and-thread, and green needlegrass. Very few native forbs or shrubs are seen in this type (Von Loh et al., 1999).

Table 2a. Common grass species of non-native grasslands monitoring type

Species	Native	Season	Annual/ Perennial	Growth Habit
Crested wheatgrass	No	Cool	Perennial	Bunchgrass
Kentucky bluegrass	No	Cool	Perennial	Sod-forming
Smooth brome	No	Cool	Perennial	Sod-forming/ Rhizomatous
Cheatgrass	No	Cool	Annual	
Japanese brome	No	Cool	Annual	Bunchgrass

Table 2b. Common forb species of non-native grasslands monitoring type

Species	Native	Annual/Biennial/ Perennial	Flowering	Reproduction
Yellow sweetclover	No	Biennial (sometimes annual)	May to September	Seeds
Common mullein	No	Biennial	June to July	Seeds

III. WOODY DRAWS

This habitat type encompasses several different plant communities as described in Von Loh et al. (1999). This grouping covers 3,909 acres or 1.6% of the park and is critical habitat for some species of birds and large mammals. Vegetation communities grouped into this monitoring type are based on a Green Ash-Elm Woody Draw and the surrounding communities. Associated edge communities in drier areas are Rocky Mountain Juniper/Little-seed Ricegrass Woodland and Ponderosa Pine/Rocky Mountain Juniper Woodland. Shrublands that occur at draw sides and heads include chokecherry, western snowberry, and skunkbush sumac. These draws occur in less steep mesic draws, small perennial drainages, and at the base of sandhills (Von Loh et al., 1999). The vegetation normally occurs on the draw bottoms and lower sideslopes (Warner, 1993). Shrubby to wooded draws are found on all aspects with slopes 0 - 60% and elevations of 2,400 to 4,000 feet. Soils are clayey, silty, claypan, and badlands overflow. Soil types are Interior-Cedarpass-Denby, Interior loam, channeled, Midway silty clay loam, and Orella-Badlands (USDA-SCS, 1987). Stands typically have closed canopies dominated by green ash with some American elm (Table 3). Cottonwood and peachleaf willow (*Salix amygdaloides*) are often present near springs and seeps. Shrubs are sparse in the understory, but form dense communities along the edge. Shrubs include chokecherry, western snowberry (*Symphoricarpos occidentalis*), skunkbush sumac and poison ivy (*Toxicodendron rydbergii*). The herbaceous component includes Kentucky bluegrass, western wheatgrass, big bluestem (*Andropogon gerardii*), and littleseed ricegrass (*Oryzopsis micrantha*) (Von Loh et al., 1999).

Table 3. Common woody species of woody draws monitoring type

Species	Native	Growth Form	Response to Fire
Green ash	Yes	Tree	Top-kill, vigorous resprout
American elm	Yes	Tree	Easily damaged or killed by fire
Chokecherry	Yes	Shrub	Top-kill, vigorous resprout
Western snowberry	Yes	Shrub	Top-kill, vigorous resprout
Skunkbush sumac	Yes	Shrub	Top-kill, vigorous resprout

MANAGEMENT OBJECTIVES

Western wheatgrass mixed-grass prairie is believed to be the pre-settlement vegetation for the area but the exact composition of the communities before settlement is unknown. Kuchler (1964) described the potential vegetation for the BADL area as wheatgrass-needlegrass prairie. The fire return intervals reported vary from as short as 5 years in level to gently rolling topography to 15-30 years in more broken topography at Scotts Bluff National Monument, Nebraska (Wendtland and Dodd 1992). Desired future conditions and prescribed fire objectives for each monitoring type are described below.

I. WESTERN WHEATGRASS MIXED-GRASS PRAIRIE

Desired future condition for the western wheatgrass mixed-grass prairie is that the community, when maintained by fire, will have reduced numbers of non-native species, particularly cool season grasses. The current diversity of associated native species would be preserved or increased. There would be short-term (2-4 years post-burn) increase in native forbs, especially milkweed and other target species for butterflies. With continued burning and follow-up monitoring we will improve knowledge of fire effects in this community. The entire community would have 25-50% of the area burned within 5 years depending on topography, with a mosaic of different aged stands across the type.

Prescribed fire objectives for this type include:

1) *Immediate Post-burn* - Burn 60-80% of the burnable project area
2) *Two Years Post-burn* - Reduce mean relative cover of non-native grasses by at least 20%; increase mean relative cover of native grasses by at least 10%; increase mean relative cover of native forbs by at least 30%

II. NON-NATIVE GRASSLANDS

The non-native grasslands, when maintained by fire, will have reduced amounts of non-native cool season grasses; especially cheatgrass, Japanese brome, smooth brome, crested wheatgrass, and Kentucky bluegrass. Repeated spring burning will check the spread of these grasses into native prairie. The number of native grasses and forbs will increase, increasing the biodiversity of these areas. These areas are highly visible because they are often disturbed areas such as roadsides. This provides an opportunity for visitor understanding and education about prescribed fire and non-native species control. The park would like these areas to be returned to mostly native plant communities and eventually have no need for this monitoring type. Various methods of seeding of native species may follow prescribed fires.

Prescribed fire objectives for this type include:

1) *Immediate Post-burn* - Burn 80-100% of the burnable project area
2) *One Year Post-burn* - Reduce mean relative cover of non-native grasses by at least 30%; increase mean relative cover of native grasses by at least 10%; increase mean relative cover of native forbs by at least 10%
3) *Five Year Post-burn* - Maintain 30% reduction of non-native grass relative cover; maintain increase of relative cover of native grass and forbs, limit reduction of native cool-season grasses to less than 20% of the pre-burn conditions.

III. WOODY DRAWS

Woody draws are believed to be part of the pre-settlement landscape for the area (Boldt et al. 1978). The exact composition of the communities before settlement is unknown. Deciduous trees are reported to be no older than 50 years and juniper no older than 100 (Warner 1983). The fire return intervals of 15-30 years were estimated for more broken topography at Scotts Bluff National Monument, Nebraska (Wendtland and Dodd 1992). This return interval would have interacted with long term wet and dry periods for the area. The edges of these draws would have been impacted by the return intervals and fire frequencies of the surrounding prairie. The more mesic areas of the draws would have only been likely to burn in dry periods.

The community, when maintained by fire, will have a mosaic of different age classes within a watershed. Browse for ungulates will increase. Sheltering cover will remain within 25% of current levels. Canada thistle and associated non-native species related to homesteading will be reduced. The structural complexity of the community will be maintained. The length of the edge habitat will be increased or maintained within 10% of current levels.

Prescribed fire objectives for this type include:

1) *Immediate Post-burn* - Reduce total down and dead woody fuel load by 20-60%
2) *One Year Post-burn* - Increase density of desired woody browse species (*Prunus* spp., *Ribes* spp., and *Symphoricarpos occidentalis*) by 30 to 50%
3) *Five Year Post-burn* - Limit overstory tree mortality of native species to no more than 25%

MONITORING DESIGN

I. MONITORING OBJECTIVE

The precision required for measurement within the different communities at Badlands is somewhat variable. For example, in the western wheatgrass mixed-grass prairie type it is expected that we can accurately assess the cover of western wheatgrass because the grass is present in large amounts and doesn't vary annually based on precipitation patterns. Other variables, like native forb cover, vary greatly from year to year depending on precipitation. Lower precision is likely on these variables because of the impracticality of collecting a sufficient sample size. Below are the accuracy standards for each monitoring type:

A. WESTERN WHEATGRASS MIXED-GRASS PRAIRIE

1) Install enough plots to be 80% confident that the relative cover of native perennial grasses, non-native grasses, and native forbs are within 25% of the true population mean.
2) Install enough plots to be 80% confident that the average density of all brush species is within 25% of the true population mean.

B. NON-NATIVE GRASSLANDS

1) Install enough plots to be 80% confident that the relative cover for non-native grasses are with in 25% of the true population mean.
2) Install enough plots to be 80% confident that the relative cover of the target grass is within 25% of the true population mean.
3) Install enough plots to be 80% confident that the relative cover of native grasses and forbs are within 25% of the true population mean.

C. WOODY DRAWS

1) Install enough plots to be 80% confident that the density of overstory trees is within 25% of the true population mean.
2) Install enough plots to be 80% confident that the density of targeted browse species are within 25% of the true population mean.
3) Install enough plots to be 80% confident that the relative cover of herbaceous plants are within 25% of the true population mean.

II. SAMPLING DESIGN

There are a number of different monitoring efforts associated with the fire program at BADL. Current monitoring at BADL include: vegetation monitoring using standard FMH protocols, roadside sampling for prairie restoration, monitoring butterfly use of vegetation, and a study to examine impacts of prescribed fire on paleontological resources.

The sampling design for the FMH plots are contained in the individual monitoring type description sheets found in Appendix (f). Each of the subsequent sections refers to the FMH plots only.

III. FIELD MEASUREMENT AND PLOT LOCATION INFORMATION ARCHIVING

The individual variables to be measured are defined in the monitoring type descriptions found in Appendix (f). All plots are marked with steel rebar approximately half a meter in height. Each piece of rebar has a brass tag indicating its location within the plot. The rebar at the zero end of each plot has a tag with complete plot data as specified by the handbook. All locations have been georeferenced via GPS. A hard copy of each plot location is retained in the Resource Management Division Files at BADL. A digital text copy is on the computer network, on the common "P" drive, within the Resource Management folder in the "Fire" folder. A GIS data layer with plot locations is on the park network GIS drive in the "GIS data" folder. The Northern Great Plains Fire Monitoring Team will retain a copy in their office, and will be responsible for providing updated versions to BADL as needed.

IV. MONITORING LOCATIONS

Currently all plots are located in the North Unit of Badlands NP. See the map of all plot locations in Appendix (e) and the individual plot location sheets for location and directions to all plots.

V. PRESCRIBED FIRE MONITORING PARAMETERS

Badlands NP has adopted the NPS Fire Monitoring Handbook (2001) as a guide for fire effects monitoring. The handbook identifies four monitoring levels:

Level 1 – Reconnaissance	Fire Cause, location, size, fuel and vegetation types, relative fire activity, potential for spread, current and forecasted weather, resource or safety threats and constraints, and smoke volume and movement
Level 2 – Fire Conditions	Fire monitoring period, ambient conditions – topographic and fire weather, fuel model, fire characteristic, and smoke characteristic
Level 3 – Immediate Post fire Effects	Fuel reduction, vegetative change or other objective dependent variables with in 1 to 5 years after a burn
Level 4 – Long-term Change	Continued monitoring of Level 3 variables to measure trends and change over time

The FMH plots that have been described in this document thus far are being used to examine levels 3 and 4.

Wildland fires that are suppressed will be monitored at levels 1 and 2 with observations entered into the park's monitoring database. In the event that long-term fire effects plots are burned in a wildland fire, they will be read by the NGPA Fire Monitoring Team, according to the schedule of plot rereads following a burn treatment. Level 1 and 2 monitoring observations will be filed with the final fire package and a copy placed with the records for the Fire Management Unit that was burned.

Wildland Fires for Resource Benefit will be monitored as described in the NPS Fire Monitoring Handbook (Level 2 monitoring), and will be completed daily on the fire. During periods of forecasted growth greater than 100 acres per day, on-site observations of dry bulb, relative humidity, wind speed, wind direction, and cloud cover will be made one hour before activity begins to two hours after activity ceases, or minimally from one hour before sunrise to two hours after sunset. Fire characteristics as described in the NPS Fire Monitoring Handbook Level 2 will be collected on-site hourly when conditions and monitor safety permit. Smoke characteristics will be monitored hourly any time a forecasted wind direction would place the smoke plume toward a community and/or highway.

Prescribed fires will meet at least the Level 1 and 2 recommended standards. If there are FMH plots in a unit, information on Level 3 and 4 Variables will be collected.

VI. LEVEL 1 VARIABLES

Reconnaissance monitoring, Level 1, provides a basic overview of the fire event. The following variables will be collected on all fires.

- Fire cause (origin), location and size
- Fuels and vegetation type
- Relative fire activity
- Potential for further spread
- Current and forecasted weather
- Resource or safety threats and constraints
- Smoke volume and movement

Specific information on the collection of these variables can be found in the NPS Fire Monitoring Handbook (2001) or the RX-91 – Monitoring prescribed and wildland fire text.

VII. LEVEL 2 VARIABLES

Fire conditions monitoring, Level 2, provides information on fire weather, fire behavior and resource values at risk. The following variables will be collected and summarized in a monitoring report (see Appendix (h) for specific protocols, data sheets, and example reports) on all wildland fires for resource benefit and all prescribed fires.

1. FIRE MONITORING PERIOD
   a) fire number and name
   b) observations data and time
   c) monitor's name
2. AMBIENT CONDITIONS
   a) Topographic variables
   b) Slope (%)
   c) Aspect
3. FIRE WEATHER VARIABLES
   a) Dry bulb temperature
   b) Relative humidity
   c) Wind speed
   d) Wind direction
   e) Fuel shading and/or cloud cover
   f) Time-lag fuel moisture
   g) Live fuel moisture
   h) Drought index
4. SOIL MOISTURE

5. FUEL MODEL
6. FIRE CHARACTERISTICS
   a) Linear rate of spread
   b) Perimeter or area growth
   c) Flame length
   d) Fire spread directions
7. SMOKE CHARACTERISTICS (BASED ON STATE AND LOCAL REQUIREMENTS)

VIII. INTENDED DATA ANALYSIS

Plot installations will be based on burn priorities and will reach a statistically valid sample size within five years for the priority monitoring types. The Northern Great Plains Fire Ecologist will be responsible for checking the minimum plot numbers in all types that have more than five plots installed. Each monitoring type description delineates the variables that will be analyzed. When minimum plot numbers have been reached, objectives will be evaluated after the data have been checked to meet the assumptions of the statistical test. If the data meet the assumptions, including normality, then confidence intervals will be used for change over time comparisons. If data do not meet the assumptions, a statistician will be consulted. Correlation of Level 2 data with vegetation data can be done with either regression or multivariate analysis.

The Northern Great Plains Fire Ecologist will compare data with fire effects research that has been completed in the park and area. Inconsistencies should lead the ecologist to examine different methodologies, data interpretation, and potential research questions.

IX. MONITORING IMPLEMENTATION SCHEDULE

1. BURN UNIT SCHEDULE

Appendix H of the Fire Management Plan identifies the planned burn schedule for the next several years. The unit rotation is based on a 5 to 15 year fire return interval. Units dominated by non-native species may require shorter burn intervals to meet desired objectives. A map of the burn units is also found in Appendix J of the Fire Management Plan.

2. TIMING OF MONITORING

All plots are currently monitored at peak diversity for the native forbs approximately halfway between the peak in cool and warm season grasses. With the addition of nested frequency monitoring the vegetative data may need to be read twice a year because of the two different peaks. This will need to be examined after pilot sampling. All plots are currently being read pre-burn, immediately post-burn, and 1, 2, 5, 10, and 20 years post-burn.

3. PRE-BURN SAMPLING

Pre-burn sampling will be done during peak phenology. Plots should be installed the growing season before prescribed burns. All plots that have not burned within 2 years of installation will not be reread until that unit is again scheduled to burn. These plots can also be considered for control plots depending on long-term burn planning.

4. POST-BURN SAMPLING

Post-burn sampling will be done immediately post-burn and 1, 2, 5,10, and 20 years after the burn. Plots that burn in the spring will be read at peak phenology that summer, and then at the regular 1, 2, 5, 10, and 20 year schedule. The 1-Year reads for grassland plots burned in the spring are during the growing season the same year as the burn, and the 2-year read occurs in the following year. The 1-year reads for forest plots burned in the spring are during the growing season one year after the burn. Fall burns will be read the following summer as 1 year post-burn reads. If a unit is scheduled to be burned for a second or third time between reads, an additional pre-burn read will be added. For example, the Pinnacles unit was burned in the spring of 2000. The post-burn reads would be an immediate post-burn read, 1 year read summer 2000, 2 year read summer 2001, and 5 year read summer 2004. The unit is then scheduled to burn again in 2008. A second pre-burn read should be added summer 2007.

DATA SHEET EXAMPLES

Most data sheets used are the standard FMH forms. Non-FMH forms used can be found in Appendix (i).

DATA MANAGEMENT

Other monitoring programs have shown that between 25-40% of the time associated with monitoring should be on data management. The data for BADL is collected and managed by the Northern Great Plains Fire Monitoring Team located at Wind Cave National Park, Hot Springs, South Dakota. All data collected at BADL will be entered and checked by this team at their office. Generally the seasonal field staff enters and checks data. This process is supervised the NGP Lead Monitor and Fire Ecologist. Original copies of all data will be kept at the team's office. Hard copies of the Plot Location Data Sheets will be archived at BADL in the Resource Management files. The Lead Monitor will provide monitoring data to the BADL Chief of Resource Management annually on CD for archiving. Data are currently entered and analyzed in the FMH software. Non FMH data may be entered and analyzed in a variety of programs. The current data are entered into Microsoft Excel spreadsheets for analysis. It is backed up to the server at Wind Cave. It will be sent annually to Badlands NP and the Midwest Regional Ecologist in conjunction with the annual report. Global positioning data of plot locations are stored on CD at the Fire Monitoring Office at Wind Cave.

I. QUALITY CONTROL

Data quality will be insured through proper training of the crew in data collection and a system of checks in the data entry process. All data sheets will be checked by the lead crewmember before leaving a plot for data accuracy and completeness. Data will be summarized annually and results reported to the park and regional fire ecologist. A program review should happen every 3-5 years to maintain consistency of data collection and analysis and re-assessment of program requirements. More frequent review may be necessary if there are significant staffing changes, additional ecological concerns, or by request of the park or monitoring crew.

II. SOURCES OF DATA ERRORS

Errors in recording can be reduced by checking all data sheets for completeness and accuracy before leaving the plot. Standardized crew training at the beginning of the season will insure all data are being collected in the same manner by all crewmembers. Transcription errors will be corrected by checking all data once entered in the computer. Collecting voucher specimens and using the study collection to verify plant identifications can minimize incorrect identification of plant species. All unknown plant species will be photographed and added to the unknown plant database. These photos can be used as a field reference to insure that all unknowns are consistently observed. BADL Resource Management personnel will be notified of unknowns of particular concern so special attention can be given to identify it. Undersampling of less-frequently occurring species is a large problem in the grass types. An additional sampling technique, nested frequency, will be added after consulting with the regional fire ecologist to better sample the species richness found in these types.

The impacts of monitoring include compacting of fuels and vegetation and the collection of voucher plant specimens. Compaction can be minimized by crew awareness as to where data are collected. Voucher specimens are not collected in the plot – if no other specimen is found, the unknown plant will be photographed and added to the unknown plant photo database. Accurate plot locations including GPS data will aid in plot location and minimize vegetative compaction. Test all directions by having new crewmembers use previously written directions to ensure accuracy. Incomplete or missing data will be corrected as soon as possible. Plot protocols need to be reviewed annually with the seasonal crew prior to beginning work to insure that data are accurately collected. Problems encountered by the field crew must be brought to the attention of the lead monitor and fire ecologist.

RESPONSIBLE PARTIES

This **Fire Monitoring Plan** was written by Kara J. Paintner, formerly the Northern Great Plains Lead Monitor and currently the Fire Ecologist at Yosemite National Park.

Administrative duties will be assigned as follows:

- Plan revision, crew supervision, and data analysis will be done by the *Northern Great Plains Fire Ecologist*
- Park liaison will be done by the *Chief of Resource Management, Badlands NP*
- Data collection, data entry, data management and field crew supervision will be done by the *Northern Great Plains Lead Monitor*
- Program reviews will be coordinated by the *Midwest Regional Fire Ecologist*

FUNDING NEEDS ASSESSMENT

FIREPRO funding for the Northern Great Plains Fire Monitoring team will be used for all monitoring activities. The new funding matrix, FY 2002, allows for non-FMH plot types to be funded with regional approval. Travel for the standard plot reads will come out of the travel budget for the crew. Travel and overtime for all prescribed, wildland fires, and immediate post-burn reads will come from the project funds. Control plots will be done in conjunction with the Badlands Resource Management staff.

MANAGEMENT IMPLICATIONS OF MONITORING RESULTS

Monitoring results will be summarized and presented to the park in the fall meeting of the Fire Committee with the NGPA Fire management Officer, Prescribed Fire Specialist and Fire Ecologist. This meeting helps coordinate fire activities including prescribed fire for the park in the coming year. The annual report information can be conveyed to the Badlands Resource Management Division in an additional meeting as requested.

Review of the data summary and analysis by the NGP Fire Ecologist, Prescribed Fire Specialist, and Badlands Resource Management staff should determine if the current program is moving the vegetation towards the desired conditions and/or having unwanted results. Targets should be reviewed and refined, and burn prescriptions and other vegetation management techniques could be adjusted to compensate. This review could also generate questions that may lead to fire effects research being conducted in the park. Information from the Badlands program could be analyzed with other parks from the NGP group as appropriate and should be presented to other parks and at scientific meetings and publications.

CONSULTATION AND COORDINATION

The Northern Great Plains Fire Monitoring Team is responsible for coordination and consultation with other parks in the group, fire management personnel, and the Midwest Regional Fire Ecologist. Badlands Resource Management staff will be responsible for coordination and consultation with the park and all other cooperators including:

US Forest Service, Buffalo Gap National Grasslands
South Dakota State Forestry Department
Oglala Sioux Tribe
Bureau of Indian Affairs
Other local cooperators

The Badlands Resource Management Division participated in shaping and preparing this plan. The following provided assistance with, or review of, this plan:

Sandee Dingman, Resource Management Specialist, Badlands NP
Eddie Childers, Wildlife Biologist, Badlands NP
Brian Kenner, Chief of Resource Management, Badlands NP

Bill Supernaugh, Superintendent, Badland NP

Andy Thorstenson, Lead Monitor, NPS, Northern Great Plains Fire Monitoring Team
Bill Gabbert, Fire Management Officer, NPS, NGPA Fire Management Office
Mike Beasley, former AFMO/Prescribed Fire Specialist, NPS, Northern Great Plains
Jim DeCoster, Regional Fire Ecologist, NPS, Midwest Region, Omaha
Cody Wienk, Fire Ecologist, NPS, NGPA Fire Management Office

PEER REVIEW

Peer/technical review for this plan was provided by:

Tonja Opperman
Fire Ecologist, US Forest Service, Bitterroot National Forest, Hamilton, MT

Linda Kerr
Regional Fire Ecologist, National Park Service, Intermountain Region, Denver, CO

Pam Benjamin
Botanist, National Park Service, Intermountain Region, Denver, CO

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APPENDIX (a): PLANT VOUCHER COLLECTION/PLANT LIST

FMH-6 Species Code List FMH Data - BADL Page: 0001
FMH version 3.10, Printed on 03/19/01, 10:11:56 am
Current directory: C:\TESTFMH

Sorted by: Scientific Name

Code	Nat.	Cycle	Form	Genus	Species	Subspecies	Variety	Common name
ACMI1	Y	P	F	Achillea	millefolium			Yarrow
AGCA1	Y	P	G	Agropyron	caninum			Slender Wheatgrass
AGCR1	N	P	G	Agropyron	cristatum			crested wheatgrass
AGSM1	Y	P	G	Agropyron	smithii			western wheatgrass
AGSP1*	Y	P	G	Agropyron	spicatum			bluebunch wheatgrass
AGSU1*	Y	P	G	Agropyron	subsecundum			western wheatgrass hybrid
ALTE1	Y	P	F	Allium	textile			wild onion
AMPS1*	Y	P	F	Ambrosia	psilostachya			western ragweed
AMFR1*	Y	P	S	Amorpha	fruticosa			False Indigo
AMNA1	Y	P	S	Amorpha	nana			dwarf wild indigo
ANAR1*	N	A	F	Anagallis	arevensis			Scarlet Pimpernel
ANGE1	Y	P	G	Andropogon	gerardii			big bluestem
ANSC1	Y	P	G	Andropogon	scoparius			little bluestem
ANPA1*	Y	P	F	Antennaria	parviflora			pussytoes
ARLO1	Y	P	G	Aristida	longiseta			three awn
ARPU1	Y	P	G	Aristida	purpurea			three awn
ARCA1	Y	P	S	Artemisia	cana			silver sage
ARFR1	Y	P	F	Artemisia	frigida			fringed sagewort
ARLU1	Y	P	F	Artemisia	ludoviciana			white sage
ARXX1*	Y	P	F	Artemisia	species			unknown sage
ASPU1*	Y	P	F	Asclepias	pumila			plains milkweed
ASVE1*	Y	P	F	Asclepias	verticillata			whorled milkweed
ASVI1	Y	P	F	Asclepias	viridiflora			green milkweed
ASER1	Y	P	F	Aster	ericoides			white aster
ASXX1	N	A	F	Aster	species			aster
ASAG1	Y	P	F	Astragalus	agrestis			field milk-vetch
ASCR1*	Y	P	F	Astragalus	crassicarpus			groundplum milkvetch
BARE1	--	-	*	Bare				Bare Ground
BERE1*	Y	P	S	Berberis	repens			Oregon grape
BOCU1	Y	P	G	Bouteloua	curtipendula			side oats grama
BOGR1	Y	P	G	Bouteloua	gracilis			blue grama
BOHI1	Y	P	G	Bouteloua	hirsuta			hairy grama
BRJA1	N	A	G	Bromus	japonicus			Japanese brome
BRTE1	N	A	G	Bromus	tectorum			downy brome
BUDA1	Y	P	G	Buchloe	dactyloides			buffalo grass
CALO1	Y	P	G	Calamovilfa	longifolia			prairie sandreed
CAGU1	Y	P	F	Calochortus	gunnisonii			sego lily
CAMI1*	N	A	F	Camelina	microcarpa			smallseed flax
CABR1	Y	P	R	Carex	brevior			Fescue sedge
CAFI1	Y	P	R	Carex	filifolia			threadleaf sedge
CAXX1	Y	P	R	Carex	spp			
CAXX3*	Y	P	R	Carex	spp 1998			
CHAL1	N	A	F	Chenopodium	album			lambsquarter
CHNA1	Y	P	S	Chrysothamnus	nauseosus			rubber rabbitbrush
CIAR1	N	P	F	Cirsium	arvense			Canada thistle
CIUN1	Y	P	F	Cirsium	undulatum			wavyleaf thistle
CIVU1*	N	B	F	Cirsium	vulgare			Bull Thistle
COLI1*	Y	A	F	Collomia	linearis			narrowleaf collomia
COAR1	N	P	V	Convolvulus	arvensis			field bindweed
COCA1	Y	A	F	Conyza	canadensis			horseweed
COMI1	Y	P	F	Coryphantha	missouriensis			cactus
LICH3*	Y	P	N	Crustose	lichen			Crustose Lichen
DACA1*	Y	P	F	Dalea	candidum			white prairie clover
DAPU1	Y	P	F	Dalea	purpurea			purple prairie clover
DASP1*	Y	P	G	Danthonia	spicata			poverty oat grass
DAST1	Y	A	F	Datura	stramonium			jimson weed
DECA1	Y	P	F	Delphinium	carolinianum			prairie larkspur
DEVI1	Y	P	F	Delphinium	virescens			prairie larkspur
DEPI1	Y	A	F	Descurainia	pinnata			tansy mustard
DUFF1*	--	-	*	Duff				Duff
ECAN1	Y	P	F	Echinacea	angustifolia			purple coneflower
ELGL1*	Y	P	G	Elymus	canadensis			Canada wild rye
ELJU1	N	P	G	Elymus	junceus			Russian wild rye

FMH-6 Species Code List FMH Data - BADL Page: 0002
FMH version 3.10, Printed on 03/19/01, 10:11:57 am

Current directory: C:\TESTFMH

Sorted by: Scientific Name

Code	Nat.	Cycle	Form	Genus	Species	Subspecies	Variety	Common name
ELVI1*	Y	P	G	Elymus	virginicus			Virginia wild rye
ERPU1*	Y	P	F	Erigeron	pumilus			low fleabane
ERST1	Y	A	F	Erigeron	strigosus			daisy fleabane
ERXX1	Y	P	F	Erigeron	unknown			fleabane
EUES1*	N	P	F	Euphorbia	esula			leafy spurge
EUMA1	Y	A	F	Euphorbia	marginata			snow-on-the-mountain
EUSP1	Y	A	F	Euphorbia	spathulata			spurge
EUXX1	Y	A	F	Euphorbia	unknown			unknown euphorbia
FEOC1	Y	A	G	Festuca	octoflora			Six weeks Fescue
FEOV1*	Y	P	G	Festuca	ovina			sheep fescue
LICH1*	Y	P	N	Foliose	lichen			Foliose Lichen
LICH2*	Y	P	N	Fruticose	lichen			Fruiticose Lichen
GAAP1	Y	A	F	Galium	aparine			cathcweed bedstraw
GAXX1	Y	P	F	Galium	unknown			
GACO1	Y	P	F	Gaura	coccinea			scarlet gaura
GAPA1	Y	A	F	Gaura	parviflora			velvet gaura
GLLE1	Y	P	F	Glycyrrhiza	lepidota			wild licorice
GRSQ1	Y	B	F	Grindelia	squarrosa			curlycup gumweed
GUSA1	Y	P	F	Gutierrezia	sarothrae			broom snakeweed
HEHI1	Y	A	F	Hedeoma	hispidum			false pennyroyal
HEAN1	Y	A	F	Helianthus	annuus			sunflower
HOJU1*	N	P	G	Hordeum	jubatum			foxtail barley
JUSC1*	Y	P	T	Juniperus	scopulorum			Rocky Mountain juniper
KOPY1	Y	P	G	Koeleria	pyramidata			junegrass
LAOB1	Y	P	F	Lactuca	oblongifolia			blue lettuce
LAPU1	Y	A	F	Lactuca	pulchella			blue lettuce
LASE1	N	A	F	Lactuca	serriola			prickly lettuce
LAOC1	Y	A	F	Lappula	occidentalis			sticktight
LARE1	Y	A	F	Lappula	redowskii			western stickseed
LAPO1	Y	P	F	Lathyrus	polymorphus			Hoary vetchling
LIRI1	Y	A	F	Linum	rigidum			yellow flax
LITT1	--	-	*	Litter				Litter
LYJU1	Y	P	F	Lygodesmia	juncea			rush skeleton plant
MESA1	N	P	F	Medicago	sativa			alfalfa
MEAL1	N	A	F	Melilotus	alba			white clover
MEOF1	N	A	F	Melilotus	officinalis			yellow sweetclover
MIGR1	Y	A	F	Microsteris	gracilis			
MOSS1*	Y	P	N	Moss				Moss
MUCU1	Y	P	G	Muhlenbergia	cuspidata			plains muhly
MUDI1*	Y	P	F	Musineon	divaricatum			leafy musineon
NECA1	N	P	F	Nepeta	cataria			catnip
OPHU1	Y	P	S	Opuntia	humifusa			plains prickly pear
OPPO1	Y	P	S	Opuntia	polycantha			plains prickly pear
OPXX1*	Y	P	S	Opuntia	unknown			
ORXX1*	Y	P	G	Oryzopsis	unknown			Indian ricegrass?
OXSE1*	Y	P	F	Oxytropis	sericea			whitepoint crazyweed
PAVI1	Y	P	V	Parthenocissus	vitacea			woodbine
PEGR1	Y	P	F	Penstemon	gracilis			slender beardtoungue
PHHO1	Y	P	F	Phlox	hoodii			Hood's Phlox
PHXX1	Y	P	F	Phlox	unknown			unknown phlox
PHVI1	Y	P	F	Physalis	virginiana			lanceleaf groundcherry
PIPO1	Y	P	T	Pinus	ponderosa			Ponderosa Pine
PLPA1	Y	A	F	Plantago	patagonica			wooly plantain Indian wheat
POCO2	N	P	G	Poa	compressa			Canada bluegrass
POPR1	N	P	G	Poa	pratensis			Kentucky Bluegrass
POAL1	Y	P	F	Polygala	alba			white milkwort
POCO1	N	A	V	Polygonum	convolvulus			climbing or wild buckwheat
PRAM1	Y	P	S	Prunus	americanus			American plum
PRVI1	Y	P	S	Prunus	virginia			
PSAR1	Y	P	F	Psoralea	argophylla			silver-leaf scurf pea
PSCU1	Y	P	F	Psoralea	cuspidata			tall breadscurf pea
PSES1	Y	P	F	Psoralea	esculenta			prarie turnip
PSTE1	Y	P	F	Psoralea	tenuiflora			slender leaf scurfpea
QUMA1	Y	P	T	Quercus	macrocarpa			bur oak
RACO1	Y	P	F	Ratibida	columnifera			prarie coneflower

RHAR1	Y	P	S	Rhus	aromatica	skunkbush sumac

FMH-6 Species Code List FMH Data - BADL Page: 0003
FMH version 3.10, Printed on 03/19/01, 10:11:57 am

Current directory: C:\TESTFMH
Sorted by: Scientific Name

Code	Nat.	Cycle	Form	Genus	Species	Subspecies	Variety	Common name
RIAM1	Y	P	S	Ribes	americanum			wild black currant
RIMI1	Y	P	S	Ribes	missouriense			Missouri gooseberry
RISE1*	Y	P	S	Ribes	setosum			goosebery
RIXX1	Y	P	S	Ribes	unknown			Unknown currant
ROCK1*	--	-	*	Rock				Rock
ROOT1*	--	-	*	Root				Root
ROWO1	Y	P	S	Rosa	woodsii			wood rose
RUCR1	N	P	F	Rumex	crispus			curly dock
RUXX1	Y	P	F	Rumex	species			Unknown dock
SAIB1	N	A	F	Salsola	iberica			Russian thistle
SAVE1*	Y	P	S	Sarcobatus	vermiculatus			greasewood
SCAT1*	--	-	*	Scat	various species of fauna			Scat
SCPA1*	Y	P	G	Schedonnardus	paniculatus			tumblegrass
SECE1*	N	A	G	Secale	cereale			rye
SEDE1*	Y	P	A	Selaginella	densa			spikemoss
SIAL1	N	A	F	Sisymbrium	altissimum			tumbling mustard
SMST1	Y	P	F	Smilacina	stellata			False Solomon's Seal
SDED1*	--	-	*	Snag	dead tree			standing dead tree
SOMI1	Y	P	F	Solidago	missouriensis			Missouri goldenrod
SOXX1	Y	P	F	Solidago	unknown			unknown solidago
SPCO1	Y	P	F	Sphaeralcea	coccinea			scarlet globemallow
SPXX1	Y	P	G	Sporobolus	species			dropseed
STCO1	Y	P	G	Stipa	comata			needle-n-thread
STSP1*	Y	P	G	Stipa	sparta			porcupine grass
STVI1	Y	P	G	Stipa	viridula			green needlegrass
STMP1*	--	-	*	Stump				Stump
SYOC1	Y	P	S	Symphoricarpos	occidentalis			western snowberry
TAOF1	N	P	F	Taraxacum	officinale			dandelion
THAR1	N	A	F	Thlaspi	arvense			field pennycress
TORA1	Y	P	S	Toxicodendron	radicans			poison ivy
TORY1	Y	P	S	Toxicodendron	rydbergii			poison ivy
TRBR1	Y	P	F	Tradescantia	bracteata			
TRDU1	N	B	F	Tragopogon	dubius			goatsbeard, salsify
TRPR1*	N	B	F	Tragopogon	pratensis			meadow salsify
BOLE1*	--	-	*	Tree	bole			Tree Bole
UNKN1	N	A	F	Unknown				Unknown
UNAN1	N	A	F	Unknown				annual
UNKN2	N	A	F	Unknown	forb			ask kobza
UNKN4*	N	A	F	Unknown	forb 1998			broad leaves
BRXX1	N	A	F	Unknown	mustard			Unknown Brassicaceae
VETH1*	N	B	F	Verbascum	thapsus			mullein
VEST1	Y	P	F	Verbena	stricta			hoary vervain
VIAM1	Y	P	F	Vicia	americana			american vetch
WOOD1*	--	-	*	Wood				Wood
YUGL1*	Y	P	S	Yucca	glauca			yucca
ZIVE1	Y	P	F	Zigadenus	venenosus			death camas

* Species marked with an asterisk were not found in any data form

Entries.	175	(G) Grass.	34
Non-plants	10	(F) Forb	95
Plants	165	(S) Shrub.	21
		(T) Tree	3
Native	130	(N) Non-vascular	4
Non-native	35	(*) Substrate.	10
		(R) Grasslike.	4
Perennial.	122	(A) Fern or ally	1
Biennial	5	(V) Vine	3
Annual	38	( ) Unknown.	0
Native perennial	110		
Native biennial.	1		
Native annual.	19		
Non-native perennial . .	12		
Non-native biennial. . .	4		

Non-native annual. . . .   19

APPENDIX (b): VEGETATION MAP

This map is too large to read at 8.5 x 11-inch size. The Vegetation Map classes are listed below and the map may eventually be viewed by quarterquad at http:\\biology.usgs.gov\npsveg

The Badlands Vegetation Map classes and codes are:

	Land Use
50	Rivers – Perennial
51	Transportation, Communications, and Utilities
52	Croplands and Pasture
53	Seeded Mixed-grass Prairie
54	Other Agricultural Land
55	Streams and Canals
56	Reservoirs
57	Beaches and Sandy Areas Other Than Beaches
58	Strip Mines, Quarries, and Gravel Pits

	Vegetation
1	Prairie Dog Town Community
2	Badlands Sparse Vegetation Complex
12	Switchgrass Grassland
14	Emergent Wetland
15	Little Bluestem - Grama Grasses - Threadleaf Sedge Grassland
16	Western Wheatgrass Herbaceous Alliance
17	Introduced Grassland
18	Blue Grama Grassland
19	Western Wheatgrass - Green Needlegrass Grassland
21	Soapweed Yucca / Prairie Sandreed Shrub Grassland
25	Silver Buffaloberry Shrubland
31	Silver Sagebrush / Western Wheatgrass Shrubland
32	Sand Sagebrush / Prairie Sandreed Shrubland
33	Rabbitbrush Shrubland
34	Chokecherry - (American Plum) Shrubland
35	Three-leaved Sumac / Threadleaf Sedge Shrub Grassland
37	Western Snowberry Shrubland
38	Sandbar Willow Temporarily Flooded Shrubland
39	Greasewood / Western Wheatgrass Shrubland
41	Eastern Cottonwood - (Peachleaf Willow) / Sandbar Willow Woodland
42	Green Ash - (American Elm) / Chokecherry Woodland
43	Ponderosa Pine / Rocky Mountain Juniper Woodland
44	Rocky Mountain Juniper / Littleseed Ricegrass Woodland

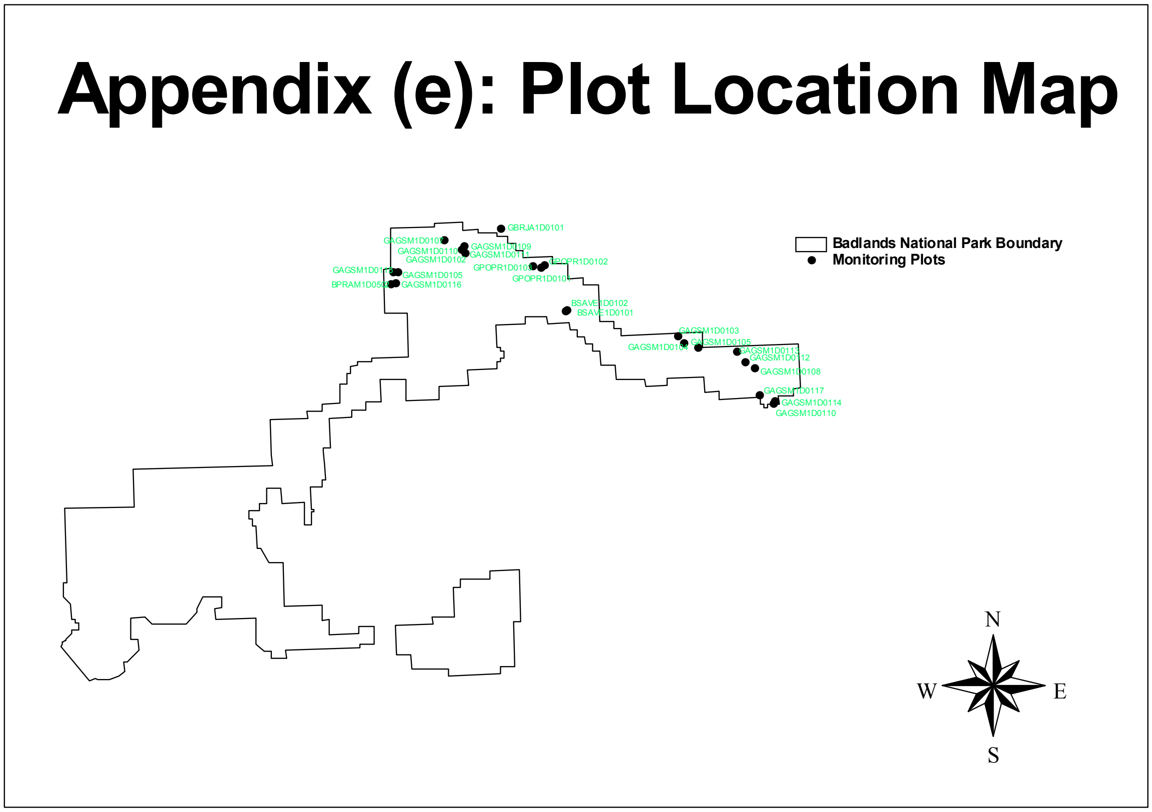
APPENDIX (c): FIRE MANAGEMENT UNIT MAP

See Appendix J of the Fire Management Plan

APPENDIX (d): FUEL MODEL MAP

The park-wide map is too large to present at 8.5 x 11-inch scale. For each burn plan, a fuel model map is prepared.

APPENDIX (e): PLOT LOCATION MAP



APPENDIX (f): MONITORING TYPE DESCRIPTIONS

FMH-4 **MONITORING TYPE DESCRIPTION SHEET** Park: **BADL**

Monitoring Type Code: GAGSM1DO1 **Date Described:** 6/12/97

Monitoring Type Name: Western Wheatgrass Mixed-grass Prairie

Prepared by: A. Powers, G. Bradshaw, B. Braudis, B. Bessken, R. Runge, B. Adams, G. Kemp, P. Reeberg

Updated by: Supernaugh, Kenner, Childers, Dingman, and Paintner – January, 1999

Physical Description
This community occurs in a wide a variety of habitats through the park. Sites are generally flat to moderately steep in slope and occur on all aspects. Associations of the type occupy clay, silt, loam and sandy soils of flats, swales, drainages, hills and slopes. (Von Loh et al., 1999) Elevations range from 2,400 to 4,000 feet. Soils are clayey, silty, claypan, and badlands overflow. Soil types are: Blackpipe clay loam, Blackpipe-Norrest complex, Blackpipe-Wortman Complex, Cedarpass silty clay loam, Cedarpass-Denby complex, Cedarpass-Interior-Badlands, Interior-Cedarpass-Denby (USDA-SCS, 1987).

Biological Description
Stands of this type have moderate to complete herbaceous cover, between 40-100%. Western wheatgrass (*Pascopyrum smithii*) is strongly dominate in ungrazed stands, less so in stands subjected to annual grazing by livestock. Species dominance can vary locally within a stand, depending on soils and use factors (Von Loh et al., 1999). Dominant graminoids are western wheatgrass, blue grama (*Bouteloua gracilis*), and green needlegrass (*Stipa viridula*). Shrubs are plains prickly pear (*Opuntia polyacantha)*, skunkbush (*Rhus aromatica)*, sand sage (*Artemisia frigida),* and silver sagebrush (*A. cana)*. Forbs include: heath aster (*Aster ericoides)*, yarrow (*Achillea millefolium*), and Missouri goldenrod (*Solidago missouriensis*).

Rejection Criteria
Large outcroppings or barren areas >20% of the plot; areas with anomalous vegetation; edges of the following types that are closer than 50 m to the plot: monitoring type boundaries or transitions; riparian areas or areas dominated by trees; bio-control areas; roads, human-made trails, burn unit boundaries or human created clearings are to be rejected.

Desired Future Condition
Western wheatgrass mixed-grass prairie is believed to be the pre-settlement vegetation for the area but the exact composition of the communities before settlement is unknown. Kuchler (1964) described the potential vegetation for the BADL area as wheatgrass-needlegrass prairie. The fire return intervals reported vary from as short as 5 years in level to gently rolling topography to 15-30 years in more broken topography at Scotts Bluff National Monument, Nebraska (Wendtland and Dodd, 1992).

The community when maintained by fire would have reduced numbers of non-native species particularly cool season grasses. The natural diversity of associated native species would be preserved or increased. There would be short-term (2-4 years post burn) increase in native forbs, especially milkweed and other target species for butterflies. With continued burning we will improve knowledge of fire effects in this community. The community would have 25-50% of the area burned within the last 5 years depending on topography with a mosaic of different aged stands across the type.

Burn Prescription
This prairie will be burned between April until green-up or late July through a season ending event in the fall. Head, flanking, and backing fire will be used as needed to meet burn objectives.

Fire Prescription Elements	
RH - 25-55%	**Live Fuel Moisture – NA**
Bulb - 30-85 o F	**Average Flame Length - 0.4-1.5 feet**
Average Mid-flame winds - 0-20 mph	**Average Rate of Spread - 0-3 chs/hour**
Fuel loading - 3-5 tons per acre	**1-hour TLFM - 6-14 %**
10-hour TLFM - 8-15 %	**100-hour TLFM - 10-30 %**

Monitoring Variables in Order of Importance
1. Native Grass Relative Cover
2. Non-native Grass Relative Cover
3. Native Forb Relative Cover

Prescribed Fire Project Objectives
<u>Immediate Post Burn</u>
1. Burn 60-80% of the burnable project area.

<u>Two Years Post Burn:</u>
1. Reduce relative cover of non-native grasses by at least 20%
2. Increase relative cover of native grasses by at least 10%
3. Increase relative cover of native forbs by at least 30%

Fire Monitoring Objectives
1. Install enough plots to be 80% confident that the relative cover for native perennial grasses, non-native grasses, and native forbs are within 25% of the true population mean.
2. Install enough plots to be 80% confident that the average density of all brush species is within 25% of the true population mean.

Data Analysis
1. Track relative cover of native grasses for each postburn read years 1, 2, and 5.
2. Track relative cover of non-native grasses for each postburn read years 1, 2, and 5.
3. Track relative cover and percent cover of native forbs for each postburn read years 1,2 & 5.
4. Track brush density and sprouting for each postburn read years 1,2, and 5.
5. Track specific forb or grass species cover requested by the wildlife biologist for each postburn read years 1,2, and 5
6. Track yellow sweetclover (*Melilotus officinalis*) cover for each postburn read years 1, 2, & 5.

Literature Cited

Kuchler, A.W. 1964. Potential natural vegetation of the coterminous Untied States. Am. Geogr. Soc. Spec. Publ. 36 (Manual), New York.

USDA Soil Conservation Service. 1987. Soil Survey of Jackson County, Northern Part, South Dakota. Washington, D.C. 216 pages plus maps

USDI National Park Service. 2001. Fire monitoring handbook. National Interagency Fire Center, Boise, ID. 288 pp.

Von Loh, J., Cogan, D., Faber-Langendoen, D., Crawford, D., and M.J. Pucherelli. 1999. USGS-NPS Vegetation Mapping Program Badlands National Park, South Dakota (Final Report). Technical memorandum No. 8260-99-03. US Bureau of Reclamation Technical Service Center. Denver, Colorado.

Wendtland, K. J., and J. L. Dodd. 1992. The fire history of Scotts Bluff National Monument. In: Smith, D. and C. Jacobs (eds.) Twelfth North American Prairie Conference. Cedar Falls, Iowa.

Notes: Brush density of snowberry (*Symphoricarpos* spp.) will be determined by stem count. Brush density for prickly pear (*Opuntia polyacantha*) will be counted by cluster immediately post burn because of increased visibility. Both species are rhizomatous. Please see brush sampling protocol in Fire Monitoring Handbook (USDI NPS 2001) for additional information.

FMH-4 PLOT PROTOCOLS

GENERAL PROTOCOLS		YES	NO		YES	NO
Preburn	Control Plots/Opt		•	Herb Height/Rec	•	
	Herbaceous Density/Opt		•	Belt Transect Width: 5 m		
	OP/Origin Buried		•	Abbreviated Tags	•	
	Voucher Specimens/Rec	•		Stakes Installed: 0P & 30P		
	Stereo Photography/Opt		•	Crown Intercept/Opt		•
	Brush Individuals/Rec	•		Herb. Fuel Load/Opt		•
	Herbaceous Data Collected at: 0P-30P					
Burn	Duff Moisture/Rec	•		Flame Zone Depth/Rec	•	
Postburn	Herbaceous Data/Opt: Not collected.			Herb. Fuel Load/Opt		•
	100 Pt. Burn Severity/Opt		•			

Rec = Recommended; Opt = Optional

FMH-4 **MONITORING TYPE DESCRIPTION SHEET** Park: **BADL**

Monitoring Type Code: FFRPE1D02 **Date Described:** 1/12/00

Monitoring Type Name: Woody Draws

Prepared by: Supernaugh, Kenner, Childers, Dingman, and Paintner

Physical Description
These draws occur in less steep mesic draws, small perennial drainages, base of sandhills (Von Loh et al., 1999). The vegetation normally occurs on the draw bottoms and lower sideslopes (Warner, 1993). Shrubby to wooded draws. All aspects are acceptable, slopes 0 - 60%, elevation 2,400 to 4,000 feet. Soils are clayey, silty, claypan, and badlands overflow. Soil types are: Interior-Cedarpass-Denby, Interior loam, channeled, Midway silty clay loam, and Orella - Badlands (USDA-SCS, 1987).

Biological Description
This habitat type encompasses several different plant communities as described in Von Loh et al. (1999). Vegetation communities grouped into this monitoring type are based on a Green Ash-Elm Woody Draw and the surrounding communities. Associated edge communities in drier areas are Rocky Mountain Juniper/Little-seed Ricegrass Woodland and Ponderosa Pine/Rocky Mountain Juniper Woodland. Shrublands that occur at draw sides and heads include chokecherry, western snowberry, and skunkbush sumac. Stands typically have closed canopies dominated by green ash (*Fraxinus pennsylvanica*) with some American elm (*Ulmus americana*). Cottonwood (*Populus deltoides*) and peachleaf willow (*Salix amygdaloides*) will be present if there is a spring or seep. Shrubs are sparse in the understory, but form dense communities along the edge. Shrubs include; chokecherry (*Prunus virginiana*), western snowberry (*Symphoricarpos occidentalis*), skunkbush sumac (*Rhus aromatica*) and poison ivy (*Toxicodendron rydbergii*). The herbaceous component includes; Kentucky bluegrass (*Poa pratensis*), western wheatgrass (*Pascopyrum smithii*), and big bluestem (*Andropogon gerardii*) (Von Loh et al., 1999).

Rejection Criteria
Large outcroppings or barren areas >20% of the plot; areas with anomalous vegetation; edges of the following types that are closer than 50 m to the plot: monitoring type boundaries or transitions; bio-control areas; roads, human-made trails, burn unit boundaries or human created clearings are to be rejected. Because of the linear shape of these communities part of the plot may fall in another monitoring type. Plots should be installed with the long axis of the plot following the long axis of the draw.

Desired Future Condition
Woody draws are believed to be part of the pre-settlement landscape for the area (Boldt et al., 1978). The exact composition of the communities before settlement is unknown. Deciduous trees are reported to be no older than 50 years and juniper no older than 100 (Warner, 1983). The fire return intervals of 15-30 years were estimated for more broken topography at Scotts Bluff National Monument, Nebraska (Wendtland and Dodd, 1992). This return interval would have interacted with long term wet and dry periods for the area. The edges of these draws would have been impacted by the return intervals and fire frequencies of the surrounding prairie. The more mesic areas of the draws would have only been likely to burn in dry periods.

The community when maintained by fire will have a mosaic of different age classes within a watershed. Browse for undulates will increase. Sheltering cover will remain within 25% of current levels. Canada thistle (*Cirsium arvense*) and associated non-native species related to homesteading will be reduced. The structural complexity will be maintained. The length of the edge habitat will be increased or maintained within 10% of current levels.

Burn Prescription
These draws will be burned in concert with the surrounding prairie. Typically the prairie will be burned between April until green-up, or late July through a season ending event in the fall. Firing methods and unit preparation will be used to exclude fire from some draws. Head, flanking, and backing fire will be used as needed to meet burn objectives.

Fire Prescription Elements	
RH - 25-55%	**Live Fuel Moisture - NA**
Bulb - 30-85 o F	**Average Flame Length - 0.4-1.5 feet**
Average Mid-flame winds - 0-20 mph	**Average Rate of Spread - 0-3 chs/hour**
Fuel loading - 3-5 tons per acre	**1-hour TLFM - 6-14 %**
10-hour TLFM - 8-15 %	**100-hour TLFM - 10-30 %**

Monitoring Variables in Order of Importance
1. Overstory Tree Density
2. Density of specific browse species as directed by the wildlife biologist
3. Total Herbaceous Relative Cover

Prescribed Fire Project Objectives
<u>Immediate Post Burn</u>
1. Reduce total down and dead woody fuel load by 20-60%

<u>One Year Post Burn</u>
1. Increase density of desired woody browse species (*Prunus* spp., *Ribes* spp., *Symphoricarpos occidentalis*) by 30 to 50%

<u>Five Year Post Burn</u>
1. Limit overstory tree mortality to no more than 25%

Fire Monitoring Objectives
1. Install enough plots to be 80% confident that density of overstory trees is within 25% of the true population mean.
2. Install enough plots to be 80% confident that density of targeted browse species is within 25% of the true population mean.
3. Install enough plots to be 80 % confident that the relative cover of herbaceous plants is within 25% of the true population mean

Data Analysis
1. Track density of overstory trees for each postburn read in year 1, 2, and 5.
2. Track density of specific targeted browse species for each postburn read in year 1, 2, and 5.
3. Track relative cover and percent cover of herbaceous plants including native grasses and forbs for each postburn read in year 1,2 and 5.
4. Track specific non-native species of concern for each postburn read in year 1,2, and 5
5. Track Kentucky bluegrass relative cover for each postburn read in year 1, 2, and 5.

Literature Cited

Boldt, C.E., C.W. Uresk, and K.E. Severson. 1978. Riparian Woodlands in Jeopardy on Northern High Plains. In: Johnson, R.R. and J.F. McCormick (eds.) National Symposium on Strategies for Protecting the Management of Floodplain Wetlands and other Riparian Ecosystems. USDA Forest Service General Technical Report WO-12. Atlanta, Georgia.

USDA Soil Conservation Service. 1987. Soil Survey of Jackson County, Northern Part, South Dakota. Washington, D.C. 216 pages plus maps

USDI National Park Service. 2001. Fire monitoring handbook. National Interagency Fire Center, Boise, ID. 288 pp.

Von Loh, J., Cogan, D., Faber-Langendoen, D., Crawford, D., and M.J. Pucherelli. 1999. USGS-NPS Vegetation Mapping Program Badlands National Park, South Dakota (Final Report). Technical memorandum No. 8260-99-03. US Bureau of Reclamation Technical Service Center. Denver, Colorado.

Warner, A.T. 1993. Soil and Hydrological Characterization of Woody and Grassy Draws Badlands National Park, South Dakota. MS Thesis. Colorado State University, Fort Collins. 108 pp.

Wendtland, K. J., and J. L. Dodd. 1992. The fire history of Scotts Bluff National Monument. In: Smith, D. and C. Jacobs (eds.) Twelfth North American Prairie Conference. Cedar Falls, Iowa.

Notes: Brush density of snowberry (*Symphoricarpos* spp.) will be determined by stem count. Brush density for prickly pear (*Opuntia polyacantha*) will be counted by cluster immediately post burn because of increased visibility. Both species are rhizomatous. Please see brush sampling protocol in Fire Monitoring Handbook (USDI NPS 2001) for additional information.

FMH-4 **PLOT PROTOCOLS**

GENERAL PROTOCOLS

		YES	NO		YES	NO
Preburn	Control Plots/Opt		•	Herb Height/Rec	•	
	Herbaceous Density/Opt		•	Belt Transect Width:	1 meter *	
	OP/Origin Buried		•	Abbreviated Tags	•	
	Voucher Specimens/Rec	•		Stakes Installed:	All	
	Stereo Photography/Opt		•	Crown Intercept/Opt		•
	Brush Individuals/Rec	•		Herb. Fuel Load/Opt		•
	Herbaceous Data Collected at: **Q4-Q1**					
	*** see notes section.**					
Burn	Duff Moisture/Rec	•		Flame Zone Depth/Rec	•	
Postburn	Herbaceous Data/Opt: FMH - 17			Herb. Fuel Load/Opt		•
	100 Pt. Burn Severity/Opt		•			

FOREST PLOT PROTOCOLS

		YES	NO		YES	NO
Overstory	Area sampled: 50 x20m	Q1 – Q4		DBH > 10 cm		
	Tree Damage/Rec	•		Crown Position/Rec	•	
	Dead Tree Damage/Opt		•	Dead Crown Position/Opt	•	
Pole-size	Area Sampled: 25 x10m	Q1		2.5 cm ≤ DBH ≤ 10 cm		
	Height/Rec	•		Poles Mapped/Rec	•	
Seedling	Area Sampled: 5 x 10m			Quarters Sampled: Subset of Q1		
	Height/Rec	•		Seedlings Mapped/Opt		•
Fuel Load	Sampling Plane Length (ft.): 6, 6, 12, 50, 50					
	Aerial Fuel Load/Opt		•	Fuel Continuity/Opt		•
Postburn	Char Height/Rec	•		Mortality/Rec	•	

Rec = Recommended; Opt = Optional

FMH-4 **MONITORING TYPE DESCRIPTION SHEET** Park: **BADL**

Monitoring Type Code: BPRUN1D05 **Date Described:** 1/12/00

Monitoring Type Name: Woody Draws--Chokecherry and Plum Shrubland

Prepared by: Supernaugh, Kenner, Childers, Dingman, Thorstenson and Rehman

Physical Description
These draws occur in less steep mesic draws, small perennial drainages, base of sandhills (Von Loh et al*.,* 1999). The vegetation normally occurs on the draw bottoms and lower sideslopes (Warner, 1993). All aspects are acceptable, slopes 0 - 60%, elevation 2,400 to 4,000 feet. Soils are clayey, silty, claypan, and badlands overflow. Soil types are: Interior-Cedarpass-Denby, Interior loam, channeled, Midway silty clay loam, and Orella -Badlands (USDA-SCS, 1987).

Biological Description
This habitat type encompasses several different plant communities as described in Von Loh et al. (1999). Vegetation communities grouped into this monitoring type are based on a Green Ash-Elm Woody Draw and the surrounding communities. Associated edge communities in drier areas are Rocky Mountain Juniper/Little-seed Ricegrass Woodland and Rocky Mountain Juniper Woodland. Shrublands that occur at draw sides and heads include chokecherry, wild plum, western snowberry, and aromatic sumac. Stands typically will have moderate to dense canopies dominated by wild plum (*Prunus americana*) and chokecherry (*P. virginiana*). Other shrubs include snowberry (*Symphoricarpos occidentalis*), wild rose (*Rosa woodsii* and *R. arkansana*), gooseberry (*Ribes missouriense*) and wild black currant (*Ribes americanum*). Trees species associated with these shrublands include Green Ash (*Fraxinus pennsylvanica*), American Elm (*Ulmus americana*), and Rocky Mountain juniper (*Juniperus scopulorum*). Cottonwood (*Populus deltoides*) and peachleaf willow (*Salix amygdaloides*) will be present if there is a spring or seep. The herbaceous component includes; Kentucky bluegrass (*Poa pratensis*), western wheatgrass (*Pascopyrum smithii*), and big bluestem (*Andropogon gerardii*) (Von Loh et al., 1999).

Rejection Criteria
Large outcroppings or barren areas >20% of the plot; areas with anomalous vegetation; edges of the following types that are closer than 50 m to the plot: monitoring type boundaries or transitions; bio-control areas; roads, human-made trails, burn unit boundaries or human created clearings are to be rejected. Because of the linear shape of these communities part of the plot may fall in another monitoring type. Plots should be installed with the long axis of the plot following the long axis of the draw.

Desired Future Condition
Woody draws are believed to be part of the pre-settlement landscape for the area (Boldt et al*.,* 1978). The exact composition of the communities before settlement is unknown. Deciduous trees are reported to be no older than 50 years and juniper no older than 100 (Warner, 1983). The fire return intervals of 15-30 years were estimated for more broken topography at Scotts Bluff National Monument, Nebraska (Wendtland and Dodd, 1992). This return interval would have interacted with long-term wet and dry periods for the area. The edges of these draws

would have been impacted by the return intervals and fire frequencies of the surrounding prairie. The more mesic areas of the draws would have only been likely to burn in dry periods.

The community when maintained by fire will have a mosaic of different age classes within a watershed. Browse for ungulates will increase. Sheltering cover will remain within 25% of current levels. Canada thistle (*Cirsium arvense*) and associated non-native species related to homestead will be reduced. The structural complexity of the community will be maintained. The length of the edge habitat will be increased or maintained within 10% of current levels.

Burn Prescription
These draws will be burned in concert with the surrounding prairie. Typically the prairie will be burned between April until green-up, or late July through a season ending event in the fall. Firing methods and unit preparation will be used to exclude fire from some draws. Head, flanking, and, backing fire will be used as needed to meet burn objectives.

Fire Prescription Elements	
RH – 25-55%	**Live Fuel Moisture – NA**
Bulb - 30-85 o F	**Average Flame Length - 0.4-1.5 feet**
Average Mid-flame winds - 0-20 mph	**Average Rate of Spread - 0-3 chs/hour**
Fuel loading - 3-5 tons per acre	**1-hour TLFM - 6-14 %**
10-hour TLFM - 8-15 %	**100-hour TLFM - 10-30 %**

Monitoring Variables in Order of Importance
1. Density of mature and resprout *Prunus* spp.
2. Density of specific browse species as directed by the wildlife biologist
3. Total herbaceous relative cover

Prescribed Fire Project Objectives
<u>Immediate Post Burn</u>
1. Reduce total down and dead woody fuel load by 20-60%

<u>One Year Post Burn</u>
1. Increase density of desired woody browse species by 30 to 50%

<u>Five Year Post Burn</u>
1. Maintain density of mature woody browse species.

Fire Monitoring Objectives
1. Install enough plots to be 80% confident that the density of *Prunus* spp. is within 25% of the true population mean.
2. Install enough plots to be 80% confident that the density of targeted browse species is within 25% of the true population mean.
3. Install enough plots to be 80% confident that the relative cover of herbaceous plants within 25% of the true population mean.

Data Analysis

1. Track density of specific targeted woody browse species for each postburn read in year 1, 2, and 5 years.
2. Track relative cover and percent cover of herbaceous plants including native grasses and forbs for each postburn read in year 1,2 and 5 years.
3. Track specific non-native species of concern for each postburn read in year 1,2, and 5 years.
4. Track Kentucky bluegrass relative cover for each postburn read in year 1, 2, and 5 years.

Literature Cited

Boldt, C.E., C.W. Uresk, and K.E. Severson. 1978, Riparian Woodlands in Jeopardy on Northern High Plains. In: Johnson, R.R. and J.F. McCormick (eds.) National Symposium on Strategies for Protecting the Management of Floodplain Wetlands and other Riparian Ecosystems. USDA Forest Service General Technical Report WO-12. Atlanta, Georgia.

USDA Soil Conservation Service. 1987. Soil Survey of Jackson County, Northern Part, South Dakota. Washington, D.C. 216 pages plus maps

USDI National Park Service. 2001. Fire monitoring handbook. National Interagency Fire Center, Boise, ID. 288 pp.

Von Loh, J., Cogan, D., Faber-Langendoen, D., Crawford, D., and M.J. Pucherelli. 1999. USGS-NPS Vegetation Mapping Program Badlands National Park, South Dakota (Final Report). Technical memorandum No. 8260-99-03. US Bureau of Reclamation Technical Service Center. Denver, Colorado.

Warner, A.T. 1993. Soil and Hydrological Characterization of Woody and Grassy Draws Badlands National Park, South Dakota. MS Thesis. Colorado State University, Fort Collins. 108 pp.

Wendtland, K. J., and J. L. Dodd. 1992. The fire history of Scotts Bluff National Monument. In: Smith, D. and C. Jacobs (eds.) Twelfth North American Prairie Conference. Cedar Falls, Iowa.

Notes: Brush density of snowberry (*Symphoricarpos* spp.) will be determined by stem count. Brush density for prickly pear (*Opuntia polyacantha*) will be counted by cluster immediately post burn because of increased visibility. Both species are rhizomatous. Please see brush sampling protocol in Fire Monitoring Handbook (USDI NPS 2001) for additional information.

FMH-4 PLOT PROTOCOLS

GENERAL PROTOCOLS		YES	NO		YES	NO
Preburn	Control Plots/Opt		•	Herb Height/Rec	•	
	Herbaceous Density/Opt		•	Belt Transect Width: 2 meters		
	OP/Origin Buried		•	Abbreviated Tags	•	
	Voucher Specimens/Rec	•		Stakes Installed: 0P & 30P; 1A & 1B		
	Stereo Photography/Opt		•	Crown Intercept/Opt		•
	Brush Individuals/Rec	•		Herb. Fuel Load/Opt	•	
	Herbaceous Data Collected at: 0P-30P					
Burn	Duff Moisture/Rec		•	Flame Zone Depth/Rec	•	
Postburn	Herbaceous Data/Opt: Collected.			Herb. Fuel Load/Opt		•
	100 Pt. Burn Severity/Opt		•			

Rec = Recommended; Opt = Optional

FMH-4 **MONITORING TYPE DESCRIPTION SHEET** Park: **BADL**

Monitoring Type Code: GPOPR1D01 **Date Described:** 6/12/97

Monitoring Type Name: Non-native Grass Prairie--Kentucky bluegrass

Prepared by: A. Powers, G. Bradshaw, B. Braudis, B. Bessken, R Runge, B. Adams, G. Kemp, P. Reeberg

Updated by: Supernaugh, Kenner, Childers, Dingman, and Paintner – January, 2000

Physical Description
Many of these areas are associated with disturbances such as roadsides, abandoned farm fields, and areas that were seeded with non-native grasses to 'improve' the range for grazing. Certain areas with high disturbance include next to the park access road and facilities, abandoned agricultural fields along the northern boundary and Sheep Mountain Tables and in seedlings on Cuny and Stronghold Tables. These areas historically supported western wheatgrass mixed prairie (Von Loh et al*.,* 1999). Topography is level to hilly grasslands, badlands crossed by grassy drains, isolated buttes, and lowland terraces. All aspects are represented with slopes from 0 - 45% and elevation 2,400 to 4,000 feet. Soils are clayey, silty, claypan, and badlands overflow. Soil types are: Blackpipe clay loam, Blackpipe-Norrest complex, Blackpipe-Wortman Complex, Cedarpass silty clay loam, Cedarpass-Denby complex, Cedarpass-Interior-Badlands, Interior-Cedarpass-Denby (USDA-SCS, 1987).

Biological Description
Stands typically have moderate herbaceous cover, ranging from 40-90 % and very dense litter over the ground surface. Areas tend to be dominated by one non-native grass species, often planted. These dominant grass could be smooth brome (*Bromus inermis*), crested wheatgrass (*Agropyron cristatum*), or Kentucky bluegrass (*Poa pratensis*). Other non-native species associated with these areas include: Japanese brome (*B. japonicus*), cheatgrass (*B. tectorum*), alfalfa (*Medicago sativa*), yellow sweet clover (*Melilotus officinalis*), common mullein (*Verbascum thapsus).* At the edge and occasionally interspersed are western wheatgrass (*Pascopyrum smithii*), needle and thread (*Stipa comata*), and green needlegrass (*S. viridula*). Very few native forbs or shrubs are seen in this type (Von Loh et al., 1999).

Rejection Criteria
Large outcroppings or barren areas >20% of the plot; areas with anomalous vegetation; edges of the following types that are closer than 50 m to the plot: monitoring type boundaries or transitions; riparian areas or areas dominated by trees; bio-control areas; roads, human-made trails, burn unit boundaries or human created clearings are to be rejected. The areas burned near the roadsides to reduce smooth brome will be monitored with an alternate protocol.

Desired Future Condition
The areas that are currently non-native cool season grasses would have been western wheatgrass historically. Western wheatgrass mixed-grass prairie is believed to be the pre-settlement vegetation for the area but the exact composition of the communities before settlement is unknown. Kuchler (1964) described the potential vegetation for the BADL area as wheatgrass-needlegrass prairie. The fire return intervals reported vary from as short as 5 years in level to gently rolling topography to 15-30 years in more broken topography at Scotts Bluff

National Monument, Nebraska (Wendtland and Dodd, 1992). Most areas of disturbance are flat to rolling and it is believed that the fire return interval in these areas would have been short.

The community when maintained by fire will have reduced amounts of non-native cool season grasses; especially cheatgrass (*Bromus tectorum*), Japanese brome (*B. japonicus*), smooth brome (*B. inermis*), crested wheatgrass (*Agropyron cristatum*), and Kentucky bluegrass (*Poa pratensis*). Repeated spring burning will check the spread of these grasses into native prairie. The number of native grasses and forbs will increase, increasing the biodiversity of these areas. These areas are highly visible because they are often disturbed areas such as roadsides. This provides an opportunity for visitor understanding and education about prescribed fire and non-native species control. The park would like these areas to be returned to mostly native plant communities and eventually have no need for this monitoring type.

Burn Prescription
This prairie will be burned when plant phenology is between green up and heading out. The preferable timing of fires will be when the seed head is in the developmental stage called the 'boot'. Backing and flanking fire will be used to generate relatively long residence times maximize damage to the undesired plants.

Fire Prescription Elements	
RH - 25-55%	**Live Fuel Moisture - NA**
Bulb - 30-85 o F	**Average Flame Length - 0.4-1.5 feet**
Average Mid-flame winds - 0-20 mph	**Average Rate of Spread - 0-3 chs/hour**
Fuel loading - 3-5 tons per acre	**1-hour TLFM - 6-14%**
10-hour TLFM - 8-15%	**100-hour TLFM - 10-30%**

Monitoring Variables in Order of Importance
1. Non-native Grass Relative Cover
2. Relative Cover of Target Species
3. Native Grass Relative Cover

Prescribed Fire Project Objectives
<u>Immediate Post Burn</u>
1. Burn 80-100% of the burnable project area.

<u>One Year Post Burn</u>
1. Reduce relative cover of non-native grasses by at least 30%
2. Increase relative cover of native grasses by at least 10%
3. Increase relative cover of native forbs by at least 10%

<u>Five Year Post Burn</u>
1. Maintain 30% reduction of non-native grass relative cover.
2. Maintain increase of relative cover of native grass and forbs.
3. Limit reduction of native cool-season grasses to less than 20% of the pre-burn level.

Fire Monitoring Objectives

1. Install enough plots to be 80% confident that the relative cover of non-native grasses is within 25% of the true population mean.
2. Install enough plots to be 80% confident that the relative cover of the target non-native grass is within 25% of the true population mean.
3. Install enough plots to be 80% confident that the relative cover of native grasses and forbs is within 25% of the true population mean

Data Analysis

1. Track relative cover of non-native grasses for each postburn read in year 1, 2, and 5.
2. Track relative cover of target grasses for each postburn read in year 1, 2, and 5.
3. Track relative cover and percent cover of native grasses and forbs for each postburn read in year 1,2 and 5.
4. Track relative cover of specific forb or grass species requested by the wildlife biologist for each postburn read in year 1,2, and 5
5. Track relative cover of sweet clover (*Melilotus officinalis*) and/or other non-native forb(s) of concern for each postburn read in year 1, 2, and 5.

Literature Cited

Kuchler, A.W. 1964. Potential natural vegetation of the coterminous Untied States. Am. Geogr. Soc. Spec. Publ. 36 (Manual), New York.

USDA Soil Conservation Service. 1987. Soil Survey of Jackson County, Northern Part, South Dakota. Washington, D.C. 216 pages plus maps

USDI National Park Service. 2001. Fire monitoring handbook. National Interagency Fire Center, Boise, ID. 288 pp.

Von Loh, J., Cogan, D., Faber-Langendoen, D., Crawford, D., and M.J. Pucherelli. 1999. USGS-NPS Vegetation Mapping Program Badlands National Park, South Dakota (Final Report). Technical memorandum No. 8260-99-03. US Bureau of Reclamation Technical Service Center. Denver, Colorado.

Wendtland, K. J., and J. L. Dodd. 1992. The fire history of Scotts Bluff National Monument. In: Smith, D. and C. Jacobs (eds.) Twelfth North American Prairie Conference. Cedar Falls, Iowa.

Notes: Brush density of snowberry (*Symphoricarpos* spp.) will be determined by stem count. Brush density for prickly pear (*Opuntia polyacantha*) will be counted by cluster immediately post burn because of increased visibility. Both species are rhizomatous. Please see brush sampling protocol in Fire Monitoring Handbook (USDI NPS 2001) for additional information.

FMH-4 PLOT PROTOCOLS

GENERAL PROTOCOLS		YES	NO		YES	NO
Preburn	Control Plots/Opt		•	Herb Height/Rec	•	
	Herbaceous Density/Opt		•	Belt Transect Width: 5 m		
	OP/Origin Buried		•	Abbreviated Tags	•	
	Voucher Specimens/Rec	•		Stakes Installed: 0P & 30P		
	Stereo Photography/Opt		•	Crown Intercept/Opt		•
	Brush Individuals/Rec	•		Herb. Fuel Load/Opt	•	
	Herbaceous Data Collected at: 0P-30P					
Burn	Duff Moisture/Rec	•		Flame Zone Depth/Rec	•	
Postburn	Herbaceous Data/Opt: Not collected.			Herb. Fuel Load/Opt		•
	100 Pt. Burn Severity/Opt		•			

Rec = Recommended; Opt = Optional

FMH-4 **MONITORING TYPE DESCRIPTION SHEET** Park: **BADL**

Monitoring Type Code: GBRJA1D01 **Date Described:** 6/12/97

Monitoring Type Name: Non-native grass prairie--Japanese brome

Prepared by: A. Powers, G. Bradshaw, B. Braudis, B. Bessken, R Runge, B. Adams, G. Kemp, P. Reeberg

Updated by: Supernaugh, Kenner, Childers, Dingman, and Paintner – January, 1999

Physical Description
Many of these areas are associated with disturbances such as roadsides, abandoned farm fields, and areas that were seeded with non-native grasses to 'improve' the range for grazing. Areas especially noted are adjacent to the park access road and facilities, and abandoned agricultural fields along the northern boundary (Von Loh et al., 1999). Topography is level to hilly grasslands, badlands crossed by grassy drains, isolated buttes, and lowland terraces. All aspects are acceptable, slopes 0 - 45%, elevation 2,400 to 4,000 feet. Soils are clayey, silty, claypan, and badlands overflow. Soil types are: Blackpipe clay loam, Blackpipe-Norrest complex, Blackpipe-Wortman Complex, Cedarpass silty clay loam, Cedarpass-Denby complex, Cedarpass-Interior-Badlands, Interior-Cedarpass-Denby (USDA-SCS, 1987).

Biological Description
A blend of tall-grass and short-grass prairies, typically dominated by *Bromus* spp., grasses include: Japanese brome (*B. japonicus*), downy brome (*B. tectorum*), western wheatgrass (*Pascopyrum smithii*), needle and thread (*Stipa comata*), and green needlegrass (*Stipa viridula*). Other species include: blue grama (*Bouteloua gracilis*), sideoats grama (*B. curtipendula*), little bluestem (*Andropogon scoparius*), and big bluestem (*A. gerardii*). Shrubs include: *Opuntia polyacantha* and *Rhus aromatica*. Forbs include: *Artemisia frigida, Artemisia cana,* heath aster (*Aster ericoides)*, yarrow (*Achillea millefolium*), and Missouri goldenrod (*Solidago missouriensis*).

Rejection Criteria
Large outcroppings or barren areas >20% of the plot; areas with anomalous vegetation; monitoring type boundaries; riparian areas or areas dominated by trees; bio-control areas; areas within 20 meters of roads, man-made trails, or human created clearings are to be rejected.

Desired Future Condition
The areas that are currently non-native cool season grasses would have been western wheatgrass historically. Western wheatgrass mixed-grass prairie is believed to be the pre-settlement vegetation for the area but the exact composition of the communities before settlement is unknown. Kuchler (1964) described the potential vegetation for the BADL area as wheatgrass-needlegrass prairie. The fire return intervals reported vary from as short as 5 years in level to gently rolling topography to 15-30 years in more broken topography at Scotts Bluff National Monument, Nebraska (Wendtland and Dodd, 1992). Most areas of disturbance are flat to rolling and it is believed that the fire return interval in these areas would have been short.

The community when maintained by fire will have reduced amounts of non-native cool season grasses; especially cheatgrass (*Bromus tectorum*), Japanese brome (*B. japonicus*), smooth brome (*B. inermis*), crested wheatgrass (*Agropyron cristatum*), and Kentucky bluegrass (*Poa* *pratensis*). Repeated spring burning will check the spread of these grasses into native prairie. The number of native grasses and forbs will increase, increasing the biodiversity of these areas. These areas are highly visible because they are often disturbed areas such as roadsides. This provides an opportunity for visitor understanding and education about prescribed fire and non-native species control. The park would like these areas to be returned to mostly native plant communities and eventually have no need for this monitoring type.

Burn Prescription
This prairie will be burned between April until green-up, or Labor Day to the end of September. Backing and flanking fires will be used as needed to meet burn objectives.

Fire Prescription Elements	
RH - 25-55%	**Live Fuel Moisture - NA**
Bulb - 30-85 o F	**Average Flame Length - 0.4-1.5 feet**
Average Mid-flame winds - 0-20 mph	**Average Rate of Spread - 0-3 chs/hour**
Fuel loading - 3-5 tons per acre	**1-hour TLFM - 6-14 %**
10-hour TLFM - 8-15 %	**100-hour TLFM - 10-30 %**

Monitoring Variables in Order of Importance
1. Non-native Grass Relative Cover
2. Relative Cover of Target Species
3. Native Grass Relative Cover

Prescribed Fire Project Objectives
<u>Immediate Post Burn</u>
1. Burn 80-100% of the burnable project area.

<u>One Year Post Burn</u>
1. Reduce relative cover of non-native grasses by at least 30%
2. Increase relative cover of native grasses by at least 10%
3. Increase relative cover of native forbs by at least 10%

<u>Five Year Post Burn</u>
1. Maintain 30% reduction of non-native grass relative cover
2. Maintain increase of relative cover of native grass and forbs
3. Limit reduction of native cool-season grasses to less than 20% of the pre-burn level

Fire Monitoring Objectives
1. Install enough plots to be 80% confident that the relative cover of non-native grasses is within 25% of the true population mean.
2. Install enough plots to be 80% confident that the relative cover of the target non-native grass is within 25% of the true population mean.
3. Install enough plots to be 80% confident that the relative cover of native grasses and forbs is within 25% of the true population mean

Data Analysis
1. Track relative cover of non-native grasses for each postburn read in year 1, 2, and 5.
2. Track relative cover of specific target grass for each postburn read in year 1, 2, and 5.
3. Track relative cover and percent cover of native grasses and forbs for each postburn read in year 1,2 and 5.

4. Track relative cover of specific forb or grass species requested by the wildlife biologist for each postburn read in year 1,2, and 5
5. Track relative cover of sweet clover (*Melilotus officinalis*) and/or other non-native forb(s) of concern for each postburn read in year 1, 2, and 5.

Literature Cited

Kuchler, A.W. 1964. Potential natural vegetation of the coterminous Untied States. Am. Geogr. Soc. Spec. Publ. 36 (Manual), New York.

USDA Soil Conservation Service. 1987. Soil Survey of Jackson County, Northern Part, South Dakota. Washington, D.C. 216 pages plus maps

USDI National Park Service. 2001. Fire monitoring handbook. National Interagency Fire Center, Boise, ID. 288 pp.

Von Loh, J., Cogan, D., Faber-Langendoen, D., Crawford, D., and M.J. Pucherelli. 1999. USGS-NPS Vegetation Mapping Program Badlands National Park, South Dakota (Final Report). Technical memorandum No. 8260-99-03. US Bureau of Reclamation Technical Service Center. Denver, Colorado.

Wendtland, K. J., and J. L. Dodd. 1992. The fire history of Scotts Bluff National Monument. In: Smith, D. and C. Jacobs (eds.) Twelfth North American Prairie Conference. Cedar Falls, Iowa.

Notes: Brush density of snowberry (*Symphoricarpos* spp.) will be determined by stem count. Brush density of prickly pear (*Opuntia polyacantha*) will be counted by cluster immediately post-burn because of increased visibility. Both species are rhizomatous. Please see brush sampling protocol in Fire Monitoring Handbook (USDI NPS 2001) for additional information.

FMH-4 **PLOT PROTOCOLS**

GENERAL PROTOCOLS		YES	NO		YES	NO
Preburn	Control Plots/Opt		•	Herb Height/Rec	•	
	Herbaceous Density/Opt		•	Belt Transect Width: 5 m		
	OP/Origin Buried		•	Abbreviated Tags	•	
	Voucher Specimens/Rec	•		Stakes Installed: 0P & 30P		
	Stereo Photography/Opt		•	Crown Intercept/Opt		•
	Brush Individuals/Rec	•		Herb. Fuel Load/Opt	•	
	Herbaceous Data Collected at: 0P-30P					
Burn	Duff Moisture/Rec		•	Flame Zone Depth/Rec	•	
Postburn	Herbaceous Data/Opt: Not collected.			Herb. Fuel Load/Opt		•
	100 Pt. Burn Severity/Opt		•			

Rec = Recommended; Opt = Optional

APPENDIX (g): PROTOCOLS FOR FIRE EFFECTS MONITORS (FEMO) FOR PRESRIBED FIRE: IMMEDIATE PRE-BURN, DURING BURN, AND IMMEDIATE POST-BURN

As stated in the BADL Fire Monitoring Plan, all fires within the Park will be monitored to insure their compliance with written policies and prescriptions. Badlands NP has adopted the NPS Fire Monitoring Handbook (2001) as a guide for fire effects monitoring. The following Table illustrates the Levels of Monitoring that will be implemented.

Level 1 – Reconnaissance	Fire Cause, location, size, fuel and vegetation types, relative fire activity, potential for spread, current and forecasted weather, resource or safety threats and constraints, and smoke volume and movement
Level 2 – Fire Conditions	Fire monitoring period, ambient conditions – topographic and fire weather, fuel model, fire characteristic, and smoke characteristic
Level 3 – Immediate Post fire Effects	Fuel reduction, vegetative change or other objective dependent variables with in 1 to 5 years after a burn
Level 4 – Long-term Change	Continued monitoring of Level 3 variables to measure trends and change over time

Wildland fires that are suppressed will be monitored at levels 1 and 2 with observations entered into the park's monitoring database. In the event that long-term fire effects plots are burned in a wildland fire, they will be read by the NGPA Fire Monitoring Team according to the schedule of plot rereads following a burn treatment. Level 1 and 2 monitoring observations will be filed with the final fire package and a copy placed with the records for the Fire Management Unit that was burned.

Wildland Fires for Resource Benefit will be monitored as described in the NPS Fire Monitoring Handbook (Level 2 monitoring) will be completed daily on the fire. During periods of forecasted growth greater than 100 acres per day, on-site observations of dry bulb, relative humidity, wind speed, wind direction, and cloud cover will be made one hour before activity begins to two hours after activity ceases, or minimally from one hour before sunrise to two hours after sunset. Fire characteristics as described in the NPS Fire Monitoring Handbook Level 2 will be collected on-site hourly when conditions and monitor safety permit. Smoke characteristics will be monitored hourly any time a forecast wind direction places the smoke plume toward a community and/or highway.

The plots described in the NPS Fire Monitoring Handbook are being used to examine variables at levels 3 and 4. Prescribed fires will meet at least the Level 1 and 2 recommended standards. If there are FMH plots in a unit, information on Level 3 and 4 Variables will be collected.

LEVEL 1 VARIABLES

Reconnaissance monitoring, Level 1, provides a basic overview of the fire event. The following variables will be collected on all fires.

- Fire cause (origin), location and size
- Fuels and vegetation type

- Relative fire activity
- Potential for further spread
- Current and forecasted weather
- Resource or safety threats and constraints
- Smoke volume and movement

Specific information on the collection of these variables can be found in the NPS Fire Monitoring Handbook (2001) or the RX-91 – Monitoring prescribed and wildland fire text.

LEVEL 2 VARIABLES

Fire conditions monitoring, Level 2, provides information of fire weather, fire behavior and resource values at risk. The following variables will be collected and summarized in a monitoring report on all wildland fires for resource benefit and all prescribed fires. Data forms for weather and fire behavior observations are found in the National Park Service National Fire Monitoring Handbook Appendix A.

<u>Fire Monitoring Period</u>
- a) fire number and name
- b) observations date and time
- c) monitor's name

<u>Ambient Conditions</u>
- a) Topographic variables
- b) Slope (%)
- c) Aspect

<u>Fire Weather variables</u>
- a) Dry bulb temperature
- b) Relative humidity
- c) Wind speed
- d) Wind direction
- e) Fuel shading and/or cloud cover
- f) Time-lag fuel moisture
- g) Live fuel moisture
- h) Drought index

<u>Soil moisture</u>
<u>Fuel Model</u>
<u>Fire Characteristics</u>
- a) Linear rate of spread
- b) Perimeter or area growth
- c) Flame length
- d) Fire spread directions

<u>Smoke Characteristics (based on state and local requirements)</u>

TIMING OF MONITORING

All plots are currently monitored at peak diversity for the native forbs approximately halfway between the peak in cool and warm season grasses. With the addition of nested frequency monitoring the vegetative data may need to be read twice a year because of the two different peaks. This will need to be examined after pilot sampling. All plots are currently being read pre-burn, immediately post-burn, and 1,2,5,10, and 20 years post-burn. The 1-Year read for plots that have burned in the spring is in the first growing season following the burn, and the 2-year read occurs in the following year.

PRE-BURN SAMPLING

Pre-burn sampling will be done during peak phenology according to National Fire Monitoring Handbook standards. Plots need to be installed in the summer before spring burns and at peak the summer before fall burns. All plots that have not burned within 2 years of installation will not be reread until that unit is again scheduled to burn. These plots can also be considered for control plots depending on long term burn planning.

IMMEDIATE PRE-BURN SAMPLING

Fuel loading samples will be taken adjacent to the long term monitoring plots within a week of the burn. Samples of a known area (usually 1 ft^2) are clipped to determine biomass or fuel loading at all plots. All samples taken were dried at 60 degrees Celsius for 24 hours then weighed to determine grams per square foot. Multiplying this by 0.048 gives a measure of tons of biomass per acre. This information will be shared with the burn boss to assist in calculating expected fire behavior.

IMMEDIATE POST-BURN SAMPLING

Plots burned in prescribed or wildfires will have an immediate postburn severity measurement as soon as it is safe to enter the area. Grassland plots are typically read within a week of the fire. Burn severity will be measured according to FMH standards. Forest plots will be read between 2 and 6 weeks post burn to assess scorch heights on trees. A monitoring report will be completed for every prescribed fire which includes staffing, observed weather, fire behavior, ignition patterns, smoke monitoring, and fire effects observations. An example monitoring report is attached at the end of the protocols section.

POST-BURN SAMPLING

Post-burn sampling will be done immediately post-burn and 1, 2, 5,10, and 20 years after the burn. Plots that burn in the spring will be read at peak phenology that summer as 1-year post burn reads, and then at the regular 2, 5, 10, and 20 year schedule. Fall burns will be read the following summer as 1 year post-burn reads. If a unit is scheduled to be burned for a second or third time between reads, an addition pre-burn read will be added. For example, the Pinnacles unit was burned in the spring of 2000. The post-burn reads would be an immediate post-burn read, a 1-year post-burn read that summer, 2 year read, and 5 year read. The unit is then scheduled to burn again in 2008. A second pre-burn read should be added the year before the burn is scheduled.

LEVEL 3 and 4 VARIABLES

Level 3 and 4 Variables of importance are outlined in the Monitoring Type descriptions of each vegetation type. Information will be collected according to FMH protocols for each of the variables of importance. The postburn measurement schedule in the preceding paragraph outlines when these variables will be measured. Analysis of the results of the monitoring will be done each year with results of change over time, and observed trends presented to Park Management.

EXAMPLE MONITORING REPORT:

BADLANDS NATIONAL PARK
Horse Pasture Prescribed Fire
Fire Monitoring Report

Prepared by Kelly Mathis
Northern Great Plains Fire Monitoring Team

INTRODUCTION

The Horse Pasture burn unit is located south of the Badlands Loop Road (Highway 240) and southeast of the intersection of Highway 377 and Highway 240 in the Cedar Pass District of BADL. The unit consists of approximately 660 acres of mixed-grass prairie (predominantly native species) and badlands formations. Ignition occurred between the hours of 1230 and 1630 hours on 17 Aug 1999 and 0900 and 1800 on 18 Aug 1999. The primary goals for the burn were to increase the vegetative age class diversity in the park and to increase the vigor of the native species through and infusion of nutrients following the burn. The specific objectives contained in the burn plan were to:

- reduce non-native grass species by 10-30%
- increase the native perennial grass cover by 10-30%
- reduce blackthorn honey locust and Russian olive trees and shrubs by 20-40%
- burn 60 to 75% of the project area.

The status of burn objectives can be found in <u>Conclusions</u> table 3.

Staff for the Horse Pasture burn included Burn Boss Mike Beasley, Ignition Specialist Bob Kobza, Holding Specialist Shaun Larson, Lead Prescribed Fire Monitor Andy Thorstenson, Fire Monitor Kelly Mathis, Fire Monitor trainee Gayla Gabriel, and Safety Officer Bill Gabbert. Fire Personnel in the ignition and holding assignments were from Badlands National Park, Black Hills Fire Use Module, Northern Great Plains Fire Monitors, and Wind Cave National Park.

SUMMARY OF EVENTS

Badlands staff did the preparation for the burn which included a mow line along the south and east boundaries of the burn. Black lining occurred along the service road on the west perimeter and near the shooting range on the first day of ignition.

Burn overhead conducted a briefing for personnel on the morning of the burn. A National Weather Service spot forecast and on-site weather observations were obtained to assess compliance with prescription parameters. These are detailed in the section that follows.

WEATHER OBSERVATIONS

Monitoring of weather conditions on the Horse Pasture Burn began at 1000 hours and monitored every half-hour until ignition ceased after 1700 hours. Observations were communicated to all burn personnel. Maximum temperatures occurred about 1300 hours. The minimum relative humidity was recorded at 1700 hours.

Winds started the day light and variable from the north-northwest and continuing variable with a north component throughout the day. The strongest winds were recorded about 1435 hours at 7-9 mph with gusts of 13 mph. Weather conditions are summarized in Table 1. Figure 1 also shows status of temperature, relative humidity, and fine dead fuel moisture throughout the day.

Table 1 Weather Conditions

Condition	Prescription	Predicted	Observed
Temperature (F)	35-90	Hi 80's	63-86
Relative Humidity	20-60%	23%	27-61%
Wind Speed (mph)	2-10mph	5-10	1-9
Wind Direction	Any	variable N	variable N, NW
1-hr Fuel Moisture	4-10%	NA	5-12%

IGNITION PATTERN

Blackline ignition on 17 Aug began at approximately 1230 hours at the shooting range and proceeded along the service road on the west boundary. Ignition of the main unit began the next day at approximately 0900 at the NE corner of the burn and continued south to the SE corner with mainly flanking and backing fire. Ignition then proceeded west toward the shooting range, again with predominantly backing fire. Once a solid blackline was completed strips were run from the NW corner near the housing area to the east tying in with the backing fire. Firing was completed about 1730 hours. See attached map of ignition and fire growth (Attachment 1).

FIRE BEHAVIOR OBSERVATIONS

During the Horse Pasture burn, fire activity was monitored in various vegetative types, in all aspects, and on varying slopes. Fire direction, rate of spread, flame zone depths, and flame lengths were measured on the long term fire effects plots and as the fire moved through the burn unit. Monitoring took place throughout the day in order to assess changes in fire behavior.

The first fire behavior observations were taken during ignition on the east side. Fire was mostly backing and flanking through fire effects plots, so there are very few head fire observations. Observations, locations, and fuel types are detailed in Table 2.

Table 2 **Fire Behavior Observations**

FIRE TYPE	FUEL MODEL	LOCATION / TIME	RATE OF SPREAD (CH/HR)	FLAME LENGTH	FLAME ZONE DEPTH	COMMENTS
Head	1	NE corner/1030	60	5-7’	6-8”	
	1	GAGSM1D0 1-14 /1400	30	4-6’	6”	Kentucky bluegrass, western wheatgrass
Flanking	1	GAGSM1D0 1-06 /1035	12	3-6’	3’	Snowberry, Japanese brome
	1	GASM1D01-14/1300	5	2-2.5’	2-3’	western wheatgrass
	1	GAGSM1D0 1-06 /1400	5	2-4’	18-24”	Kentucky bluegrass, western wheatgrass
Backing	1	NE corner/1030	2	8-12”	6-8”	good consumption
	1	SE corner/1100	1.5	9”	7”	
	1	S line/1220	3	8-15”	6-12”	2’FL in dead clover
	1	GAGSM1D0 1-14 /1249	5	5-6”	5”	Canadian thistle, western wheatgrass
	1	GAGSM1D0 1-14 /1300	2.5	2’	15”	Kentucky bluegrass, western wheatgrass
	1	GAGSM1D0 1-06 /1412	3	3’	15”	

FUEL LOADING AND FUEL MOISTURE MEASUREMENTS

Fuel loading samples were taken adjacent to the long term monitoring plots a week before the burn. Eight samples of a known area were clipped to determine biomass or fuel loading at all plots. All samples taken were weighed and then dried at 60 degrees Celsius for 24 hours. The average pre-burn fuel loading was 4.06 tons/acre and varied from 2.65 to 5.33

tons/ acre. Fuel loading was high due to a very wet growing season and a thick thatch layer. Fuel loading post burn showed 0.77 tons/acre or an 82% reduction in biomass.

SMOKE MONITORING

North and Northwest winds caused smoke to drift over the line during ignition along the east and south boundaries. Visibility varied between 10 and 100m near the active ignition. Fireline visibility improved within ½ hr behind ignition. Smoke rose quickly off the fireline and mixing height was over 2,000' at the end of ignition. There were no roads or heavily populated areas affected during the burn, although one firefighter was treated for heat/smoke related illness.

FIRE EFFECTS OBSERVATION

Two long-term fire monitoring plots are located within the Horse Pasture unit and both were burned. These plots were read immediately postburn to determine burn severity and will be read 1, 2, 5, and 10 years after the fire to determine the vegetative effects of this prescribed burn. The Fire Monitoring Handbook has levels of fire severity that describe the intensity which material burned. Separate readings are taken for substrate (litter and soil) and vegetation to determine severity. The average severity for the substrate of both plots was lightly to moderately burned. The residence time of the fire allowed for partial consumption of the thatch layer leaving mostly black ash and charred dead stems. The vegetation burn severity of both plots showed the vegetation being moderately consumed. High fuel loading due to a heavy thatch layer caused the fire to burn intensely. The vegetation was mostly consumed leaving stems of shrubs and low stubs of grass behind.

CONCLUSIONS

Since it is the long term health of the ecosystem that is the focus of the prescribed burning program, may criteria need to be assessed. Some objectives are immediately measurable while others need to be viewed over the course of several years before results can be determined. The objective to burn 60-75% of the project area was met with fire blackening close to 80% of the unit. The reduction of non-native grass species and increase in native grasses will not be able to be assessed until new growth occurs next spring and in successive years. The goal to reduce blackthorn honey locust and Russian olive trees and shrubs is not valid, as there are none of these species present in the burn unit. With a long-term fire monitoring program in place, quantifiable assessment of prescribed fire goals can be made. A summary of results is shown in table 3.

Table 3	
Objective	**Results**
1. Reduce non-native grass species by 10-30%	Will be measured in 1,2,5,10 yr post rereads of FMH Plots
2. Increase the native perennial grass cover by 10-30%	Will be measured in 1,2,5,10 yr post rereads of FMH Plots
3. Burn 60 to 75% of the project area.	Achieved
4. Reduce blackthorn honey locust and Russian olive trees and shrubs by 20-40%	Not applicable

APPENDIX (h): PROTOCOL FOR ROADSIDE SMOOTH BROME PROJECT

Project: Roadside Burning for Control of Smooth Brome, a cooperative project for prairie restoration

Designed by: Kara J. Paintner and Sandee Dingman

Updated by: Cody L. Wienk and Andy Thorstenson (7/26/01)

Project Rationale
Smooth brome (*Bromus inermis* Leyss.) is a non-native cool season grass. Brought in to the Pacific Northwest in the 1880s (Archer and Branch, 1953), it has been planted in roadsides across the United States. Its spread into native prairies is a concern for managers across the northern Great Plains and tall grass prairies (Willson, 1992). Prescribed burning has had some success at reducing smooth brome in native prairie (Gates et al., 1982; Old, 1969). Willson (1992) burned the grass at different growth stages to determine the best phenological timing for reduction. He found that burning during tiller elongation significantly reduced fall tillering. This study and others (Becker, 1989) showed that burning too early has no effect. Willson quantified that elongated tillers have more than 5 leaves while unelongated have less than five. Other studies have shown that rainfall after the burn has a significant effect on the success of control (Willson and Stubbendieck, 1996).

Smooth brome was probably planted on the Loop Road at BADL around the 1950's, when the park roads were initially being surfaced. Spring prescribed fire will target these roadsides in three stages. Phase 1 is located between Bigfoot Road and Quinn Road (6 miles-FY00). Phase 2 is located between Quinn Road and the Pinnacles Entrance and is partially treated within the Pinnacles Prescribed Fire project (9 miles-FY00). Phase 3 is located between Bigfoot Road and the Northeast Entrance (13 miles-FY02). The area will be monitored to track brome coverage area and the composition of the brome strip and adjacent native prairie. During Phase 1 small plots will be seeded with native grasses to determine if seeding can help speed the recovery of these areas. All monitoring methods are described below. Areas may be reburned to maintain brome reduction either the following spring or two years later based on fuel availability and weather conditions.

Desired Future Conditions
The park resource management staff and superintendent put together a desired future conditions statement for the areas of the park that are currently non-native grass as part of the long term fire monitoring done at the park.

At this time a literature search has been initiated to determine the desired future conditions for non-native grass prairie at BADL, but is not complete. The areas now dominated by non-native cool season grasses would have been western wheatgrass previously. Western wheatgrass mixed-grass prairie is believed to be the pre-settlement vegetation for the area but the exact composition of the communities before settlement is unknown. Kuchler (1964) described the potential vegetation for the BADL area as wheatgrass-needlegrass prairie. The fire return intervals reported vary from as short as 5 years in level to gently rolling topography to 15-30 years in more broken topography at Scotts Bluff National Monument, Nebraska (Wendtland and Dodd, 1992). Most areas of disturbance are flat to rolling it is believed that the fire return interval in these areas would have been short.

The community when maintained by fire will have reduced amounts of non-native cool season grasses; especially cheatgrass (*Bromus tectorum*), Japanese brome *(B. japonicus*), smooth brome (*B. inermis*), crested wheatgrass (*Agropyron cristatum*), and Kentucky bluegrass (*Poa pratensis*). Repeated spring burning will check the spread of these grasses into native prairie. The number of native grasses and forbs will increase, increasing the biodiversity of these areas. The burns are highly visible due to the areas that are disturbed like roadsides. This provides an opportunity for visitor understanding and education about prescribed fire and non-native species control. The park would like these areas to be returned to mostly native plant communities and eventually have no need for this monitoring type.

Prescription and Burn Timing
Backing fire will be used for the longest residence time to damage the sensitive growing points. The burn will be timed to tiller elongation using the methods from Willson (1992). At least half of the smooth brome will have more than 5 green leaves per tiller before burning starts. The following prescription describes fire behavior as either a backing fire under the coolest conditions or a flanking fire in the windiest and driest conditions specified in the environmental prescription. This prescription was developed utilizing the Fire Behavior Prediction System developed by Rothermel (1972). The BEHAVE software package was used to apply this model mathematically to user provided inputs describing fuel and environmental conditions.

INPUTS	
Fuel Model and Vegetation	1 - Perennial Grasses, Western Grasses
Air Temperature	35-90
Relative Humidity	20-60
Mid-flame Wind Speed	2-10
Wind Direction	Any (roadside strips will always be lit as a backing fire to maximize damage to non-natives)
1-Hr. fuel moisture	4-11
OUTPUTS	
Rate of spread (m/min)	0.8-17
Heat/unit area (BTU/sq.ft.)	35-96
Fireline Intensity (BTU/ft/sec)	1-30
Flame Length (ft)	0.3-2.1

Monitoring Methods

1) Brome/native prairie interface: The interface between the brome and native prairie will be recorded every other year using a global positioning system (GPS). Spots of brome outside the interface will be georeferenced as points and the radius of each spot will be estimated to determine the spread of brome outside the general front.

2) Brome cover: Transects were installed in spring 2000 across the burn area to determine brome and native prairie composition. Transects were installed at mileposts (north side) and half way between mileposts (south side). These transects will be modified slightly for continued monitoring. Ten transects (5 north and 5 south of the road) will be sampled in 2002. Each transect will be 12 meters long. When possible the existing transects will be used. In this case, the rebar that marked the brome/native interface will become the END (11 m) of the transect. The START (0 m) rebar will be placed toward the road so that the transect is perpendicular to the road. The END rebar will continue to mark the original location of the brome/native interface.

   If the distance between the original rebar and the road is too small (< 11 m) there are three options: 1) move 50 m east and install transect, 2) move 50 m west and install transect, or 3) relocate to next milepost or half-mile beyond last transect. Try to install the transect so that the entire transect is between the road and the brome/native interface so that END is near the brome/native interface. Install one rebar for START and one for END. Transects should run perpendicular to the road. Record azimuth of transect from START to END for all the transects. Distance from START to brome/native interface should be measured if the brome/native interface is distinct. This measurement should be taken directly on the same line as the transect.

   Vegetation cover, litter, and bare ground will be sampled with a 0.1 m^2 Daubenmire frame (Daubenmire 1959). Each frame is 0.2-m X 0.5-m. Ten frames will be read on the right side (looking from START to END) of each transect, starting at 1.0 to 1.2 m and ending at 10.0 to 10.2 m on the transect. Six cover classes will be used: 1 (0-5%), 2 (6-25%), 3 (26-50%), 4 (51-75%), 5 (76-95%), and 6 (96-100%). Vegetation cover can equal greater than 100%, while litter and bare ground should equal 100% cover. Transects will be read at peak biomass, approximately mid-July.

3. Native seeding: Portions of the area will be seeded with native grass seeds in conjunction with treatments of prescribed fire. A ‘standard’ seed mix for Badlands will be seeded at a rate of 5 pounds of pure live seed (PLS) per acre. The seed mix consists of 40% PLS western wheatgrass, 20%PLS blue grama (*Bouteloua gracilis*), 20% PLS buffalograss (*Buchloe dactyloides*) and 20% PLS green needlegrass (*Stipa viridula*). Viability of the seed will be tested before it is used. Areas receiving the seeding treatment will be monitored with same methods as described above.

Sampling Schedule
Vegetation transects will be read at peak biomass, about mid July. Transects installed in Phase 2 or 3 will be installed during this same time period for future burning. Transects will be re-read at 1,2,3, and 5 years post burn. If areas burn more than once, the schedule will start over.

Data Analysis
All data will be entered into an Excel spreadsheet and analyzed in the fall of each year. The GPS data will be assessed to determine if large-scale shifts can be seen. The transect data will be analyzed to determine changes in cover of native and nonnative species. The weather data will be used to correlate relative wet and dry periods with both the burn and subsequent growing seasons. The Northern Great Plains fire ecologist will oversee all data analysis.

Future Management Direction
Phase 1 areas will be burned either the next spring or one year later to maintain potential brome reduction. Seeding will be examined to determine if recovery time is faster and worth the increased cost per acre. Sampling will be at 1, 2, 3 and 5 years postburn to determine both short and long term effectiveness.

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APPENDIX (i): NON FMH-DATA FORMS

Badlands NP – Roadside Smooth Brome Project

Plot ID: ________________ **Date:** ________________ **Recorder:** _______________
Location: ________________ **Azimuth:** ________________
UTM Coord.: ____ **Datum:** ___________
Treatment Status: __________________________

For each 0.2 x 0.5-m Daubenmire frame record cover class for each class and species present
Cover classes: **1**=0-5% **2**=6-25% **3**=26-50% **4**=51-75% **5**=76-95% **6**=96-100%
Frames read every meter, starting at 1 m, on the right side of the transect
TOCO = total cover, TOGR = total grass, TOFO = total forbs, TOSH = total shrubs

Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Notes**
TOCO											
TOGR											
TOFO											
TOSH											
LITT											
BARE											
BRIN											
AGSM											
BOGR											
STVI											
BUDA											

Notes or other observations:
For species codes see FMH-6