Ecological site R105XY020WI
Sandstone Colluvium Bluff Prairie

Accessed: 07/17/2024

General information

Approved. An approved ecological site description has undergone quality control and quality assurance review. It contains a working state and transition model, enough information to identify the ecological site, and full documentation for all ecosystem states contained in the state and transition model.

Figure 1. Mapped extent

Areas shown in blue indicate the maximum mapped extent of this ecological site. Other ecological sites likely occur within the highlighted areas. It is also possible for this ecological site to occur outside of highlighted areas if detailed soil survey has not been completed or recently updated.

MLRA notes

Major Land Resource Area (MLRA): 105X–Upper Mississippi River Bedrock Controlled Uplands and Valleys

The Northern Mississippi Valley Loess Hills includes parts of four US states, including Wisconsin, Iowa, Minnesota, and Illinois (Figure 1). The region is often referred to informally as the “Driftless Area”, because it was not glaciated during the most recent, Wisconsin aged glacial period, and some areas have never been glaciated. Another commonly used name is the “Paleozoic Plateau”, because the region is a deeply dissected, ancient plateau, composed of bedrock formations primarily from the Paleozoic Era. These bedrock layers are mostly sedimentary dolomites and sandstones from the Ordovician and Cambrian Periods, along with some shale. The area consists mostly of gently sloping to rolling summits with steeper valley walls that join small to very large floodplains. Wisconsin age loess covers much of the area, adding to the fertility and productivity of many soils. Valley bottoms are deeply filled by glacially derived outwash, or more recent erosional sediments. Steep valley sides are covered by colluvium (i.e., slope alluvium, or hillslope sediments) and can have prominent cliffs. The climate is warm in the summer and very cold in the winter. Two-thirds or more of the precipitation falls during the growing season. The soil temperature regime is mesic (i.e., mean annual soil temperature between 46 and 59°F) and the soil moisture regime is udic, implying a humid climate with well distributed rainfall. Historic vegetation was a mosaic of rich hardwood forests with fire dependent oak woodlands, savannas, and prairies prior to European settlement.

Classification relationships

Major Land Resource Area (MLRA): Northern Mississippi Valley Loess Hills (105)

USFS Subregions: North-Central U.S. Driftless and Escarpment Section (222L) ; Mississippi-Wisconsin River Ravines (222Lc), Kickapoo-Wisconsin River Ravines (222Ld), and Western Paleozoic Plateau (222Lf) Subsections

Ecological site concept

The central concept of the Sandstone Colluvium Bluff Prairie (SCBP) ecological site is dry prairie natural communities in a landscape that typically supports forest ecosystems, occurring on bluffs and valley sides in deeply dissected terrain. Soils are formed in sandy-skeletal colluvium, and are derived from the Jordan bedrock Formation. Slope, aspect, and hillslope position are the main environmental factors that affect the composition and structure of the vegetation on these prairies (Kraszewski and Waller, 2008; Weaver, 1968).

Vegetation generally is thin, with noticeable bio-crusts and bare soil present. SCBP consists exclusively of dry prairie species that tolerate droughty, exposed conditions (Curtis, 1959). Grasses dominate these sites, and consist of primarily short and mid height grasses, and a small proportion of tall grasses, with a percent cover ratio of 47-47-

6, respectively. Short grasses usually are around 47 percent cover. Dominant short grass species include sideoats grama (Bouteloua curtipendula), hairy grama (Bouteloua hirsuta), or long-stalked panic grass (Dichanthelium perlongum). Mid height grasses also are around 47 percent of the cover, including species like little bluestem (Schizachyrium scoparium) and prairie dropseed (Sporobolus heterolepis). Tall grasses are not common. There are many dozens forbs common to the site. Species occurring at most or all sites include stiff tickseed (Coreopsis palmata), flowering spurge (Euphorbia corollata), and fewleaf sunflower (Helianthus occidentalis). Small shrubs, like lead plant (Amorpha canescens) and smooth sumac (Rhus glabra) also can be present, but generally are not abundant. Without regular burning, these plant communities become invaded by woody species like eastern redcedar (Juniperus virginiana) and/or various deciduous shrub and tree species (Shea et al., 2014).

Associated sites

R105XY021WI	**Limestone Colluvium Bluff Prairie** This ecological site often co-occurs with Dolomite Colluvium Bluff Prairie (DCBP, 105XY001). They are commonly found together on the same landform when the bedrock stratigraphy is Oneota dolomite over Jordan sandstone over St. Lawrence dolomite. DCBP generally makes up 60 to 99 percent of the landform, while SCBP makes up one to 40 percent. If SCBP is of low percent on a bluff, the most likely place to find it is below any sandstone cliff or ledge. Often, the loamy-skeletal dolomite colluvium from DCBP covers the sandy soils of SCBP, masking the effect of the underlying sandstone geology. Sites that have more than 12 inches of loamy-skeletal colluvium covering sandier textures are considered within the range of DCBP. This is particularly common on bluffs where there is no outcropping of the Jordan sandstone. Also, embedded within this ecological site are cliff and shallow to bedrock ecological sites. There are many surrounding ecological sites which include a number of reference plant community types, including oak savanna, dry-mesic oak woodland, and mesic hardwood forest. Ecological Site Descriptions have not been completed on any of these soils and plant communities.

Similar sites

R105XY021WI	**Limestone Colluvium Bluff Prairie** Dolomite Colluvium Bluff Prairie (DCBP, 105XY001) is both associated and similar to SCBP (see above). DCBP has a similar disturbance regime and shares many of the same species. However there is a distinct difference in productivity and height form. DCBP produces almost double (192%) the total annual production (lbs/ac) of the associated sandstone ecological site. DCBP includes a complex dry-mesic and dry prairie, whereas SCBP is exclusively dry prairie. The short-mid-tall grass ratio of grass cover differs to a great extent (20-60-20 for DCBP versus 47-47-6 for SCBP). Species like side-oats grama are common on DCBP but make up a small fraction of the total annual production, as compared to the SCBP. Some species, like hairy grama, are virtually exclusive to the associated SCBP. These differences are noticeable when traversing a bluff that has both DCBP and SCBP. The vegetation on DCBP is thicker and taller, and does not have significant areas of bio-crusts or soil surface exposure. In comparison, SCBP vegetation is thinner and and shorter, with more bio-crusts and soil surface exposure.

Table 1. Dominant plant species

Tree	Not specified
Shrub	Not specified
Herbaceous	(1) *Schizachyrium scoparium* (2) *Bouteloua curtipendula*

Physiographic features

This ecological site is located on the steep bluffs and valley sides of the river hills and breaks landscapes of the Paleozoic Plateau (e.g., Mississippi, Wisconsin, Root, and Upper Iowa River Valleys; Table 1). The Oneota-Jordan-St. Lawrence geologic sequence is the most common stratigraphy for bluff prairie landforms in the MLRA, particularly along the Mississippi River and its tributaries in the northern two thirds of the MLRA (Figure 2). Most of these bluff prairie landforms have a least a portion of their slope in this ecological site, but it can be small. SCBP sites are associated with the Jordan sandstone Formation, and occur mostly on middle backslopes, between the Oneota and St. Lawrence dolomite Formations (which are associated with the DCBP ecological site). The best expression of SCBP is where there is a distinct sandstone ledge or cliff above the site. Where there is no distinct sandstone ledge or cliff, there is a tendency for loamy-skeletal colluvium from the Oneota dolomite to cover the

sandy soils developed from the underlying sandstone. If more than twelve inches of this loamy-skeletal colluvium covers the underlying sandy soil, it is not part of this ecological site (Figure 3). Because of this dynamic, SCBP is often discontinuous along the middle backslope, in between sporadic dolomite colluvium flows that now represent the associated dolomite-based ecological site. SCBP may also occur on the younger, Ordovician aged St. Peter sandstone Formation. However, these areas are more gently sloping, and occur further inland, away from the Mississippi River. The St. Peter sandstone can either be found on coulees (e.g., first order unbranched, intermittent stream tributaries) or on isolated bluffs and mesas surrounded by a plain. In the western parts of the MLRA, these isolated bluffs and mesas were historically surrounded by prairie, rather than being surrounded by forest, as is typical for this ecological site. Further soil and plant community relationship studies are needed for these prairies underlain by St. Peter sandstone.

Aspect, slope steepness, slope shape, and soil interact to characterize this ecological site, making this site drier and more exposed to climatic extremes than adjacent sites. Aspect is the most defining parameter, and typically ranges from south to west. South-southeast aspects can occur on the upper most backslopes and shoulders, but are less common on lower backslopes. The longest slope lengths within a SCBP ecological site occur on southwest and south aspects. Slopes are generally steep to very steep, ranging from 20 to 90 percent slope. Shoulder slopes occur where there are changes in bedrock, often near outcrops or cliffs. Shoulder slopes are generally steeper than their adjacent backslope. The predominant slope shape is convex both up slope and across slope. This is particularly true on bluffs, which are either at the end of a ridge or at the corner of a valley side. Slope shape can also be linear, but it is typical to have at least one component of slope shape be convex. If concavities do exist, either up or across slope, it is most likely part of a different ecological site. For example, a narrow drainageway that is linear up slope, and concave across, is likely a different ecological site (e.g., oak savanna).

The topography of the site can include sandstone bedrock outcrops, ledges and/or cliffs. These are a unique ecological site. Because outcrops and cliffs have a small horizontal surface area and are so intermingled with the rest of this ecological site, they are considered to be a normal component of the site. Elevation ranges from 900 to 1200 feet. Runoff is high. These sites do not flood or pond.

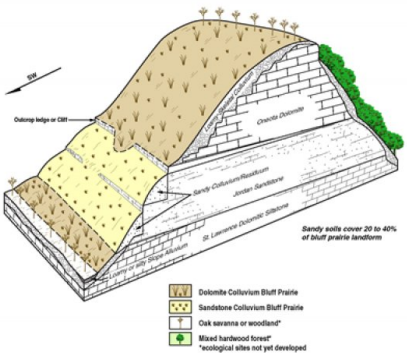


Figure 2. Bluff prairie landform with both DCBP and SCBP.

Table 2. Representative physiographic features

Landforms	(1) Bluff (2) Valley side
Flooding frequency	None
Ponding frequency	None
Elevation	800–1,200 ft
Slope	20–90%
Water table depth	80 in
Aspect	S, SW, W

Climatic features

The average freeze-free period of this ecological site is about 162 days, and ranges from 145 to 205 days (Table 2). Average annual precipitation is 37.57 inches, which includes rainfall plus the water equivalent from snowfall (Table 3). Two thirds or more of the precipitation falls during the growing season. The majority of rainfall occurs as high intensity, convective thunderstorms during the summer months. Most of the spring snowmelt runs off the steeply sloping or high relief surfaces into high gradient drainageways and then into large floodplains. The average annual temperature is 35.6 to 56.1° F. These data are derived from 30-year averages gathered from seven National Oceanic and Atmospheric Administration (NOAA) weather stations contained within the range of this ecological site (Table 4), but were not necessarily located on soil map units correlated to DCBP.

Bluff prairies have a harsher environment than what is characteristic for other ecological sites in the MLRA. They are subject to fluctuating extremes of temperature and moisture because of their aspect and hillslope positon. For example, bluff prairies have an aspect exposed to the full drying effect of the sun and a bluff setting exposed to prevailing winds, which combine to enhance evapotranspiration compared to surrounding sites. Also, although DCBP occurs in a humid climate, soils are calcareous soil at or near the surface, indicating greater evapotranspiration than precipitation. Another example of how DCBP is more climatically extreme comes from their soil temperature class, which categorizes physiographic areas based on mean annual soil temperature. The soil temperature regime of MLRA 105 is classified as “mesic” (i.e., mean annual soil temperature between 46 and 59°F). However, when looking at the average soil temperature of bluff prairie sites by season, they are more similar to “thermic” (i.e., between 59 and 72°F) in the summer, and “frigid” (i.e., between 32 and 46°F) in the winter (USDA-NRCS, unpublished data).

Table 3. Representative climatic features

Frost-free period (average)	141 days
Freeze-free period (average)	162 days
Precipitation total (average)	38 in

Climate stations used

- (1) POSTVILLE [USC00136766], Postville, IA
- (2) PRAIRIE DU CHIEN [USC00476827], Prairie du Chien, WI
- (3) VIROQUA [USC00478827], Viroqua, WI
- (4) LA CROSSE MUNI AP [USW00014920], La Crosse, WI
- (5) RICHLAND CTR [USC00477158], Richland Center, WI
- (6) CALEDONIA [USC00211198], Caledonia, MN
- (7) THEILMAN 1SSW [USC00218227], Kellogg, MN

Influencing water features

There are no water features influencing this site.

Soil features

The parent material for these soils is sandstone colluvium over sandstone residuum, although a thin surface layer (up to 12 inches thick), of finer-textured course-loamy colluvium is allowed (Table 5). These soils are usually very deep (>60 inches to bedrock), but can also include deep soils (40-60 inches to bedrock). Drainage class is excessively drained, and there is never a saturated zone in the upper 80 inches. Available water capacity is very low. The soil family particle size class ranges from sandy to sandy-skeletal (i.e., having more than 35 percent rock fragments by volume). Rock fragments are primarily sandstone, but can include some dolomite that has moved downslope, from the above Oneota Formation. These soils are often slightly alkaline in the surface horizon (i.e., A horizon), and range from slightly to moderately alkaline in the subsoil. The sandy residuum is neutral to moderately alkaline. The surface horizon has a texture of loamy sand, loamy fine sand, fine sandy loam, sandy loam, and their gravelly and channery analogues. Theses sandy loam and fine sandy loam textures are light, usually less than 10 percent clay. The A horizon ranges from three to 19 inches thick, and has Mollic colors (e.g., 10YR 2/1). Soil

textures in the subsoil are loamy fine sand, fine sand, sand, and their gravelly and channery analogues. Soils classify as Mollisols (e.g., Entic Hapludolls), Inceptisols (e.g., Humic Eutrudepts), and Entisols (e.g., Typic Udipsamments). The Bellechester soil series, which was set up for the St. Peter sandstone, comes closest to representing the soils found on this ecological site. Further investigation is needed to either expand the concept of Bellechester, or develop a new soil series that is associated with the Jordan Sandstone. In general, soils associated with the St. Peter sandstone will have less free carbonates and lower pH than soils associated with the Jordan sandstone.

Figure 7. Photo is of a soil pit showing the characteristic

Table 4. Representative soil features

Parent material	(1) Colluvium–sandstone
Surface texture	(1) Loamy fine sand (2) Fine gravelly sandy loam (3) Gravelly loamy sand
Family particle size	(1) Sandy
Drainage class	Excessively drained
Permeability class	Rapid to very rapid
Soil depth	40–80 in
Surface fragment cover <=3"	0–40%
Surface fragment cover >3"	20–45%
Available water capacity (0-40in)	2.16–3.24 in
Calcium carbonate equivalent (0-40in)	0–5%
Soil reaction (1:1 water) (0-40in)	6.1–8.4
Subsurface fragment volume <=3" (Depth not specified)	10–45%
Subsurface fragment volume >3" (Depth not specified)	10–15%

Ecological dynamics

Sandstone Colluvium Bluff Prairies are open areas on steep, exposed slopes in an otherwise forested landscape. Herbaceous plants that can tolerate droughty, rocky soil conditions dominate the site. Bluff prairie plants in general possess many adaptations enabling them to survive in a harsh environment, often subject to widely fluctuating extremes of temperature and moisture. Also, having aspects exposed to the full drying effect of the sun as well the full brunt of prevailing winds combine to enhance evapotranspiration compared to adjacent ecological sites. Bluff

prairie plants are both pyrogenic (fire adapted) and heliophytic (sun-loving).

Prior to European settlement, open prairies persisted on these sites since the Holocene Thermal Maximum, 9000-5000 BP (i.e., the hypsithermal; Anderson 1954). Fire, drought, and native grazers were the primary natural disturbances on pre-settlement bluff prairies. It is likely that these sites burned at least three to five times per decade (Jones and Bowles 2013). These periodic fires removed litter and stimulated the growth and flowering of grasses and forbs. They also limited the growth and dominance of trees, especially eastern redcedar, which is extremely fire intolerant. In landscapes with predominant south to west facing valley sides, there was a complex pattern of open bluff prairie, savanna, and open oak woodlands (Figure 4). Fire tolerant bur oak (*Quercus macrocarpa*) and black oak (*Quercus velutina*) occupied the edges of bluff prairie landforms. Only during long, fire-free intervals in times of higher than average precipitation, would tree and shrub species increase on bluff prairies. In comparison, in landscapes with predominately north to east facing valley sides, ravines favored development of true forests, due primarily to the change in aspect.

Bluff prairies greatly increase the diversity of plants and animals in the landscape (see Table 6, later in document). Prairie grasses and prairie forbs not usually found on other landform settings in the region occur on bluff prairies. Common native prairie grasses that are present include little bluestem, sideoats grama, prairie dropseed, and hairy grama. Short and mid height grasses bluestem and prairie dropseed, dominate the site. Likewise, a significant presence of prairie forbs like: stiff tickseed, flowering spurge, fewleaf sunflower, cylindrical blazing star, birdfoot violet, and field sagewort, are indicators of SCBP. In addition, annual species like Michaux's stitchwort, grooved flax, ragweeds (Artemesia spp.), and prairie fleabane (*Erigeron strigosus*) can be common, which in part distinguishes SCBP from the associated DCBP ecological site. Some of these prairie forbs found on bluff prairies are the sole host to certain insect species. There are many invertebrate species, including some 29 species of land snails that are found only on prairies and savannas (Theler 1997). Several vertebrate species also rely heavily on bluff prairie habitat. These include the six-lined racerunner (Cnemidophorus sexlineatus), prairie ringneck snake (Diadophis punctatus), and the timber rattlesnake (Crotalus horridus). For example, it is the open bluff prairie habitat that allows timber rattlesnakes to successfully reproduce at the northern limit of their range. Also, golden eagles (Aquila chrysaetos) wintering in the region are often seen hunting on bluff prairies. It is possible that the recent expansion of this species into the MLRA is due in part to restoration of DCBP, and related ecological sites (Craig Maier, Ecologist with the Tallgrass Prairie and Oak Savanna Fire Science Consortium, personal communication).

The last 300 years can be divided into three disturbance eras that relate to bluff prairies: 1) before 1866, prior to European settlement; 2) from 1866 to 1960, post settlement; and 3) 1960 to present. The first period ended with European settlement, no later than 1865. In this pre-settlement time period, SCBPs were in the Reference State (State 1; Figure 5), fluctuating between the High Diversity Prairie community (Phase 1.1) and the Reduced Diversity Prairie community (Phase 1.2) depending on the frequency of fire. Prior to European settlement, indigenous cultures used fire liberally for a multitude of purposes, over thousands of years (Abrams and Nowacki 2008). During this time, drought-driven landscape fires were common, as many as five per decade, and were not suppressed (Jones and Bowles 2013). Native species on bluff prairies were in a dynamic equilibrium related to the frequency of landscape wide fires. Native grazers, like elk (Cervus canadensis), bison (Bison bison), and white-tailed deer (Odocoileus virginianus) were present, and undoubtedly had an effect on bluff prairie dynamics. However, it is generally unclear to what level native grazers may have affected disturbance dynamics of bluff prairies.

The second period started immediately post European settlement, roughly between 1866 and 1960 (Figure 6). Many, if not most SCBP sites were completely transitioning from the Phase 1.1 to Phase 1.2 at this time. However, fire continued to be commonplace. Tree ring data at Fults Hill Prairie Nature Preserve in Illinois indicate that fires occurred three to five times per decade from the late 1800s, all the way through the middle 1900s (Jones and Bowles 2013). This confirms many of the observations of local residents, land managers and conservation professionals – in that land owners commonly burned bluff prairie sites up until about 1960. These fires were set for various reasons. In parts of the Root River Valley in Minnesota, for example, neighbors would gather and set fires to pastured areas in and around bluff prairies (Valiree Green, MN DNR Forester, personal communication). Also, people in Lansing, Iowa recall seeing fires burning on bluff prairies across the Mississippi River that were set by Wisconsin citizens, in an attempt to control timber rattlesnake populations (Armund Bartz, WI DNR Ecologist, personal communication). During this time period, bluff prairies were used intermittently for grazing purposes. Specifically, a mix of grazers would forage on these sites, including cattle, sheep, and goats (Jaime Edwards, MN DNR Nongame Biologist, personal communication). Livestock numbers increased from the early 1900s through the middle 1900s. Grazing on bluff prairies became intensive during the severe drought years of the 1930s, when farmers were desperate for forage (Dr. Stanley Trimble, UCLA Professor, personal communication). Many bluff

prairies were overgrazed, and became degraded by soil erosion. However, in some cases, this varied and diverse mix of grazing systems limited significant encroachment of trees and shrubs, which undoubtedly helped maintain bluff prairies in the Reference State.

Also during this second time period, non-native plants were first introduced. The impact of non-native, invasive species gradually increased over time, and is continuing to increase today. In addition, some native species, such as common pricklyash (*Zanthoxylum americanum*), smooth sumac, and gray dogwood (*Cornus racemosa*) gradually became invasive; historically, their abundance was controlled by fire. Most bluff prairies were not transitioning to the Eastern Redcedar/Prairie State (State 2) and probably not to the Scrub Deciduous Tree and Shrub/Prairie State (State 3) in the second time period, as is evidenced by aerial photos from the 1930s thru 1950s, showing little significant change in eastern redcedar cover.

The third period started in 1960 and continues to present day, when fire intervals on bluff prairies generally decreased to less than two per decade, with fire free intervals of ten to twenty years, or more (Jones and Bowles 2013). Historically, there was a direct relationship between fire frequency and climate, in that fire occurrence was more likely during times of drought (Stambaugh and Guyette 2006, Jones and Bowles 2012). With the advent of fire suppression, which was used as a mechanism for public safety, the relationship between fire and climate became negated. This fire suppression coincided with an increase in non-farm rural population, along with fragmentation of land ownership, both of which contributed to the reduction in fire frequency. Old, cultural ways of land management through burning were abandoned, which contributed to the reduction in landscape wide fires. This period of local fire suppression is embedded within a larger geographical area spanning much of the eastern United States, whereby fire has been ubiquitously suppressed, leading to forest encroachment and “mesophication” (Nowacki and Abrams 2008). There was also a dramatic change in farming practices in this third time period. The diversity of grazing animals found on farms decreased, and grazing on bluff prairies ceased altogether in many areas. Most of the remaining Reference State SCBPs transitioned to Phase 1.2, the Reduced Diversity Prairie, as fire return intervals decreased. It was during this most recent time period that many DCBPs transitioned to States 2 and 3. The introduction and spread of non-native, invasive plants continued in this time period. Specifically, the introduction of common buckthorn (*Rhamnus cathartica*) has degraded many native habitats, including bluff prairies, and is the hallmark invasive species of the Non-Native Invaded State (State 4).

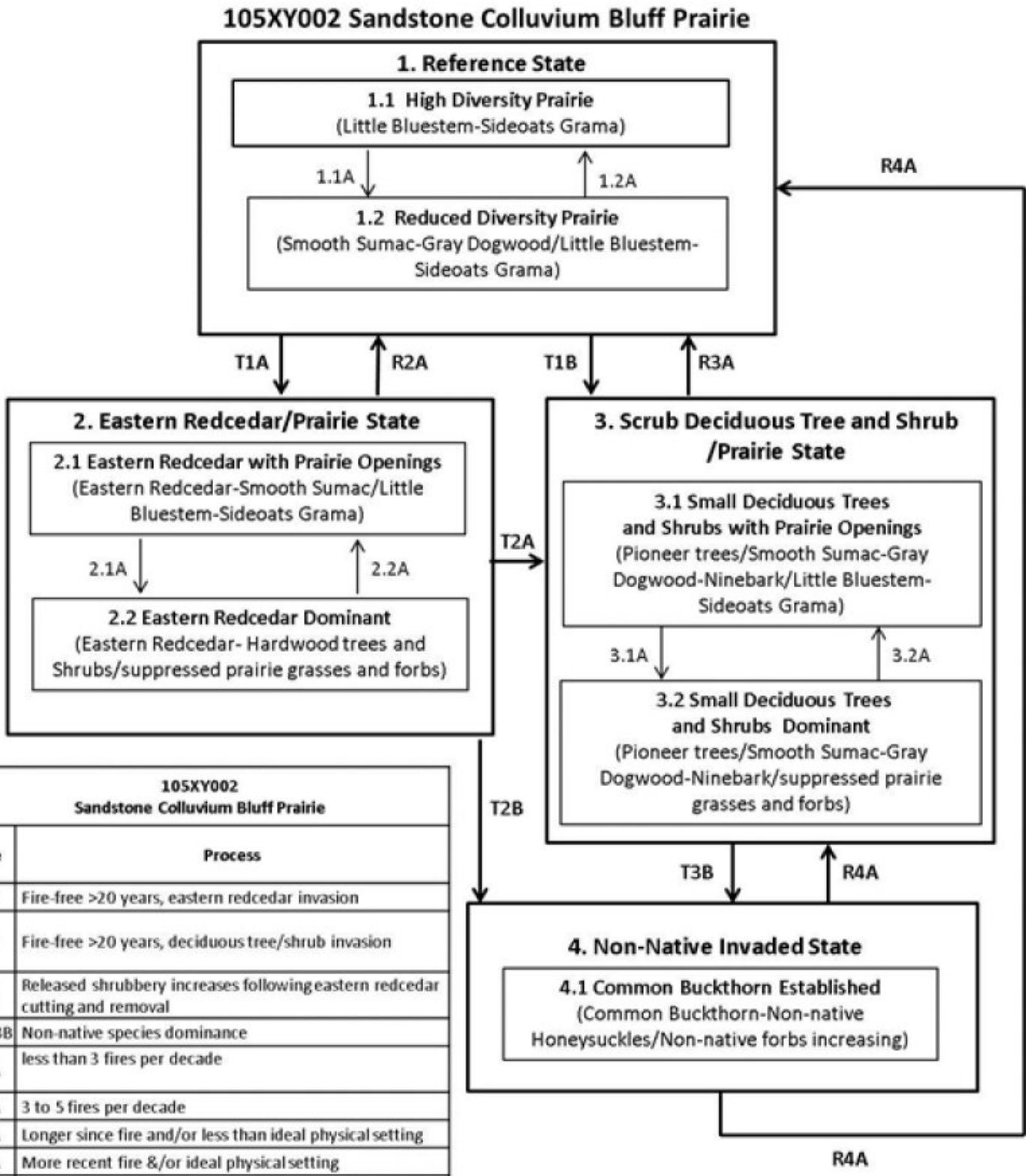
In general, xeric site conditions contribute to extended persistence of these ecosystems, due in large part to the fact that few species can tolerate such extreme sites (Evers 1955). SCBP is particlulary xeric because of the extremely low available water capacity, often half that of DCBP. This makes SCBP a likely refuge for the last enclave of prairie vegetation bluff when fire has been suppressed. Still, fire is an essential process, needed to maintain even the most xeric prairies (Jones and Bowles 2013; Greg Nowacki, USFS Ecologist, personal communication). The exact frequency of fire that is required to maintain the SCBP Reference State, or restore alternative states, depends on physical setting and the unique history of a given bluff prairie site. The fire intervals stated in the state-and-transition model (Figure 4) are not based on empirical data. Rather, they are based on data published from similar ecosystems, and most importantly, input from numerous land managers and local conservation experts. Today, many bluff prairies exist as small, fragmented relics, surrounded by encroaching woody species. Restoration requires a combination of management techniques, including mechanical removal of invading trees and shrubs, herbicide application to tree and shrub species with propensity to stump sprout, and prescribed fire. Management should always start in areas near the highest quality prairie openings of a site (i.e., the steepest, most convex slopes, with south to southwest aspect). These areas are most likely to respond to restoration treatments. Once at least some herbaceous cover is restored (e.g., after one or more growing seasons), prescribed fire can be introduced, and repeated up to every other year, if possible (Jones and Bowles 2013). Prescribed fires will further stimulate dormant prairie seed. In subsequent years, gradual expansion of management to the entirety of the site can be considered. In cases of resulting low species diversity, supplemental seed or plugs are sometimes introduced, ideally from local sources and similar ecological sites. The initial stages of bluff prairie restoration could be impacted if sites are located near common buckthorn seed sources. When any bluff prairie restoration project is considered, an evaluation of potential common buckthorn seed sources should be completed. Adjacent woodlands with common buckthorn will be a likely seed source.

The presence of restricted plants and animals presents a challenge when using prescribed burning as a management tool. Fires may impose greater stress on certain plant and animal populations in contemporary, confined landscapes that lack connectivity (Nelson et al. 2013). Although fire is essential for restoring and maintaining bluff prairies, burns should be designed so they do not have unintended impacts. Burning only a portion of a bluff prairie unit in any given year may reduce the likelihood of these impacts.

Some variability in SCBP sites can be described, often depending on differences in physical landform features, disturbance and management history, and type of adjacent plant communities. The driest, most xeric locations of any given SCBP site is on shoulder slopes, or upper most backslopes of large, doubly convex nose slopes. These south and southwest facing slopes are the most exposed to climatic extremes, and are the most likely locations to persist in the absence of fire. In contrast, locations on a bluff prairie landform that are even slightly concave, can provide comparatively better growing conditions for plants, In some cases allowing trees to persist, even in the presence of fire.

Small areas of rock outcrops do occur on this ecological site. Areas of rock outcrop include small ledges and cliffs, which often have a higher density of shrubs and trees immediately adjacent to them. These areas provide protection from fire, as well as cooler, shaded microsites where woody species can become established. This complexity adds to the diversity of a site by providing unique habitat for plants like purple-stemmed cliff brake (Pallaea atropurpurea) and smooth cliffbrake (Pallaea glabella), that are not found anywhere else on the SCBP ecological site. Even large boulders can produce similar dynamics. In fact, historically these cliff areas were likely the historic refugia for eastern redcedar, ultimately becoming the primary seed source fueling the invasion of this species onto SCBP sites during the third time period.

State and transition model



105XY002 Sandstone Colluvium Bluff Prairie	
Code	**Process**
T1A	Fire-free >20 years, eastern redcedar invasion
T1B	Fire-free >20 years, deciduous tree/shrub invasion
T2A	Released shrubbery increases following eastern redcedar cutting and removal
T2B T3B	Non-native species dominance
1.1A	less than 3 fires per decade
1.2A	3 to 5 fires per decade
2.1A	Longer since fire and/or less than ideal physical setting
2.2A	More recent fire &/or ideal physical setting
3.1A	Longer since fire &/or less than ideal physical setting
3.2A	More recent fire &/or ideal physical setting
R2A, R3A	Woody removal, prescribed burning, herbicide treatment of deciduous trees/shrubs, seeding to increase diversity
R4A	Difficult restoration, many long term treatments

Figure 8. State-and-transition diagram for Sandstone Colluvi

State 1
Reference State

SCBP Reference States can be found in scattered locations throughout the MLRA 105, particularly in Wisconsin and Minnesota. Prior to European settlement, over 8,000 acres of the Reference State once existed, mostly in

Community Phase 1.1 (Tables 6 through 9). River valleys trending east-west, with south-facing valley sides had bluff prairies on almost all suitable physical settings (Figure 6; Scottston and Atherton 2013). During this period, drought-driven fires were unimpeded, often set by indigenous peoples. As many as five fires per decade burned large, landscape scale areas (Jones and Bowles 2013). Evidence for what this phase looked like comes from realistic landscape painters, such as one by Henry Lewis in 1947 (Figure 4). Other artists, like George F. Fuller (1853), Edwin Whitefield (1858) and Alfred Sederberg (1867) depicted similar landscapes of the Mississippi River valley that included reference to bluff prairies (Coen 1976). There are also historical accounts of bluff prairies. For example, in 1781, Jonathan Carver described a prairie on a steep hillside along the lower Wisconsin River: “For miles nothing was to be seen but lesser mountains, which appeared at a distance like haycocks, they being free from trees…and only a few groves of hickory and stunted oaks covered some of the vallies” (Curtis 1959). Reference states of SCBP on a given site are often relatively small, surrounded by the associated DCBP. The combined SCBP and DCBP Reference States range in size from wide open, grassy areas covering the entire portion of bluffs and valley sides, to small parts of bluffs limited to the most exposed, steepest, and convex areas. Breaks in the slope, either from changes in the underlying bedrock, bedrock outcrops, or drainageways, may have a higher concentration of shrub and tree species, but do not detract from overall prairie condition. Periodic disturbances from fire maintained the dominance of drought and fire adapted native grasses and forbs by limiting the growth and dominance of trees and shrubs, especially eastern redcedar. Disturbance-free periods initially favor grass dominance and eventually allow encroachment shrubs, then trees. Two community phases are recognized in this state. Shifts between these phases are based primarily on fire frequency, and secondarily on grazing. With decreasing fire frequency, a shift from Community Phase 1.1 to 1.2 will occur, and exhibit an increase in shrub densities and overall decrease in species diversity, especially the loss of annuals and species of shorter stature (Kraszenski and Waller 2008). Mesic tall grass prairies, which occur on soils with higher available water capacity, have been reported to develop into close canopy forest in as little as 35 years without fire (Hoch and Briggs 1999). In comparison, the persistence of bluff prairies in the absence of fire would likely be longer, especially on sandstone soils. The transition to State 2 (Eastern Redcedar/Prairie) versus State 3 (Scrub Deciduous Tree and Shrub/Prairie) remains a question. It at least partially depends on what plant communities are surrounding the site. Aspect may also be a factor. Bluff landforms that have a larger proportion of south or southwest aspects compared to west to west-southwest, and/or south-southeast may be more likely to transition to State 2. Soil type may be another factor. Sites that transition to State 2 may have lower available water capacity soils than State 3. These higher available water capacity soils could result from a thin loess cap. Further study is needed on this topic.

Community 1.1
High Diversity Prairie

Figure 9. Community Phase 1.1, High Diversity Prairie for Sa

Community Phase 1.1 represents the central concept of the SCBP ecological site (Figure 7). During pre-settlement, and immediate post settlement time periods, SCBP sites were maintained in Phase 1.1 as long as there were three to five fires per decade (Jones and Bowles 2013). On bluffs where fire didn’t occur at this frequency, communities transitioned to Phase 1.2, and diversity of prairie species declined. Early grazing systems which included a diversity of grazers (e.g., cattle, sheep, goats, etc.) may have helped maintain bluff prairies in Phases 1.1 and 1.2. A good example of what this complex of Reference State communities may have looked like is portrayed in a photo from the Winnebago Creek Valley, Minnesota (Figure 6). Bluff prairies extended from the lower backslope to the summit on most bluffs and valley sides that are in the range of bluff prairie physical setting parameters.

Table 5. Annual production by plant type

Plant Type	Low (Lb/Acre)	Representative Value (Lb/Acre)	High (Lb/Acre)
Grass/Grasslike	337	506	562
Forb	190	285	317
Shrub/Vine	60	90	100
Total	**587**	**881**	**979**

Table 6. Soil surface cover

Tree basal cover	0%
Shrub/vine/liana basal cover	0%
Grass/grasslike basal cover	4-13%
Forb basal cover	0%
Non-vascular plants	0-3%
Biological crusts	0-15%
Litter	30-68%
Surface fragments >0.25" and <=3"	3-18%
Surface fragments >3"	1-13%
Bedrock	0%
Water	0%
Bare ground	13-41%

Table 7. Canopy structure (% cover)

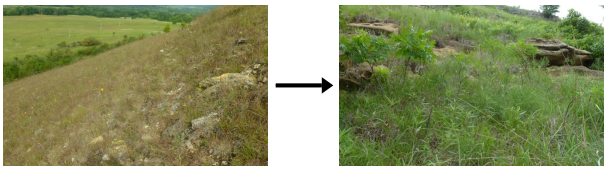
Height Above Ground (Ft)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.5	0%	0-1%	7-65%	1-8%
>0.5 <= 1	0%	0-3%	9-35%	1-5%
>1 <= 2	0%	0-3%	1-36%	0-5%
>2 <= 4.5	0%	0-1%	0-2%	0-1%
>4.5 <= 13	0%	0%	0%	0%
>13 <= 40	0%	0%	0%	0%
>40 <= 80	0%	0%	0%	0%
>80 <= 120	0%	0%	0%	0%
>120	0%	0%	0%	0%

Community 1.2
Reduced Diversity Prairie

Figure 11. Community Phase 1.2, Reduced Diversity Prairie for

A small decrease in fire frequency from Phase 1.1 results in increasing grass and shrub dominance, along with a decrease in forbs (Figure 8). Little bluestem, sideoats grama, and prairie dropseed thatch builds up, thus not allowing some forbs to proliferate. Annuals, and shorter prairie species are the first to decline (Kraszewski and Waller 2008). Smooth sumac, gray dogwood, and common ninebark are the primary increasing shrubs. Less than ideal landform settings (like small drainageways) transition first, and develop outward from there. In this Phase, Reference State bluff prairies risk fragmentation, isolation, and possible decline in species diversity. In contemporary restoration settings, there is a tendency for prescribed fires to be set in the late winter to early spring. During this time, surrounding forested ecological sites are often still covered in snow, which provides a natural fire break, helping with containment of prescribed fires. Historically, Reference State fires would have also occurred during the growing season and into fall, and were likely more intense. Implementing fall and late spring fires will provide a greater impact on setting back shrub and tree species, and likely produce more immediate restoration results (Jon Cole, MN DNR Area Manager, personal communication. However, vertebrate species like the timber rattlesnake, and many invertebrate species may be impacted with this strategy (Armund Bartz, WI DNR Ecologist, personal communication and Jaime Edwards, MN DNR Nongame Biologist, personal communication).

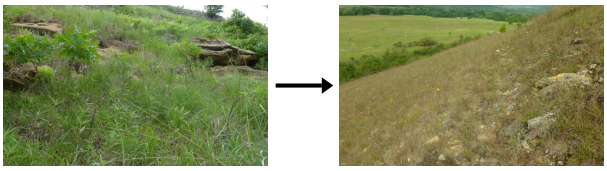
Pathway 1A
Community 1.1 to 1.2



High Diversity Prairie **Reduced Diversity Prairie**

Fire frequency less than three fires per decade. A possible decrease in grazing intensity, especially by a diversity of grazers may also be a factor.

Pathway 2A
Community 1.2 to 1.1



Reduced Diversity Prairie **High Diversity Prairie**

Increase fire frequency to at least three to five fires per decade. Supplemental controlled grazing and herbicide treatment of shrubs near cliffs, ledges, and large boulders will speed up restoration to Phase 1.1.

State 2
Eastern Redcedar/Prairie State

This state is dominated by eastern redcedar, which can be relatively even-aged, but there often are a few scattered older trees, especially near cliffs and ledges, or on very steep slope breaks. Eastern redcedar is a fire sensitive species, especially in their early growth stages. Their presence is an indication that fire has been absent for a prolonged period (>20 years). Determining the age of dominant even-aged trees could give an idea of when fire was excluded. Historically, eastern redcedar is thought to colonize from cliff habitat during periods of fire exclusion (Jones and Bowles 2013). Other shrubs common to bluff prairies and scattered deciduous trees are also present at an increased density. Densities can range from 40 percent to nearly 100 percent. Interconnected patches of prairie are common when densities closer to 40 percent. However, the decline in diversity of prairie species (in particular the loss of annuals and those of shorter stature) may have already taken place (Kraszewski and Waller 2008). When densities reach nearly 100 percent, a few prairie species persist with diminutive stature, and it is likely that the soil contains a reservoir of prairie species in the seed bank.

Community 2.1
Eastern Redcedar with Prairie Openings

Figure 12. Community Phase 2.1, Eastern Redcedar with Prairie

This phase consists of 40 to 80 percent cover of eastern redcedar, with small, patchy prairie openings (Figure 9). The prairie openings are not completely shaded by adjacent trees. Native deciduous shrubs and trees are also encroaching, but not dominant. Invading trees gain initial footing on the less than ideal landform settings. They begin to invade slightly concave areas that collect runoff, and around boulders, cliffs, and ledges. South to southwest aspects on, the steepest and most convex areas, tend to persist as prairie openings. West to west-southwest aspects and south-southeast aspects are more prone to tree encroachment. Upper backslopes and shoulder slopes tend to persist as prairie opening while lower backslopes tend to be invaded by woody species. Because of fragmentation and isolation of the prairie openings, the diversity of prairie species, and in particular the loss of shorter prairie species may have already taken place (Kraszewski and Waller 2008). Taller and more mesic prairie species, like wild bergamot (*Monarda fistulosa*) and narrowleaf mountainmint (*Pycnanthemum tenuifolium*) may become established in the prairie openings (Armund Bartz, WI DNR Ecologist, personal communication). This phase can be relatively easily restored to the Reference State.

Community 2.2
Eastern Redcedar Dominant

Figure 13. Community Phase 2.2, Eastern Redcedar Dominant for

This phase consist of greater than 80 percent eastern redcedar cover (Figure 10). Between dense thickets of eastern redcedar, formerly persistent prairie openings are subject to shading. Some native deciduous shrubs and trees exist, but eastern redcedar is the dominant canopy tree. Under this dense cover, some stunted prairie species remain. At this stage, there has been a significant loss in species diversity. However, it is likely that a seedbank of prairie species persists in the soil. Species particularly capable of persisting in the seedbank include: leadplant (frequent), little bluestem, prairie dropseed (fairly frequent), panic grasses (Dichanthelium spp.), stiff tickseed, flowering spurge, bluebell bellflower (*Campanula rotundifolia*), field pussytoes (Antennaria negelecta), and candle anemone (Jaime Edwards, MN DNR Nongame Biologist, personal communication). Prescribed burns may not carry if there is not enough fuel beneath dense eastern redcedar thickets. Mechanical removal, herbicide treatment, and spot burning can be used to create openings as intermediate steps toward natural community restoration. Various bird species use eastern redcedar thickets and carry in seeds from offsite. As a result, when eastern redcedar is removed, shrub species like smooth sumac, gray dogwood, blackberry species (Rubus spp.), and pricklyash may rapidly become released. Herbicide treatment of these shrubs is often critical for their control. Proceed with caution if common buckthorn, or other invasive species are, or may be present.

Pathway 1A
Community 2.1 to 2.2

Eastern Redcedar with Prairie Openings **Eastern Redcedar Dominant**

Continued absence of fire, with a gradual increase in eastern redcedar density (>80 percent cover) and height.

Pathway 2A
Community 2.2 to 2.1

Eastern Redcedar Dominant **Eastern Redcedar with Prairie Openings**

Reduction of eastern redcedar and other tree and shrub species to 40 to 80 percent cover.

State 3
Scrub Deciduous Tree and Shrub/Prairie State

This state is dominated by native deciduous shrubs and small, immature trees, mixed with a small amount of eastern redcedar. This gradual transition results from prolonged periods of fire suppression, generally over 20 years. Deciduous shrub species that are normally found on this ecological site increase in density and height. Pioneer deciduous tree species invade from local sources. Prairie grasses and forbs still exist in the understory, but woodland forbs, grasses, and sedges may be appearing. Shrubs are tall and relatively dense. The most common species include: smooth sumac, gray dogwood, common ninebark, blackberry species, and common pricklyash. Sapling trees are scattered, and often of poor form. Common species may include: pin cherry (*Prunus pensylvanica*), bur oak, black oak, quaking aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*), black cherry (*Prunus serotina*), green ash (*Fraxinus pennsylvanica*), and black walnut (*Juglans nigra*). Overall tree and shrub densities can range from 40 percent to nearly 100 percent. Interconnected patches of prairie are common when densities closer to 40 percent. However, a decline in the diversity of prairie species (in particular the loss of annuals and those of shorter stature) may have already taken place (Kraszewski and Waller 2008). When densities reach nearly 100 percent, a few prairie species persist with diminutive stature, and it is likely that the soil contains a reservoir of prairie species in the seed bank.

Community 3.1
Small Deciduous Trees and Shrubs with Prairie Openings

Figure 14. Scrub Deciduous Tree and Shrub /Prairie State (Com

This phase consists of 40 to 80 percent cover of deciduous shrubs (Figure 10), many of which are native to the site, but occur at a much higher density than before. Eastern redcedar can be present, but it is not dominant. The prairie openings are not completely shaded by adjacent trees. Invading shrubs gain initial footing on the less than ideal landform settings. They begin to invade slightly concave areas that collect runoff, and around boulders, cliffs, and ledges. South to southwest aspects on, the steepest and most convex areas, tend to persist as prairie openings. West to west-southwest aspects and south-southeast aspects are more prone to tree encroachment. Upper backslopes and shoulders tend to persist as prairie opening while lower backslopes tend to be invaded by woody species. Because of fragmentation and isolation of the prairie openings, the diversity of prairie species, and in particular the loss of shorter prairie species may have already taken place (Kraszewski and Waller 2008). Taller and more mesic prairie species, like wild bergamot (*Monarda fistulosa*) and narrowleaf mountainmint (*Pycnanthemum tenuifolium*) may become established in the prairie openings (Armund Bartz, WI DNR Ecologist, personal communication). This community phase has potential for restoration to the Reference State, but will probably require use of herbicide to control deciduous trees and shrubs.

Community 3.2
Small Deciduous Trees and Shrubs Dominant

Figure 15. Community Phase 3.2, Small Deciduous Trees and Shr

This phase consists of greater than 80 percent cover of deciduous trees and shrubs. Trees are tall enough to form a discontinuous canopy over parts of the shrub layer. Shrubs can form a discontinuous canopy under the trees. Trees are typically immature and of poor form. The understory is shaded by a combination of both the tree and shrub layers. Prairie grasses and forbs are present, but their diversity is significantly reduced and most species are completely absent. Savanna and open woodland species are beginning to appear, such as: feverwort (*Triosteum perfoliatum*), white rattlesnakeroot (*Prenanthes alba*), Canada lettuce (*Lactuca canadensis*), Virginia wildrye (*Elymus virginicus*), hairy wildrye (*Elymus villosus*) (Jaime Edwards, MN DNR Nongame Biologist, personal communication). Sites in this phase require considerable effort to restore, and may be considered essentially not restorable because of the investment required. Prescribed burns may not carry if there is not enough fuel beneath the dense canopy. Mechanical removal, herbicide treatment, and spot burning can be used to create openings as intermediate steps toward community restoration. Herbicide treatment of shrubs and trees is critical for their control. Proceed with caution if common buckthorn, or other invasive species are, or may be present.

Pathway 1A
Community 3.1 to 3.2

Small Deciduous Trees and Shrubs with Prairie Openings → **Small Deciduous Trees and Shrubs Dominant**

Continued absence of fire, with a gradual increase in height and density of shrubs and young deciduous trees.

Pathway 2A
Community 3.2 to 3.1

Small Deciduous Trees and Shrubs Dominant → **Small Deciduous Trees and Shrubs with Prairie Openings**

Reduction of deciduous trees and shrubs to 40 to 80 percent cover.

State 4
Non-Native Invaded State

This state occurs when non-native, invasive shrubs become well established and produce novel, monotypic plant communities. Common buckthorn is the primary species of concern, but the non-native honeysuckles (Lonicera

tartarica, L. morrowii) may be present as well. Sites near urban areas are more likely to be in this state. These species produce abundant seed and can rapidly spread by other by coppice regeneration, especially when they are cut without herbicide treatment. Birds are a primary dispersal agent of common buckthorn, often importing seed to DCBP sites that are in States 2 or 3. In some cases, when common buckthorn is present in the understory, but is not noticeable, attempts for restoration can release it, ultimately transitioning the site to State 4. In addition, thickets of common buckthorn can sometimes be found on the edges of sites in Community Phase 2.2. If eastern redcedar is removed there can be an onslaught of common buckthorn invading the site. This state is more common on DCBP ecological sites compared to SCBP. Although common buckthorn will become established on SCBP, it takes longer, and plants are not as vigorous. This is probably due a combination of the difference in pH and available water capacity between DCBP and SCBP. The initial stages of bluff prairie restoration could be impacted if sites are located near common buckthorn seed sources. When any bluff prairie restoration project is considered, an evaluation of potential common buckthorn seed sources should be completed.

Community 4.1
Common Buckthorn Established

Figure 16. Community Phase 4.1, Common Buckthorn Established

In this phase, common buckthorn is mature, produces abundant seed, and has spread throughout the site (Figure 13). Other non-native woody species may also be present, including non-native honeysuckles. Non-native forbs may also be increasing, such as sweetclover (*Melilotus officinalis*), which is a primary non-native forb invading bluff prairies. Native woody species are also present (as in States 2 and 3) and can have a high percent canopy cover. Prairie grasses and forbs still persist under the tree and shrub canopies, but their diversity is reduced, with many or most species being absent. Sites in this phase require considerable effort to restore, and may be considered essentially not restorable because of the investment required to control trees and shrubs. Prescribed burns may not carry if there is not enough fuel beneath the dense canopy. Mechanical removal, herbicide treatment, and spot burning can be used to create openings as intermediate steps toward natural community restoration. Herbicide treatment of common buckthorn is critical for its control.

Transition 1A
State 1 to 2

A gradual transition to a tree and shrub dominated condition (primarily eastern redcedar), resulting over 20 years of fire suppression. A lack of grazing by a diversity of grazers may also accelerate this transition.

Transition 1B
State 1 to 3

A gradual transition to a tree and shrub dominated condition (primarily deciduous trees and shrubs), resulting over 20 years of fire suppression. A lack of grazing by a diversity of grazers may also accelerate this transition.

Restoration pathway 2A
State 2 to 1

Complete removal of eastern redcedar and restoration of fire regime, leading to restoration of prairie flora characteristic of the Reference State.

Transition 2A
State 2 to 3

Increased shade, providing potential for more shade tolerant deciduous trees and shrubs to become established. Sudden removal of eastern redcedar in State 2 can release seeds of shrubs brought in by birds, such as: smooth sumac, gray dogwood, blackberry species, and pricklyash.

Transition 2B
State 2 to 4

Common buckthorn becomes an established, co-dominant shrub, and is reproducing onsite.

Restoration pathway 3A
State 3 to 1

Nearly complete removal of deciduous trees and shrubs and restoration of fire regime, leading to restoration of prairie flora characteristic of the Reference State.

Transition 3B
State 3 to 4

Common buckthorn becomes an established, co-dominant shrub, and is reproducing onsite.

Restoration pathway 4A
State 4 to 1

Removal of common buckthorn, and other native and non-native shrubs and trees, with restoration of fire regime. This will likely require consecutive years of multiple types of management treatments.

Additional community tables

Table 8. Community 1.1 plant community composition

Group	Common Name	Symbol	Scientific Name	Annual Production (Lb/Acre)	Foliar Cover (%)
Grass/Grasslike					
1				515–572	
	little bluestem	SCSC	*Schizachyrium scoparium*	50–250	25–75
	sideoats grama	BOCU	*Bouteloua curtipendula*	25–200	15–50
	slimleaf panicgrass	DILI2	*Dichanthelium linearifolium*	25–100	5–15
	big bluestem	ANGE	*Andropogon gerardii*	0–100	0–10
	prairie dropseed	SPHE	*Sporobolus heterolepis*	0–100	0–10
	Pennsylvania sedge	CAPE6	*Carex pensylvanica*	10–50	5–15
	hairy grama	BOHI2	*Bouteloua hirsuta*	10–50	5–15
	Muhlenberg's sedge	CAMU4	*Carex muehlenbergii*	5–25	1–5
	Heller's rosette grass	DIOLO	*Dichanthelium oligosanthes var. oligosanthes*	0–5	0–5
	plains muhly	MUCU3	*Muhlenbergia cuspidata*	0–5	0–5
	Indiangrass	SONU2	*Sorghastrum nutans*	0–5	0–5

Forb					
2				699–1165	
	stiff tickseed	COPA10	*Coreopsis palmata*	15–150	1–25
	fewleaf sunflower	HEOCO	*Helianthus occidentalis ssp. occidentalis*	0–100	0–15
	Ontario blazing star	LICY	*Liatris cylindracea*	0–100	0–15
	Leonard's skullcap	SCPAM	*Scutellaria parvula var. missouriensis*	0–75	0–15
	gray goldenrod	SONE	*Solidago nemoralis*	0–75	0–15
	purple prairie clover	DAPU5	*Dalea purpurea*	0–75	0–15
	birdfoot violet	VIPE	*Viola pedata*	0–75	0–15
	flowering spurge	EUCO10	*Euphorbia corollata*	15–50	1–25
	stiff goldenrod	OLRIR	*Oligoneuron rigidum var. rigidum*	0–50	0–15
	aromatic aster	SYOB	*Symphyotrichum oblongifolium*	0–25	0–15
	western silver aster	SYSE2	*Symphyotrichum sericeum*	0–25	0–15
	stiff sunflower	HEPA19	*Helianthus pauciflorus*	0–25	0–15
	downy paintedcup	CASE5	*Castilleja sessiliflora*	0–25	0–15
	hoary puccoon	LICA12	*Lithospermum canescens*	0–15	0–5
	whorled milkweed	ASVE	*Asclepias verticillata*	0–15	0–5
	bluebell bellflower	CARO2	*Campanula rotundifolia*	0–15	0–5
	false boneset	BREU	*Brickellia eupatorioides*	0–5	0–5
	woman's tobacco	ANPL	*Antennaria plantaginifolia*	0–5	0–5
	bastard toadflax	COUM	*Comandra umbellata*	0–5	0–5
	skyblue aster	SYOOO	*Symphyotrichum oolentangiense var. oolentangiense*	0–5	0–5
	white heath aster	SYERE	*Symphyotrichum ericoides var. ericoides*	0–5	0–5
	prairie blue-eyed grass	SICA9	*Sisyrinchium campestre*	0–5	0–5
	hoary verbena	VEST	*Verbena stricta*	0–1	0–1
	twistspine pricklypear	OPMA2	*Opuntia macrorhiza*	0–1	0–1
	prairie groundsel	PAPL12	*Packera plattensis*	0–1	0–1
	Canadian lousewort	PECA	*Pedicularis canadensis*	0–1	0–1
	cutleaf anemone	PUPAM	*Pulsatilla patens ssp. multifida*	0–1	0–1
	wood lily	LIPHP	*Lilium philadelphicum var. philadelphicum*	0–1	0–1
	grooved flax	LISU4	*Linum sulcatum*	0–1	0–1
	palespike lobelia	LOSP	*Lobelia spicata*	0–1	0–1
	Michaux's stitchwort	MIMI2	*Minuartia michauxii*	0–1	0–1
	prairie fleabane	ERST3	*Erigeron strigosus*	0–1	0–1
	rough false pennyroyal	HEHI	*Hedeoma hispida*	0–1	0–1
	prairie sagewort	ARFR4	*Artemisia frigida*	0–1	0–1
	lyrate rockcress	ARLY2	*Arabis lyrata*	0–1	0–1
	annual ragweed	AMAR2	*Ambrosia artemisiifolia*	0–1	0–1
	Cuman ragweed	AMPS	*Ambrosia psilostachya*	0–1	0–1
	field pussytoes	ANNE	*Antennaria neglecta*	0–1	0–1
	yellow sundrops	CASE12	*Calylophus serrulatus*	0–1	0–1

Shrub/Vine					
3				91–136	
	leadplant	AMCA6	*Amorpha canescens*	0–50	0–15
	smooth sumac	RHGL	*Rhus glabra*	0–50	0–15
	common ninebark	PHOP	*Physocarpus opulifolius*	0–15	0–5

Inventory data references

A total of 22 integrated plots, ranging from Tier 2 to Tier 3 intensity, were used as a basis for this ecological site. Three of these were Type Locations representing the data-supported Community Phase 1.1 in the state-and-transition model, and included all necessary data elements for a Tier 3 dataset (Table 10). No other community phases were supported with quantitative data analysis. All 22 plots had soil pedon and site data collected by a professional soil scientist using a form equivalent to SF-232. All pits were hand-dug using sharpshooters and/or bucket augers. All pits used a rock probe to a depth of at least 60 inches, to confirm depth of soils. Of the 22 plots, 11 of the sites were in Minnesota and 11 were in Wisconsin. Of the sites in Minnesota, 11 had an associated MN DNR relevè and/or element occurrence data.

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Contributors

Peter Hartman

Rangeland health reference sheet

Interpreting Indicators of Rangeland Health is a qualitative assessment protocol used to determine ecosystem condition based on benchmark characteristics described in the Reference Sheet. A suite of 17 (or more) indicators are typically considered in an assessment. The ecological site(s) representative of an assessment location must be known prior to applying the protocol and must be verified based on soils and climate. Current plant community cannot be used to identify the ecological site.

Author(s)/participant(s)	Peter Hartman and John Zinn
Contact for lead author	John.Zinn@mn.usda.gov
Date	07/29/2014
Approved by	
Approval date	
Composition (Indicators 10 and 12) based on	Annual Production

Indicators

1. **Number and extent of rills:** Rills are none to very rare. Very few rills expected and any present associate with deer tails.

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2. **Presence of water flow patterns:** Water flow patterns are none to rare. Short intermittent flow patterns may increase after a prescribed fire, especially if the site hasn't greened up before an intense rainfall event. Occasionally deer trails run diagonally up slope and are a place where water flow patterns follow.

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3. **Number and height of erosional pedestals or terracettes:** Pedestals are none to few. Wind pedestals are none. Terracettes are few to common. If the site has bedrock ledges or cliffs above, it tends to funnel wild life or human trails.

These trails are typically along the contour below movement restricting sandstone ledges or cliffs. There can be a series of parallel terracettes that result in this way. The terracettes may not be continuous for any distance. Bare ground is usually associated with terracettes resulting from wildlife trails.

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4. **Bare ground from Ecological Site Description or other studies (rock, litter, lichen, moss, plant canopy are not bare ground):** Bare Ground is noticeable amidst the thin short grass cover. After a fire bare ground increase. Bare Ground ranges from 13-41% depending mostly upon the time elapsed since the last fire. After an early spring fire, bare ground can be 37-41%. If there hasn't been a fire for a couple of years, bare ground can range from 13 -41%. The steepest slopes and the most convex/convex slope shape areas would be expected to have the most bare ground. Bare ground would expect to increase to more than 37% the first year following a prescribed fire. Multi-year droughts can also increase bare ground.

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5. **Number of gullies and erosion associated with gullies:** Typically there are none. If the base of the bluff prairie slope is being cut by a river, gullies can work their way up and into this ecological site.

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6. **Extent of wind scoured, blowouts and/or depositional areas:** None.

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7. **Amount of litter movement (describe size and distance expected to travel):** Litter movement is rare to none. If litter movement is present, it is along wildlife trails running up slope. But even along deer trails litter movement occurs only for short distances. Litter movement would be expected to be the greatest following an intense thunder storm shortly after a fire.

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8. **Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):** Soil surface resistance to erosion is good. Soil stability values should be 3 to 6 on most soil textures found on this site.

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9. **Soil surface structure and SOM content (include type of structure and A-horizon color and thickness):** Surface structure is typically granular. Soil surface colors are very dark grayish brown to very dark brown - mollic colors. Soils are may or may not have a mollic epipedon. Organic matter of the surface 3 to 11 inches is about 3 percent, dropping off rapidly below.

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10. **Effect of community phase composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:** Changes in plant community composition are expected around sandstone ledges and cliffs where shrubs and immature trees may encroach and shade out grassy species. Runoff increases around bedrock outcrops. Short steep slope breaks on convex/convex shoulders often have higher percentages of rock fragments on the surface and thinner shorter herbaceous cover resulting in lower infiltration and higher runoff. Drainageways and areas with linear/linear or linear/concave slope shape may have a higher percent cover coming from shrubs or small trees and also tend to have higher percent cover of taller grasses and generally thicker herbaceous cover.

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11. **Presence and thickness of compaction layer (usually none; describe soil profile features which may be**

mistaken for compaction on this site): Compacted layers are none.

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12. **Functional/Structural Groups (list in order of descending dominance by above-ground annual-production or live foliar cover using symbols: >>, >, = to indicate much greater than, greater than, and equal to):**

    Dominant: Deep-rooted, warm season, perennial grasses, perennial forbs, short shrubs (lead plant and smooth sumac)

    Sub-dominant: cool season annual forbs

    Other:

    Additional: After prescribed fires, the functional/structural dominance of perennial forbs increases and shrubs decrease. With lengthening duration of fire return shrubs increase and small trees begin to appear.

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13. **Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence):** No or little plant mortality is apparent. Most of the perennial plants are long-lived. After a fire dead shrubs and small trees map persist for a time.

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14. **Average percent litter cover (%) and depth (in):** Litter cover ranges from 30-68%. After prescribed fires, litter cover and depth decreases dramaticly. Because annual production is relatively low, it may take several to five growing seasons for litter to reach pre-fire levels.

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15. **Expected annual annual-production (this is TOTAL above-ground annual-production, not just forage annual-production):** For normal or average growing season (end of July beginning of August) ± 915 lbs/ac; Favorable years ± 1017 lbs/ac and unfavorable years ± 610 lbs/ac.

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16. **Potential invasive (including noxious) species (native and non-native). List species which BOTH characterize degraded states and have the potential to become a dominant or co-dominant species on the ecological site if their future establishment and growth is not actively controlled by management interventions. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants. Note that unlike other indicators, we are describing what is NOT expected in the reference state for the ecological site:** Potential invaders are mostly woody species and include: eastern redcedar, smooth sumac, gray dogwood, several Rubus species, common buckthorn, honeysuckle, paper birch, quaking aspen, burr oak, black oak, and common juniper. Potential herbaceous invaders include: Kentucky bluegrass, and sweetclover.

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17. **Perennial plant reproductive capability:** All functional groups should reproduce in average (or normal) and above average growing season years. Only limitations to reproductive capability are weather related, natural disease, insect infestations, or combinations of all of the disturbances.
