WESTERN GREAT PLAINS CLIFF, OUTCROP AND SHALE BARREN ECOLOGICAL SYSTEM

ECOLOGICAL INTEGRITY ASSESSMENT

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Prepared by: Karin Decker

Colorado Natural Heritage Program
Colorado State University
254 General Services Building
Fort Collins, CO 80523

Table of Contents

ECOLOGICAL INTEGRITY ASSESSMENT

A. INTRODUCTION

A.1 Classification Summary

CES303.665 Western Great Plains Cliff and Outcrop

Classifiers:

Landcover class:	Barren
Spatial Scale & Pattern:	Small patch
Classification Confidence:	Moderate
Required Classifiers:	Natural/Seminatural, Upland
Diagnostic Classifiers:	
Non-Diagnostic Classifiers:	Cliff (Landform) Very Shallow Soil Ustic Flood Scouring Wind: High intensity, patch-scale

U.S. Distribution: CO, KS, MT, ND, NE, NM, OK, TX
Global Range: This system ranges throughout the Western Great Plains Division from northern Texas to southern Canada.
Primary Biogeographic Division: 303 – Western Great Plains
TNC Ecoregions:

26	Northern Great Plains Steppe	Confident or certain
27	Central Shortgrass Prairie	Confident or certain
28	Southern Shortgrass Prairie	Confident or certain
33	Central Mixed-Grass Prairie	Confident or certain
37	Osage Plains/Flint Hills Prairie	Predicted or probable
66	Aspen Parkland	Predicted or probable
67	Fescue-Mixed Grass Prairie	Predicted or probable

Concept Summary: This system includes cliffs and outcrops throughout the Western Great Plains Division. Substrate can range from sandstone and limestone, which can often form bands in the examples of this system. Vegetation is restricted to shelves, cracks and crevices in the rock. However, this system differs from Western Great Plains Badlands (CES303.663) in that often the soil is slightly developed and less erodible, and some grass and shrub species can occur at greater than 10%. Common species in this system include short shrubs such as *Rhus trilobata* and *Artemisia longifolia* and mixedgrass species such as *Bouteloua curtipendula* and *Bouteloua gracilis* and *Calamovilfa longifolia*. Drought and wind erosion are the most common natural dynamics affecting this system.

This system includes cliffs, outcrops, breaks and barrens throughout the Western Great Plains. Substrates are variable from north to south, and can include sandstone, limestone, clay, siltstone, and shale. Vegetation patterns are also variable across the range of the system, and species composition changes with changing latitude.

Similar Ecological Systems
CES303.663 Western Great Plains Badlands
CES303.664 Southwestern Great Plains Canyon

Component Associations

ALLIANCE/Association name	Element code	G rank
ARENARIA HOOKERI BARRENS HERBACEOUS ALLIANCE (A.1642)		
Arenaria hookeri Barrens Herbaceous Vegetation	CEGL001951	GU
ARTEMISIA LONGIFOLIA SPARSELY VEGETATED ALLIANCE (A.1874)		
Artemisia longifolia - Calamovilfa longifolia Sparse Vegetation	CEGL001521	G3G4
FRANKENIA JAMESII DWARF-SHRUBLAND (PROPOSED)		
Frankenia jamesii/ Achnatherum hymenoides [undescribed]	CPSAFRJA0A	---
Glossopetalon spinescens var. meionandrum - Frankenia jamesii [undescribed]	---	---
JUNIPERUS MONOSPERMA WOODLAND ALLIANCE (A.504)		
Juniperus monosperma / Bouteloua curtipendula Woodland	CEGL000708	G5
Juniperus monosperma / Bouteloua eriopoda Woodland	CEGL000709	GNR
Juniperus monosperma / Bouteloua gracilis Woodland	CEGL000710	G5
Juniperus monosperma / Cercocarpus montanus - Ribes cereum Woodland	CEGL000714	GU
Juniperus monosperma / Cercocarpus montanus Woodland	CEGL000713	GNR
Juniperus monosperma / Hesperostipa neomexicana Woodland	CEGL000722	G4
LESQUERELLA (GORDONII, OVALIFOLIA) HERBACEOUS ALLIANCE (A.1619)		
Lesquerella (gordonii, ovalifolia) - Schizachyrium scoparium Herbaceous Vegetation	CEGL004917	G2G3
OPEN CLIFF SPARSELY VEGETATED ALLIANCE (A.1836)		
Limestone Butte Sparse Vegetation	CEGL002296	GNR
Sandstone Butte Sparse Vegetation	CEGL002297	GNR
Sandstone Dry Cliff Sparse Vegetation	CEGL002045	G4G5
Sandstone Great Plains Xeric Butte - Bluff Sparse Vegetation	CEGL002290	GNR
Sandstone Great Plains Dry Cliff Sparse Vegetation	CEGL005257	G4G5
ROCK OUTCROP SPARSELY VEGETATED ALLIANCE (A.1838)		
Siltstone - Sandstone Rock Outcrop Sparse Vegetation	CEGL002047	G4?
Shale Barren Slopes Sparse Vegetation	CEGL002294	GNR

A.2 Ecological System Description

A.2.1 Environment

The Western Great Plains landscape is generally characterized by relatively low topographic relief, but does include numerous scattered outcrops and erosional features that interrupt the relative flatness of the landscape. The action of the South Platte River to the north, and the Arkansas River to the South have removed great volumes of Tertiary (65- to 2-million-year-old) sedimentary rock layers of the Great Plains in Colorado, leaving remnants of higher ground here and there in the Colorado Piedmont. Along the mountain front the layers of older sedimentary rock have been sharply upturned by the rise of the Rocky Mountains. These differentially eroded layers form conspicuous hogback ridges of hard sandstone and limestone. At the northern edge of Colorado, a scarp cut in the rocks of the High Plains forms the Chalk Bluffs. The Pawnee Buttes are two of the more conspicuous outliers of High Plains rocks near the scarp, as is Scotts Bluff in Nebraska. To the south, the Arkansas River has excavated much of the Tertiary piedmont deposits and exposed Cretaceous marine rocks from Canon City to the Kansas border (Trimble 1980). Mountain-front hogbacks are found here as well. Near the Palmer divide north of Colorado Springs, outcrops are formed by caprock of resistant Oligocene Castle Rock Conglomerate on mesas and buttes. These and other outcrops of the Great Plains are exceptional in having escaped the nearly continuous mantle of windblown sand and silt that softens much of the rest of the Colorado Piedmont (Trimble 1980).

Climate

The western Great Plains has a continental climate with both east-west and north-south gradients. Over the central plains, precipitation decreases from east to west, while temperatures and day-lengths increase from north to south. Mean summer rainfall decreases very sharply westward from the 100th meridian, especially in the summer months (Borchert 1950). Mean annual precipitation decreases from 40-60 in. east of the Mississippi River to about 10 in. in the western part of the central shortgrass Prairie, with an abrupt increase to around 18-23 inches in the narrow strip just east of the Rocky Mountains (Hansen et al. 1978). Although the number of wet days is essentially the same from west to east at a given latitude, the amount of precipitation from any single storm event is generally higher toward the east (Borchert 1950).

Geology and soils

In northeastern Colorado this ecological system includes rimrock and erosional remnants of the High Plains escarpment stretching for many miles north of the South Platte River, as well as other isolated buttes and outcrops to the south. Topography ranges from steep rocky bluffs below the escarpments and buttes with intervening swales or gullies to smaller breaks and barrens with gentle slopes. The Ogallala, Arikaree, and White River Formations are the most common cliff and outcrop forming substrates, consisting primarily of sandstones of varying hardness, and often interspersed with limestone, ashy claystone, or volcanic tuff (Tweto 1979). Shale barrens of the Niobrara and Pierre Formations are also found near the mountain front, where they are associated with conspicuous hogbacks along foothills of the Colorado Front Range. Aspects are often north and east facing, but the system can occur on other exposures. Slopes are variable from less than 5% to greater than 50% (Riedel 2007).

In southeastern Colorado, occurrences of this system are most often found Cretaceous bedrock of the Middle and Upper Chalk members of the Smoky Hills Member of the Niobrara Formation. The area between Pueblo and Cañon City contains the highest frequency of such shale barrens in southeastern Colorado (Kelso 1999). Slope angles range from flat on summits to moderately steep on side slopes, and exposures are variable, depending on how uplift, regional erosion, or downcutting has occurred (Kelso 1999). Sites feature highly weathered bedrock on the surface, consisting of small flat pieces less than four centimeters long that form a thin surface layer with shallow mineral soil underneath (Kelso et al. 2003). Soils belong to the Penrose series and are typically shallow and fine-grained, with about 60 percent of the particles composed of silts and clays. Soil pH tends to be alkaline with a range from 7.4 to 8.3 (Kelso et al. 2003). Summit flats have shallower soils than slopes, with slope bottoms generally deeper than slope tops (Kelso 1999). In the southern portion of the Western Great Plains, occurrences of this system may be inclusions in the Southwestern Great Plains Canyon ecological system complex.

Barrens are generally found on shales, soft limestone (chalk), or shale-derived soils, and are characterized by a high percentage of open, rocky ground between the low-growing shrubs and herbaceous cover. Some occurrences have an overstory of sparse juniper, and may include scattered larger shrubs and bunchgrasses. Shale substrates often form a rocky "pavement" between plants. In the Central Shortgrass Prairie ecoregion, this system may provide suitable habitats for northward range extension of species that are more typical further south (Kelso 1999).

A.2.2 Vegetation & Ecosystem

Cliffs and outcrops support a variety of plant communities, depending on the steepness, exposure, and soil conditions of the site. The tops of the escarpment are often dominiated by the adjacent shortgrass or mixedgrass prairie communities. Vegetation of the cliffs and outcrops is typically sparse, and often restricted to shelves, cracks and crevices in the rock, or other areas where soil accumulation allows growth. The lack of vegetation on many sites protects them from fire, and in a few instances the rocky cliffs support disjunct populations of foothills species such as *Pinus ponderosa, Juniperus scopulorum, Pinus flexilis,* and *Cercocarpus montanus*. Sheltered areas on the bluff slopes typically support sparse shrub cover of *Rhus trilobata, Prunus virginiana, Ribes* spp., *Artemisia filifolia, Gutierrezia sarothrae, Opuntia polyacantha,* and *Yucca glauca*, along with prairie grasses such as *Bouteloua gracilis, Aristida longiseta, Hesperostipa comata*, *Bouteloua curtipendula*, *Calamovilfa longifolia* and *Vulpia octoflora*. Claystone and limestone layers within the sandstone form gravelly barrens that support a characteristic "cushion plant" community that typically includes *Arenaria hookeri, Oenothera caespitosa, Phlox hoodii, Tetraneuris acaulis, Astragalus sericoleucus*, and other species typical of the nearby grasslands. These barrens are also home to the regionally rare plants *Lomatium (Aletes) nuttallii, Cryptantha cana* and *Parthenium (Bolophyta) alpinum*. Along the mountain front in northeastern Colorado, shale outcrops support populations of the local endemic *Physaria bellii,* often in association with communities of *Hesperostipa comata - Achnatherum hymenoides* or *Hesperostipa neomexicana.*

In the southwestern portion of the Central Shortgrass Prairie ecoregion, vegetation is characterized by a "cushion-plant" community, with cover less than 25%, and often much lower. Some occurrences may support a sparse overstory of *Juniperus monosperma.* Typical shrub species are *Frankenia jamesii, Glossopetalon meionandra, Atriplex canescens*, and *Artemisia bigelovii.* Perennial low-growing forbs and sub-shrubs include *Tetraneuris acaulis, Eriogonum* spp., *Oxybaphus rotundifolius, Lesquerella fendleri*, *Chamaesyce glyptosperma, Townsendia hookeri, Melampodium leucanthum*, *Zinnia grandiflora, Crypthantha* spp., and *Oönopsis foliosa*. Occurrences may include low cover of bunchgrasses such as *Hesperostipa neomexicana, Achnatherum hymenoides*, *Aristida purpurea,* and *Bouteloua* spp.. Along with the substrate, wind appears to be an important factor shaping the appearance of this system. As this community grades into adjacent communities in more sheltered areas below ridgetops, cover and plant height increases.

Shale barrens often support populations of narrowly endemic species. Kelso et al. (2003) found that plants endemic to the Niobrara chalk barrens in Colorado's Arkansas River Valley did not require the specialized chemistry of the chalk substrate, but rather were functionally adapted to survive in these habitats that exclude many species. Many of the barrens species have woody rhizomes or roots that are able to penetrate the thin, moisture-retentive chalk strata, allowing the plants to access limited soil moisture, and making them resistant to disturbance (Kelso et al. 2003).

Ecosystem processes
Little is known about biogeochemistry and nutrient cycling in this system. Productivity is generally low; both soil nutrients and moisture are probably limiting. These areas are dominated by the few species that can utilize barren areas with limited soil development.

A.2.3 Dynamics

Cliffs, outcrops, and barrens often serve as refugia for endemic species adapted to the particular environmental conditions of the site. Although fire can be an important element that slows or eliminates tree establishment in many of these habitats, the shallow soils over bedrock, and extremes of climate or microclimate, are important factors as well (Anderson, Fralish, and Baskin 1999). For rock outcrop communities with extensive exposed bedrock, fire is typically not an important factor. Differences in microhabitat between rock outcrop sites and the surrounding habitats with deeper soils produce distinctive vegetation of these sites.

Little is known about the system-level effects of disturbance, natural or anthropogenic, in many of these occurrences. Kelso et al. (2003) found no significant effect of disturbance by cattle grazing, camping, road proximity, motorcycle racing, or tracked vehicle maneuvers on the presence of *Mirabilis rotundifolius* in southeastern Colorado. Some barrens species are not well adapted to disturbance, so moderate disturbance produces distinctive plant communities dominated by species that tolerate these activities (Kelso et al. 1999, 2003). Natural disturbance by wind and water erosion may have similar effects, leading to the differentiation of plant communities according to microsite characteristics.

A.2.4 Landscape

Small patch communities usually have discrete boundaries, occur in very specific ecological settings, such as on specialized landform types or in unusual microhabitats, and are strongly linked to and dependent upon the local landscape conditions. The specialized conditions of small patch communities, however, are often dependent on the maintenance of ecological processes in the surrounding matrix and large patch communities. (Anderson et al. 1999).

These communities are closely tied to edaphic conditions, so minor breaks or small barriers due to changes in substrate are part of the natural distribution and variability. If the breaks are larger, barriers may exist for some species. Primary criteria to be considered are the reaction of native species to fragmentation, seed dispersal by dominant plants, and the dispersal behavior and requirements of invertebrates, small mammals and birds.

A.2.5 Size

Very large examples of many of these communities are probably naturally rare in the Central Shortgrass Prairie ecoregion. Furthermore, occurrence size criteria may not be as critical for small patch communities as it is for matrix-forming communities (Anderson et al. 1999). The current condition, historical continuity, and landscape context may contribute more to the diversity of an occurrence than size, although the species-area relationship still applies for small patch type communities.

The largest occurrences of this system (>1000 acres) would likely contain sufficient internal variability to capture characteristic biophysical gradients and retain natural geomorphic disturbance, and may survive accelerated erosion disturbance problems. They are large enough that most of the occurrence is buffered from edge effects. Very small occurrences (< 10 ac) are too small to remain viable with altered natural geomorphic processes and contain insufficient area to maintain a diversity of plant associations. They are also extremely susceptible to invasions by non-natives making them subject to loss of characteristic plant associations and their associated plants and animals.

A.3 Ecological Integrity

A.3.1 Threats

Lists and describes the actual or potential impact of anthropogenic threats to the system.

Non-consumptive biological resource use

A primary threat to this system is anthropogenic surface disturbance that leads to change in soil structure or change in vegetation structure. In the Central Shortgrass Prairie ecoregion, such disturbance is primarily due to military training activities, or to recreational use. Tracked vehicles ("tanks") are exceptional in their ability to dramatically change soil structure in a single pass. Although some native communities are able to recover from occasional heavy disturbance during tracked vehicle maneuvers (Milchunas et al. 1999), and at least one possibly disturbance-dependant species was able to expand into disturbed areas (Schulz and Shaw 1992), the long term effects of such use are unknown. At least some of the occurrences at Fort Carson and Piñon Canyon Maneuver Site are likely to be exposed to disturbance by tracked vehicles during training maneuvers, especially if frequency of use increases. Many of the occurrences of this system along the mountain are found on public (open space) lands where recreational use can be a major source of disturbance.

Abiotic resource use
Along the Colorado Front Range, sandstone and limestone outcrops are quarried for a variety of uses. This activity essentially destroys the habitat for these communities.

Habitat conversion
Land use within the outcrop area as well as in adjacent areas can fragment the landscape and reduce connectivity between patches and between outcrops and the surrounding landscape. This fragmentation can adversely affect the movement of surface/ groundwater, nutrients, and dispersal of plants and animals. In the Colorado Front Range, many of these habitats are in areas that are highly desirable for suburban development, roads, or recreational infrastructure.

Invasive species
In some occurrences of this system, invasive species are considered only a low threat because the limited soil development and extreme edaphic conditions render the substrate less habitable for both native and exotic species. Nonetheless, exotic or invasive species reported from Niobrara outcrops along the Colorado Front Range include *Bromus inermis, B. japonicus, Cirsium* spp., *Euphorbia esula, Melilotus* spp (Supples 2001) *Acosta diffusa, Convolvulus arvensis,* and *Alyssum alyssoides* (Carpenter 1997).

A.3.2 Justification of Metrics

<u>Landscape Context</u>: Land use in the adjacent land as well as in the larger surrounding landscape has important effects on the connectivity and sustainability of many ecological processes critical to this system. The amount and configuration of natural landscape will determine the degree to which natural processes such as fire and species dispersal can function or be simulated by management.

<u>Biotic condition</u>: Species composition and diversity, presence of conservative plants, regeneration, and invasion of exotics are important measures of biological integrity.

<u>Abiotic Condition</u>: Disturbance patterns that are beyond the natural range of variability for this system can affect community structure and composition, as well as nutrient cycling and other abiotic processes.

<u>Size</u>: Absolute size is important for consideration of conservation values as well as ecosystem resilience. Absolute size relative to potential size provides information regarding historical loss or degradation of occurrence size.

A.3.3 Ecological Integrity Metrics

A synopsis of the ecological metrics and ratings is presented in Table 1. The three tiers refer to levels of intensity of sampling required to document a metric. Tier 1 metrics are able to be assessed using remote sensing imagery, such as satellite or aerial photos. Tier 2 typically require some kind of ground sampling, but may require only qualitative or semi-quantitative data. Tier 3 metrics typically require a more intensive plot sampling or other intensive sampling approach. A given measure could be assessed at multiple tiers, though some tiers are not doable at Tier 1 (i.e., they require a ground visit). The focus for this System is primarily on a Tier 2 approach.

Core and Supplementary Metrics
The Scorecard (see Tables 1 & 2) contains two types of metrics: Core and Supplementary. Separating the metrics into these two categories allows the user to adjust the Scorecard to available resources, such as time and funding, as well as providing a mechanism to tailor the Scorecard to specific information needs of the user.

Core metrics are shaded gray in Tables 1 & 2 and represent the minimal metrics that should be applied to assess ecological integrity. Sometimes, a Tier 3 Core metric might be used to replace Tier 2 Core Metrics. For example, if a Vegetation Index of Biotic Integrity is used, then it would not be necessary to use similar Tier 2 Core metrics such as Percentage of Native Graminoids, Percentage of Native Plants, etc.

Supplementary metrics are those which should be applied if available resources allow a more in depth assessment or if these metrics add desired information to the assessment. Supplementary metrics are those which are not shaded in Tables 1 & 2

A.4 Scorecard Protocols

For each metric, a rating is developed and scored as A – (Excellent) to D – (Poor). The background, methods, and rationale for each metric are provided in section B. Each metric is rated, then various metrics are rolled together into one of four categories: Landscape Context, Biotic Condition, Abiotic Condition, and Size. A point-based approach is used to roll-up the various metrics into Category Scores.

Points are assigned for each rating level (A, B, C, D) within a metric. The default set of points are A = 5.0, B = 4.0, C = 3.0, D = 1.0. Sometimes, within a category, one measure is judged to be more important than the other(s). For such cases, each metric will be weighted according to its perceived importance. Points for the various measures are then added up and divided by the total number of metrics. The resulting score is used to assign an A-D rating for the category. After adjusting for importance, the Category scores could then be averaged to arrive at an Overall Ecological Integrity Score.

Supplementary metrics are not included in the Rating Protocol. However, they could be incorporated if the user desired.

Table 1. Overall Set of Metrics for the Western Great Plains Cliff, Outcrop and Shale Barren System.

Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive. Shading indicates core metrics.

Category	**Essential Ecological Attribute**	**Indicators / Metrics**	**Tier**
LANDSCAPE CONTEXT	Landscape Composition	Adjacent land use	1
		Buffer width	1
		Percentage of unfragmented landscape within 1 km	1
BIOTIC CONDITION	Community Composition	Percent cover of native plant species	2
		Floristic quality index	3
		Presence and abundance of noxious spp.	2, 3
	Patch Diversity	Patch structure - variety	2
		Patch structure - interspersion	2
	Indicator species	Status of endemic species	2, 3
ABIOTIC CONDITION	Energy/Material Flow	Soil erosion & compaction	2, 3
		Disturbance & Fragmentation – land use within occurrence	1, 2
SIZE	Size	Total area of system occurrence	1
		Area of system occurrence in best Biotic and Abiotic Condition class	1

Table 2. Metrics and Rating Criteria for the Western Great Plains Cliff, Outcrop and Shale Barren System.

Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive. (Alpha-numeric codes in parentheses is reference to the metric ID and corresponds to the section in which the metric is described). Confidence column indicates that reasonable logic and/or data support the index. Shading indicates core metrics.

Category	**Essential Ecological Attributes**	**Indicators/ Metics**	**Tier**	**Metric Ranking Criteria**			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
LANDSCAPE CONTEXT	Landscape Compostion	Adjacent land use (B.1.1)	1	Average land use score = 1.0 – 0.95	Average land use score = 0.80 – 0.95	Average land use score = 0.40 – 0.80	Average land use score = <0.40
		Buffer width (B.1.2)	1	Wide >500m	Medium 250 – 500m	Narrow 100 – 250m	Very narrow < 100 m
	Landscape Pattern and Process	Percentage of unfragmented landscape within 1 km. (B.1.3)	1	Embedded in 90-100% unfragmented, roadless natural landscape; internal fragmentation absent	Embedded in 60-90% unfragmented natural landscape; internal fragmentation minimal	Embedded in 20-60%% unfragmented natural landscape; Internal fragmentation moderate	Embedded in < 20% unfragmented natural landscape. Internal fragmentation high
BIOTIC CONDITION	Community composition	Percent cover of native plant species (B.2.1)	2	100% cover of native plant specis	85-100% cover of native plant specis	50-85% cover of native plant specis	<50% cover of native plant specis
		Floristic quality index (Mean C) (B.2.2)	3	>4.5	3.5 – 4.5	3.0 – 3.5	<3.0
		Presence and abundance of noxious species (B.2.3)		Invasive exotics with major potential to alter structure and composition are absent	Invasive exotics with major potential to alter structure and composition occupy less than 1% of occurrence.	Invasive exotics with major potential to alter structure and composition occupy less than 3% of occurrence.	Invasive exotics with major potential to alter structure and composition occupy more than 5% of occurrence.
	Community Extent	Patch structure – variety (B.2.5)	2	> 75-100% of possible patch types are present in the occurrence	> 50-75% of possible patch types are present in the occurrence	25-50% of possible patch types are present in the occurrence	< 25% of possible patch types are present in the occurrence
		Patch structure – interspersion	2	Horizontal structure consists of a very	Horizontal structure consists of a	Horizontal structure consists of a simple	Horizontal structure consists

Category	**Essential Ecological Attributes**	**Indicators/ Metics**	**Tier**	**Metric Ranking Criteria**			
				Excellent (A)	Good (B)	Fair (C)	Poor (D)
		(B.2.6)		complex array of nested and/or interspersed, irregular biotic/abiotic patches, with no single dominant patch type	moderately complex array of nested or interspersed biotic/abiotic patches, with no single dominant patch type	array of nested or interspersed biotic/abiotic patches.	of one dominant patch type and thus has relatively no interspersion
		Status of endemic barrens species (B.2.6)	2, 3	Present at natural levels of abundance, with evidence of successful reproduction	Present at near natural levels of abundance, with evidence of successful reproduction	Present, but reproduction not often observed, numbers may be declining	Populations in decline.
ABIOTIC CONDITION	Energy/ Material Flow	Soil erosion & compaction (B.3.1)	2,3	Score = 4.5-5.0	Score = 3.5-4.4	Score = 2.5-3.4	Score = 1.0-2.4
		Land use within the occurrence (B.3.2)	1, 2	Average land use score = 1.0 – 0.95	Average land use score = 0.80 – 0.95	Average land use score = 0.40 – 0.80	Average land use score = <0.40
SIZE	Size	Total area of system occurrence (B.4.1)	1	> 500 acres	100-500 acres	10-100 acres	< 10 acres
		Area of system occurrence in best Biotic and Abiotic Condition class (B.4.2)	1	> 500 acres	100-500 acres	10-100 acres	< 10 acres

A.4.1 Landscape Context Rating Protocol

Rate the Landscape Context metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 3) to roll up the metrics into an overall Landscape Context rating.

<u>Rationale for Scoring:</u> Adjacent land use, buffer width, and connectivity of the occurrence are judged to be more important than the amount of fragmentation within 1 km of the occurrence since an occurrence with no other natural communities bordering it is very unlikely to have a strong biological connection to other natural lands at a further distance.

The following weights apply to the Landscape Context metrics:

Table 3. Landscape Context Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight	Score (weight x rating)
Adjacent Land Use (B.1.1)	Addresses the intensity of human dominated land uses within 100 m of the occurrence.	1	5	4	3	1	0.40	
Buffer Width (B.1.2)	Buffers are vegetated, natural (non-anthropogenic) areas that surround an occurrence.	1	5	4	3	1	0.30	
Percentage of unfragmented landscape within 1 km. (B.1.3)	An unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems.	1	5	4	3	1	0.30	
Landscape Context Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

A.4.2 Biotic Condition Rating Protocol

Rate the Biotic Condition metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 4) to roll up the metrics into an overall Biotic Condition rating.

<u>Rationale for Scoring</u>: The Floristic Quality Index (FQI) metric is judged to be more important than the other metrics as the FQI provides a more reliable indicator of biotic condition.

Scoring for Biotic Condition is a bit more complex. For example, the Floristic Quality Index (FQI) may or may not be assessed, depending on resources (since it is a Tier 3 metric). If it is included then the weights without parentheses apply to the Biotic

Condition metrics. If FQI is not included then the weight in parentheses is used for the Tier 2 metrics.

Table 4. Biotic Condition Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Percent of Cover of Native Plant Species (B.2.1)	Percent of the plant species which are native to the Southern Rocky Mountains.	2	5	4	3	1	0.20 (0.70)	
Floristic Quality Index (Mean C) (B.2.2)	The mean conservatism of all the native species growing in the occurrence.	3	5	4	3	1	0.60 (N/A)	
Presence and abundance of noxious species (B.2.3)	Presence/abundance of invasive exotics with major potential to alter structure and composition of system.	2	5	4	3	1	0.20 (0.30)	
Biotic Condition Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

* The weight in parentheses is used when metric B.2.2 is not used.

A.4.3 Abiotic Condition Rating Protocol

Rate the Abiotic Condition metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 5) roll up the metrics into an overall Abiotic Condition rating.

Rationale for Scoring: Quantitative water table data are judged to more reliable than the other metrics for indicating Abiotic Condition (shaded metric in Table 5). However, if such data are lacking then stressor related metrics (Land Use & Hydrological Alterations) are perceived to provide more dependable information concerning Abiotic Condition.

Table 5. Abiotic Condition Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Soil erosion & compaction		2,3	5	5	0	0	0.50	
Disturbance & Fragmentation – land use within occurrence	Addresses the intensity of human dominated land uses within the occurrence.	1, 2	5	4	3	1	0.50	
Abiotic Condition Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

A.4.4 Size Rating Protocol

Rate the two measures according to the metrics protocols (see Table 2 and details in Section B). Use the scoring table below (Table 6) to roll up the metrics into an overall Size rating.

Rationale for Scoring: Since the importance of size is contingent on human disturbance both within and adjacent to the wetland, two scenarios are used to calculate size:

(1) When Landscape Context Rating = "A":
Size Rating = Relative Size metric rating (weights w/o parentheses)

(2) When Landscape Context Rating = "B, C, or D".
Size Rating = (weights in parentheses)

Table 6. Size Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Total size (B.4.1)	The current size of the occurrence	1	5	4	3	1	0.0 (0.40)	
Size of area in best condition (B.4.2)	Area of system occurrence in best Biotic and Abiotic Condition class	1	5	4	3	1	1.0 (0.60)	
Size Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

* The weight in parentheses is used when Landscape Context Rating = B, C, or D.

A.4.5 Overall Ecological Integrity Rating Protocol

If an Overall Ecological Integrity Score is desired for a site, then a weighted-point system should be used with the following rules:

1. If Landscape Context = *A* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Landscape Context Score * (0.25)] + [Size Score * (0.15)]**

2. If Landscape Context is *B*, *C*, or *D* AND Size = *A* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Size Score * (0.25)] + [Landscape Context Score * (0.15)]**

3. If Landscape Context is *B*, *C*, or *D* AND Size = *B* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Landscape Context Score * (0.20)] + [Size Score * (0.20)]**

4. If Landscape Context is *B*, *C*, or *D* AND Size = *C* or *D* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Landscape Context Score * (0.25)] + [Size Score * (0.15)]**

The Overall Ecological Rating is then assigned using the following criteria:

A = 4.5 - 5.0
B = 3.5 – 4.4
C = 2.5 – 3.4
D = 1.0 – 2.4

B. PROTOCOL DOCUMENTATION FOR METRICS

Note: Much of the following discussion is adapted from Rocchio (2006).

B.1 Landscape Context Metrics

B.1.1 Adjacent Land Use

Definition: This metric addresses the intensity of human dominated land uses within 500 m of the occurrence.

Background: This metric is one aspect of the landscape context of an individual occurrences of the ecological system.

Rationale for Selection of the Variable: These communities are closely tied to edaphic conditions, so minor breaks or small barriers due to changes in substrate are part of the natural distribution and variability. If the breaks are larger, barriers may exist for some species. Primary criteria to be considered are the reaction of native species to fragmentation, seed dispersal by dominant shrubs, and the dispersal behavior and requirements of invertebrates, small mammals and birds. The intensity of human activity in the landscape has a proportionate impact on the ecological processes of natural systems. Each land use type occurring in the 500 m buffer is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the occurrence (Hauer et al. 2002).

Measurement Protocol: This metric is measured by documenting surrounding land use(s) within 500 m of the occurrence. This should be completed in the field then verified in the office using aerial photographs or GIS. However, with access to current aerial photography and/or GIS data a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use within 100 m of the edge.

To calculate a Total Land Use Score estimate the % of the adjacent area within 500 m under each Land Use type and then plug the corresponding coefficient (Table 7) with some manipulation to account for regional application) into the following equation:

Sub-land use score = ∑ LU x PC/100

where**:** LU = Land Use Score for Land Use Type; PC = % of adjacent area in Land Use Type.

Do this for each land use within 500 m of the occurrence edge, then sum the Sub-Land Use Score(s) to arrive at a Total Land Score. For example, if 30% of the adjacent area was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4

Data:

Table 7. Current Land Use and Corresponding Land Use Coefficients

Current Land Use	Coefficient
Paved roads/parking lots/residential or commercially developed buildings/gravel pit operation/ Energy development (pumping station/ wind machine farm / strip mine) / Live fire range	0.0
Unpaved Roads (e.g., driveway, tractor trail) / Mining / Energy development (well pad, pipeline, exploration) / Tracked vehicle use	0.1
Agriculture (tilled crop production)	0.2
Heavy grazing by livestock / intense recreation (ATV use/camping/popular fishing spot, etc.)	0.3
Logging, chaining, or tree removal with 50-75% of trees >50 cm dbh removed	0.4
Hayed	0.5
Moderate grazing	0.6
Moderate recreation (high-use trail)	0.7
Selective logging or tree removal with <50% of trees >50 cm dbh removed	0.8
Light grazing / light recreation (low-use trail)	0.9
Fallow with no history of grazing or other human use in past 10 yrs	0.95
Natural area / land managed for native vegetation	1.0

Adapted from Table 21 in Hauer et al. (2002).

Scaling Rationale: Land uses have differing degrees of potential impact. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and grazing), while other activities (e.g., hay production and agriculture) may replace native vegetation with nonnative or cultural vegetation yet still provide potential cover for species movement. Intensive land uses (i.e., urban development, roads, mining, etc.) may completely destroy vegetation and drastically alter hydrological processes. The coefficients were assigned according to best scientific judgment regarding the potential impact from each land use (Hauer et al. 2002).

Confidence that reasonable logic and/or data support the index: Medium.

B.1.2 Buffer Width

Definition: Buffers are vegetated, natural (non-anthropogenic) areas that surround an occurrence. This includes woodlands, grasslands, shrublands, natural lakes and ponds, streams, or wetlands.

Background: This metric evaluates one aspect of the landscape context of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: The intensity of human activity in the landscape often has a proportionate impact on the ecological processes of natural systems. The intensity of human activity in the landscape often has a proportionate impact on the ecological processes of natural systems. Buffers are known to reduce potential impacts to wetlands and riparian areas, but their effects on terrestrial ecological systems are less well studied. Although the term "buffer" is retained for this metric, there is insufficient data to confirm that an adjacent natural landscape acts to mitigate the effects of stressors on an occurrence. The relative extent of adjacent natural landscape, however, is potentially important, and is retained until further information is available. This metric may be adequately addressed by the previous metric, or may need to be replaced with some measure of fragmentation.

Measurement Protocol: This metric is measured by estimating the width of the buffer surrounding the occurrence. Buffer boundaries extend from the occurrence edge to intensive human land uses which result non-natural areas. Some land uses such as light grazing and recreation may occur in the buffer, but other more intense land uses should be considered the buffer boundary.

Measurement should be completed in the field then verified in the office using aerial photographs or GIS. Measure or estimate buffer width on four or more sides of the occurrence then take the average of those readings. This may be difficult for large occurrences or those with complex boundaries. For such cases, the overall buffer width should be estimated using best scientific judgment.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Wide > 500 m	Medium. 250 m to 500 m	Narrow. 100 m to 250 m	Very Narrow. < 100 m

Data: N/A

Scaling Rationale: Scaling is based on minimum separation distance for an occurrence.

Confidence that reasonable logic and/or data support the index: Medium.

B.1.3 Percentage of Unfragmented Landscape Within One Kilometer

Definition: An unfragmented landscape is one in which human activity has not destroyed or severely altered the landscape. In other words, an unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc.

between natural ecological systems. Fragmentation results from human activities such as timber clearcuts, roads, residential and commercial development, agriculture, mining, utility lines, railroads, etc.

Background: This metric evaluates one aspect of the landscape context of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: The intensity of human activity in the landscape often has a proportionate impact on the ecological processes of natural systems. The percentage of fragmentation (e.g., anthropogenic patches) provides an estimate of connectivity among natural ecological systems. Although related to metric B.1.1 and B.1.2, this metric differs by addressing the spatial interspersion of human land use as well as considering a much larger area.

Measurement Protocol: This metric is measured by estimating the amount of unfragmented area in a one km buffer surrounding the occurrence and dividing that by the total area. This can be completed in the office using aerial photographs or GIS.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Embedded in 90-100% unfragmented, roadless natural landscape; internal fragmentation absent	Embedded in 60-90% unfragmented natural landscape; internal fragmentation minimal	Embedded in 20-60% unfragmented natural landscape; Internal fragmentation moderate	Embedded in < 20% unfragmented natural landscape. Internal fragmentation high

Data: N/A

Scaling Rationale: Less fragmentation increases connectivity between natural ecological systems and thus allow for natural exchange of species, nutrients, and water. The categorical ratings are based on Rondeau (2001).

Confidence that reasonable logic and/or data support the index: Medium.

<u>B.2 Biotic Condition Metrics</u>

B.2.1 Percent of Cover of Native Plant Species

Definition: Percent of the plant species which are native to the Western Great Plains.

Background: This metric evaluates one aspect of the condition of an individual occurrence of the ecological systems.

Rationale for Selection of the Variable: Occurrences dominated by native species typically have excellent ecological integrity. This metric is a measure of the degree to which native plant communities have been altered by human disturbance. With increasing human disturbance, non-native species invade and can dominate the occurrence.

Measurement Protocol: A qualitative, ocular estimate of cover is used to calculate and score the metric. The entire occurrence of the system should be walked and a qualitative ocular estimate of the total cover of native species growing in the area should be made. Alternatively, if time and resources allow a more quantitative determination of species presence and cover such methods (i.e. Peet et al. 1998) should be used. The metric is calculated by dividing the total cover of native species by the total cover of all species and multiplying by 100.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
100% cover of native plant species	85-< 100% cover of native plant species	50-85% cover of native plant species	<50% cover of native plant species

Data: N/A

Scaling Rationale: The criteria are based on extrapolated thresholds from similar systems in Rondeau (2001), and best scientific judgment. These are tentative hypotheses as they have not been validated with quantitative data.

Confidence that reasonable logic and/or data support the index: High

B.2.2 Floristic Quality Index (Mean C)

Definition: The mean conservatism of all the native species growing in the area.

Background: This metric evaluates one aspect of the condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: Plants are generally adapted to biotic and abiotic fluctuations associated with the habitat where they grow (Wilhelm and Masters 1995). However, when disturbances to that habitat exceed the natural range of variation (e.g. many human-induced disturbances), only those plants with wide ecological tolerance will survive. In contrast, conservative species (e.g. those species with strong fidelity to habitat integrity) will decline or disappear according to the degree of human disturbance (Wilhelm and Master 1995).

The Floristic Quality Index (FQI) is a vegetative community index designed to assess the degree of "naturalness" of an area based on the presence of species whose ecological tolerance are limited (U.S. EPA 2002). See discussion in Rocchio (2007) for additonal information on this method.

A preliminary FQI for Colorado has been developed (Rocchio 2007). However, calibration of the FQI will likely occur over many years of use and this metric should be updated accordingly.

Measurement Protocol: Species presence/absence data need to be collected from the area. Although, quantitative measurements are preferred, depending on time and financial constraints, this metric can be measured with qualitative or quantitative data. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire occurrence of the system and make notes of each species encountered. A thorough search of each macro- and micro-habitat is required. (2) Quantitative Plot Data: The plot method described by Peet et al. (1998) is recommended for collecting quantitative data for this metric. This method uses a 20 x 50 m plot which is typically established in a 2 x 5 arrangement of 10 x 10 m modules. However, the array of modules can be rearranged or reduced to meet site conditions (e.g. 1 x 5 for linear areas or 2 x 2 for small, circular sites). The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods.

The metric is calculated by referencing only native species C value from the Colorado FQI Database, summing the C values, and dividing by the total number of native species (Mean C).

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
> 4.5	3.5-4.5	3.0 – 3.5	< 3.0

Data: Colorado FQI Database (Rocchio 2007).

Scaling Rationale: In the Midwest, field studies using FQI have determined that a site with a Mean C of 3.0 or less is unlikely to achieve higher C values thus this value was used as the Restoration Threshold (between Fair and Poor). In other words, those sites have been disturbed to the degree that conservative species are no longer able to survive and or compete with the less conservative species as a result of the changes to the soil and or hydrological processes on site (Wilhelm and Masters 1995). Sites with a Mean C of 3.5 or higher are considered to have at least marginal quality or integrity thus this value was used as the Minimum Integrity Threshold (between Good and Fair) (Wilhelm and Masters 1995). The threshold between Excellent and Good was assigned based on best scientific judgment upon reviewing the FQI literature. Although it is not know if these same thresholds are true for the Southern Rocky Mountains, they have been used to construct the scaling for this metric. As the FQI is applied in this region, the thresholds may change.

Confidence that reasonable logic and/or data support the index: High

B.2.3 Presence and abundance of invasive species.

Definition: This metric estimates the presence and abundance of invasive species with the potential to alter system functioning.

Background: This metric evaluates one aspect of the biotic condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: Invasives are introduced species that can thrive in areas beyond their natural range of dispersal. These species are generally adaptable, aggressive, and have a high reproductive capacity, so that in the absence of natural enemies they can increase dramatically and displace native species. The worst invasives can change the character of an entire habitat by affecting ecosystem processes like fire, nutrient flow, flooding, etc

Measurement Protocol: This metric is measured by determining the presence and rough abundance of system altering invasive species in the occurrence. This is completed in the field and ocular estimates are used to match the categorical ratings in the scorecard.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
System altering invasive species, such as leafy spurge, Russian knapweed, diffuse knapweed, spotted knapweed, or yellow toadflax are either not present or occupy less than 1 percent of the occurrence, with no patches larger than 1 acre.	System altering invasive species, such as leafy spurge, knapweed species, or yellow toadflax occupy no more than 1-3% of the occurrence with no patches larger than 1 acre.	System altering invasive species, such as leafy spurge, knapweed species, or yellow toadflax occupy 3-5% of the occurrence, with some patches larger than 1 acre	System altering invasive species, such as leafy spurge, knapweed species, or yellow toadflax occupy >5% of the occurrence.

Data: N/A

Scaling Rationale: The criteria are based on extrapolated thresholds from similar systems in Rondeau (2001), and best scientific judgment. These are tentative hypotheses as they have not been validated with quantitative data.

Confidence that reasonable logic and/or data support the index: Medium

B.2.4 Biotic/Abiotic Patch Richness

Definition: The number of biotic/abiotic patches or habitat types present in the occurrence. The metric is not a measure of the spatial arrangement of each patch.

Background: This metric evaluates one aspect of the condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: Spatial heterogeneity (i.e., the types and arrangement of habitat patches within a landscape) can strongly influence the abundance and distribution of species that use a particular habitat (Pulliam et al. 1992) Unimpacted sites have an expected range of biotic/abiotic patches. Human-induced alterations can decrease patch richness.

Measurement Protocol: This metric is measured by determining the number of biotic/abiotic patches present at a site and dividing by the total number of possible patches for the specific type (Table 8). This percentage is then used to rate the metric in the scorecard.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
> 75-100% of possible patch types are present in the occurrence	> 50-75% of possible patch types are present in the occurrence	25-50% of possible patch types are present in the occurrence	< 25% of possible patch types are present in the occurrence

Data:

Table 8. Biotic/Abiotic Patch Types in Cliff, Outcrop and Shale Barrens

Patch Type
Tree canopy
Shrub canopy
Herbaceous canopy - graminoid
Herbaceous canopy - forb
Non-vascular cover
Litter cover
Bare soil
Rock outcrop

TOTAL = 8

Scaling Rationale: Simple quartiles were used. Need additional information about appropriate breaks.

Confidence that reasonable logic and/or data support the index: Medium

B.2.5 Interspersion of Biotic/Abiotic Patches

Definition: Interspersion is the spatial arrangement of biotic/abiotic patch types within the occurrence, especially the degree to which patch types intermingle with each other (e.g. the amount of edge between patches).

Background: This metric evaluates one aspect of the condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: Spatial heterogeneity (i.e., the types and arrangement of habitat patches within a landscape) can strongly influence the abundance and distribution of species that use a particular habitat (Pulliam et al. 1992)

Measurement Protocol: This metric is measured by determining the degree of interspersion of biotic/abiotic patches present in the occurrence. This can be completed in the field for most sites, however aerial photography may be beneficial for larger sites. The metric is rated by matching site interspersion with the categorical ratings in the scorecard.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Horizontal structure consists of a very complex array of nested and/or interspersed, irregular biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a moderately complex array of nested or interspersed biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a simple array of nested or interspersed biotic/abiotic patches,	Horizontal structure consists of one dominant patch type and thus has relatively no interspersion

Data: See B.2.4 for list and definitions of Biotic Patches.

Scaling Rationale: In the absence of quantitative data, the scale is based on guidelines for professional judgment.

Confidence that reasonable logic and/or data support the index: Medium

B.2.6 Status of endemic species

Definition: This metric assesses the status of plant species that are characteristic of chalk, or shale substrates.

Background: Endemic species of barrens and shale or chalk substrates are among the most threatened and least protected plants (Decker et al. 2007).

Rationale for Selection of the Variable: The status of chalk/shale endemics is not captured by any of the other metrics. Not every occurrence of this system will be expected to support these species. When chalk/shale endemics are expected to be present, however, the condition of their occurrence is likely to reflect the condition of the system occurrence as a whole. This metric is designated as non-core because these species are not necessarily present on every occurrence of the system, and because of the difficulty of obtaining data.

Measurement Protocol: Endemic species present and rough abundances are determined by population counts or estimates in the field. Species data are compared to expected or previously measured data to determine rating. Appropriate means of comparison need to be developed. With further research, this measurement may potentially be replaced by a more targeted measurement of selected indicator species.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Characteristic endemic species present at natural levels of abundance, with evidence of successful reproduction	Characteristic endemic species present at near natural levels of abundance, with evidence of successful reproduction	Some characteristic endemic present, but reproduction not often observed, numbers may be declining	Few or no endemics present when they are expected to occur. Populations in decline.

Data: Previous observations (e.g. CNHP element occurrence records, other survey or monitoring data) may provide a basis for appropriate species and abundances, but more data will likely be needed to characterize the life histories of these species and the determine the natural range of variation in population dynamics.

Scaling Rationale: In the absence of quantitative data, the scale is based on guidelines for professional judgment.

Confidence that reasonable logic and/or data support the index: High for inclusion of the index. Medium to low for the specific measures and thresholds.

<u>B.3 Abiotic Condition Metrics</u>

B.3.1 Soil erosion & compaction

Definition: An index measure of the degree to which erosion and soil compaction are out of the range of natural variation.

Background: This metric evaluates one aspect of the abiotic condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: The functional integrity of this ecological system type is dependent in part on the the integrity of the soil surface (National Research Council 1994, Smith et al. 1995). The selected variables are part of a more comprehensive assessment of rangeland health that is focused on soil condition (Pellant et al. 1995).

Measurement Protocol: This metric is estimated in the field by observing overland water flow patterns, signs of rill formation and wind scour, the presence of pedestals and terrecettes, drainage patterns, bare ground, and soil compaction.

Metric Rating: Assign each of the six metrics in Table 9 an Excellent, Good, Fair, or Poor rating on the scorecard. Use the scores and weights shown to compile a final score.

Table 9. Soil erosion and compaction scoring.

Metric (weight)	Excellent Score = 5	Good Score =4	Fair Score = 3	Poor Score = 1	Score (weight x rating)
Water patterns (0.10)	Minimal evidence of past or current soil deposition or erosion.	Matches what is expected for the site; erosion is minor with some instability and deposition	More numerous than expected; deposition and cut areas common; occasionally connected.	Water flow patterns may be extensive and numerous; unstable with active erosion; usually connected.	
Rills, wind scour (0.10)	Slight to no evidence	Some evidence of rill formation or accelerated wind scour	Rill formation or accelerated wind scour may be moderately active and well defined throughout most of the occurrence.	Rill formation or accelerated wind scour may be severe and well defined throughout most of the occurrence	
Pedestals and/or Terracets (0.10)	Absent or uncommon.	Occasionally present	Common	Abundant	
Drainages (0.10)	Represented as natural stable channels with no signs of unnatural erosion.	Represented as natural stable channels with only slight signs of unnatural erosion.	Gullies may be present with indications of active erosion; vegetation is intermittent on slopes. Headcuts are active; downcutting is apparent	Gullies common, with indications of active erosion and downcutting; vegetation is infrequent on slopes or bed of gully.	
Bare Ground (0.10)	Bare areas are no higher than expected for the substrate.	Bare areas are moderately larger than expected size and only sporadically connected.	Bare ground is moderate to much higher than expected for the site. Bare areas are large and may be connected.	Much higher than expected for the site. Bare areas are large and generally connected.	

Soil compaction (0.50)	Soils are not compacted and are not restrictive to water movement and root penetration.	Soil compaction moderately widespread and moderately restricts water movement and root penetration.	Soil compaction widespread and greatly restricts water movement and root penetration.	Soil compaction is extensive throughout the occurrence, severely restricting water movement and root penetration	
Final rating:	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4				**Total = sum of N scores**

Data: Based on Pellant et al. 2005. There is some evidence that soil aggregate stability (AS) could be used as a composite index for this metric (Bestelmeyer et al. 2006), but data collection may be more labor intensive.

Scaling Rationale: In the absence of quantitative data, the scale is based on guidelines for professional judgment.

Confidence that reasonable logic and/or data support the index: High for inclusion of the index. Medium to low for the specific measures and thresholds.

B.3.2 Disturbance and Fragmentation – land use within occurrence

Definition: This metric addresses the intensity of human dominated land uses within the occurrence.

Background: This metric is one aspect of the abiotic condition of an individual occurrence of the ecological system.

Rationale for Selection of the Variable: Fragmentation and disturbance are important factors on the ecological processes of natural systems. Due to the difficulties of applying measures of fragmentation (Hargis et al. 1998, Tischendorf and Fahrig 2000) this variable is measured using the same technique as in Section B.1.1.

Measurement Protocol: This metric is measured by documenting land use(s) withinthe boundaries of the occurrence. This should be completed in the field then verified in the office using aerial photographs or GIS. However, with access to current aerial photography and/or GIS data a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use.

To calculate a Total Land Use Score estimate the % of the adjacent area within the occurrence under each Land Use type and then plug the corresponding coefficient (Table 7, section B.1.1) into the following equation:

$$\textit{Sub-land use score} = \sum \text{LU} \times \text{PC}/100$$

where: LU = Land Use Score for Land Use Type; PC = % of total area in Land Use Type.

Do this for each land use within the occurrence, then sum the Sub-Land Use Score(s) to arrive at a Total Land Score. For example, if 30% of the area was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4

Data: See table in Section B.1.1.

Scaling Rationale: Land uses have differing degrees of potential impact. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and grazing), while other activities (e.g., hay production and agriculture) may replace native vegetation with nonnative or cultural vegetation yet still provide potential cover for species movement. Intensive land uses (i.e., urban development, roads, mining, etc.) may completely destroy vegetation and drastically alter hydrological processes. The coefficients were assigned according to best scientific judgment regarding each land use's potential impact (Hauer et al. 2002).

Confidence that reasonable logic and/or data support the index: Medium.

B.4 Size Metrics

B.4.1 Total size of system occurrence

Definition: This metric assesses the total size of all areas included in the occurrence or stand, i.e., all stands or patches that are close enough together to fall within the same occurrence.

Background: Size (area) of the occurrence has a large effect on the internal heterogeneity and diversity of an occurrence. To define the area, rules are needed to specify when two or more patches or stands are close enough together to belong to the same occurrence.

Rationale for Selection of the Variable: Most ecological function is proportional to size of occurrences, and some is disproportionately related to large occurrences. Some ecological functions occur only, or at much greater levels, in areas in good condition, while other ecological functions may occur even in relatively poor or degraded areas. Some species are specific to habitat in the best condition while others are more tolerant of degraded examples. Other ecological functions may occur in poorer quality areas, but only at a much reduced frequency/intensity, and some species may occur there but only at low density. Poorer areas thus contribute to the ecological significance of occurrences, but to a lesser degree than areas in better condition.

Measurement Protocol: This metric is evaluated by measuring or estimating the total area of the occurrence.

Measure	Definition Tier	A Excellent	B Good	C Fair	D Poor
Total system size	Total area of system within separation distance	>5000 acres	2000-5000 acres	1000-2000 acres	< 1000 acres

Data:

Scaling Rationale: The present scale is based on the range of sizes of occurrences in eastern Colorado and professional judgment about thresholds (CNHP 2004). The range of sizes is expected to be similar throughout the range of the system. The scale could be improved by basing it on the correlation of species presence/richness with size values.

Confidence that reasonable logic and/or data support the index: High.

B.4.2 Size of high quality area

Definition: This metric assesses the size of the area to which the highest condition rating applies.

Background: For occurrences that are heterogeneous with regard to condition, this metric indicates the size of area which is in the best condition class. For homogeneous occurrences, this will be the same as the total system size, but for heterogeneous occurrences it may be smaller.

Rationale for Selection of the Variable: Most ecological function is proportional to size of occurrences, and some is disproportionately related to large occurrences. Some ecological functions occur only, or at much greater levels, in areas in good condition, while other ecological functions may occur even in relatively poor or degraded areas. Some species are specific to habitat in the best condition while others are more tolerant of degraded examples. Other ecological functions may occur in poorer quality areas, but only at a much reduced frequency/intensity, and some species may occur there but only at low density. Because the combined rating for the occurrence is based on a combination of size and condition, the size of the high quality area, the area corresponding to the condition rating, is the most important size measure. However, having large additional areas in poorer condition may compensate to some degree.

Measurement Protocol: This metric is evaluated by measuring or estimating the total area within the occurrence that meets the criteria for the best condition rating score given to the occurrence, the most intact area within the overall occurrence.

Measure	Definition - Tier	A Excellent	B Good	C Fair	D Poor
Size of high quality area	Area of system in best condition class (see rollup of condition metrics) 2, 3	>5000 acres	2000-5000 acres	1000-2000 acres	< 1000 acres

Data:

Scaling Rationale: The present scale is based on the range of sizes of occurrences in eastern Colorado and professional judgment about thresholds (CNHP 2004). The range of sizes is expected to be similar throughout the range of the system. The scale could be improved by basing it on the correlation of species presence/richness with size values.

Confidence that reasonable logic and/or data support the index: High.

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