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Evaluation of Off-site Mitigation Practices for Ecosystem Services and Wildlife Habitat in Sagebrush Ecosystems[1]

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Abstract–*A fundamental concept of mitigation is that it is possible to compensate for impacts to ecosystem services at one site (the impact site) by replacing or increasing the same services at another site (the mitigation site). A challenge in the use of off-site mitigation is assuring that ecosystem services, including wildlife habitat, produced by off-site mitigation are commensurate with on-site impacts. Recent increases in energy developments within the sagebrush biome have raised concerns about impacts associated with these activities and efforts to mitigate those impacts. To help address these concerns, we developed a metric system to quantify impact losses and mitigation benefits based on a combination of Natural Resources Conservation Service ecological sites, existing vegetation conditions, and habitat assessment conducted at the landscape level for sagebrush-associated wildlife species. Changes to vegetation conditions within sagebrush ecosystems produced by on-the-ground mitigation treatments or by impacts are quantified based on comparison to a reference standard developed from the Ecological Site Description for the specific plant communities associated with either the mitigation or impact site. Wildlife benefits are also evaluated at a landscape scale using models that quantify the gains or losses in habitat quality associated with the mitigation or development activities. This metric system provides a standardized way of quantifying gains and losses of ecosystem services and wildlife habitat associated with impacts and mitigation which will help to ensure that gains associated with mitigation activities are commensurate with losses resulting from development.*

KEY WORDS: *Artemisia* spp., credits, ecological sites, ecological site descriptions, ecosystem services, mitigation, sagebrush

INTRODUCTION

A fundamental concept for mitigation is that it is possible to compensate for impacts to ecosystem services at one site (the impact site) by replacing or increasing the same services at another site (the mitigation site). A challenge in the use of off-site mitigation is assuring that ecosystem services, including wildlife habitat, produced by off-site

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mitigation are commensurate with on-site impacts. A related challenge is to be able to effectively quantify the losses and gains in services in a scientifically valid and reproducible manner.

Recent increases in energy developments within the sagebrush biome have raised concerns about impacts associated with these developments and efforts to mitigate these impacts. Substantial interest exists in use of off-site mitigation if this can be shown to produce benefits that are equivalent to the impacts. This paper describes a framework and measurements for mitigation metrics that can evaluate and quantify impacts to ecosystem services at development sites and compare and quantify these with commensurate amounts of ecosystem services produced through off-site mitigation.

THE CONCEPTUAL UNDERPINNINGS

It should be noted that it is not assumed that all impacts on all sites can be compensated through off-site mitigation. Some sites of high ecological value should be protected from development activities because their value to ecosystem services such as wildlife habitat cannot be effectively mitigated and therefore should not be impacted. The methodologies described here are directed at those sites where development has been approved as an appropriate activity and we seek to mitigate on-site impacts through use of off-site mitigation.

The basic framework for quantifying services lost at impact sites and gained at mitigation sites requires assessments of the following:

1. The *existing level* of services provided at the impact and mitigation sites prior to the initiation of development and mitigation activities. These services are considered to be influenced by both the characteristics of the specific impact and mitigation sites as well as the surrounding landscape;

2. The *resulting level* of services expected at the impact and mitigation sites after the impact development and mitigation activities are carried out, considering both site and landscape effects;

3. The *duration* of the change (or period of time over which a change in services occurs) at the impact and mitigation sites; and

4. The *length of time* before the mitigation is expected to be fully successful at the mitigation site.

By assessing the above factors, it should be possible to design a metric system that allows consistent quantification of mitigation required to offset expected impacts from a broad range of development activities. The basic units proposed to quantify benefits associated with mitigation activities or detriments associated with development impacts are really a variety of ecosystem services lost or gained over time. They are calculated in the same manner, so that a “credit unit” has an equal, but opposite, value as a “debit unit.” Thus, the benefits of credit units produced are intended to fully and specifically offset the detrimental debit units from a development.

CONSIDERATIONS ASSOCIATED WITH MITIGATION METRICS FOR SAGEBRUSH ECOSYSTEMS

In the case of the sagebrush biome, the number of credit units or debit units associated with any activity should be a function of the following factors:

1. The area affected by the activity;

2. The ecological sites occurring in the affected areas;

3. The existing conditions within the area (essentially a measure of quality evaluated relative to a baseline);

4. The extent of change (positive or negative) caused by the activity relative to the existing conditions;

5. The spatial or landscape context in which the area is located (related primarily to habitat quality for selected species); and

6. The timing and duration of the expected change.

The discussion that follows elaborates on these factors. What is presented here is a general framework of factors that should be included in the determination of credit units and debit units. An example is provided to show how the metrics framework could be applied. Its actual utilization would need to be specifically tailored and calculated for a location.

Area Affected

The quantification of credit or debit units begins with a determination of the size and characteristics of the area affected by any action. Development activities will often affect both the specific area directly impacted by the development (the physical "footprint" of the activity), and additional area where the activity is expected to exert a negative influence (e.g., effects of noise, disturbance, visual features, or other impacts that discourage use of nearby areas by sagebrush-associated wildlife). The additional areas impacted by a disturbance beyond the actual development footprint are considered in the landscape context, discussed below. Basic units for impacts or mitigation are the size (in acres or hectares) of the actual footprint of the impact or mitigation site. This area will then be modified by the level of change in ecosystem services as a result of the development or mitigation treatments. In many cases, development will create a change from existing conditions and the level of ecosystem services that they currently provide to no provision of ecosystem services with the development activity. For mitigation sites, the area treated will have an existing value of ecosystem services that should be increased through mitigation treatments. If a site is improved by 50%, then the number of acres mitigated would be multiplied by this level of improvement to determine the number of mitigation credit units produced.

Ecological Sites

The area affected must be characterized in terms of its existing and inherent (potential) conditions. Natural Resources Conservation Service (NRCS) ecological sites (http://esis.sc.egov.usda.gov/) provide a classification system that can facilitate identification of biotic and underlying abiotic drivers of ecosystem diversity that could provide consistency for measuring ecosystem services and thus mitigation benefits. Ecological sites classify areas that have similar soils and other abiotic and biotic conditions for defined precipitation zones within a Major Land Resource Area (MLRA). MLRAs are geo-climatically defined areas delineated by NRCS that have been mapped for the entire U.S. (NRCS 2006, http://soils.usda.gov/survey/geography/mlra/). Ecological site classifications have been developed for most MLRAs, with ecological site descriptions developed for each specific ecological site within these MLRAs. These sites are linked to soils, and are therefore mapped wherever NRCS soils mapping has occurred.

For each ecological site, various plant communities described as specific "states" as influenced by natural or anthropogenic disturbances have been identified. The dynamics of these plant communities or states are incorporated into a state and transition model for each site. Changes among states are defined as "transitions," with some changes crossing "thresholds" that may make transition back to a prior state difficult (Friedel 1991, Laycock 1991). Various states that might occur on each ecological site have been described in ecological site descriptions (ESDs) for most MLRAs in the Rocky Mountain West, with work proceeding on those areas not yet completed. Descriptions of states for a specific ecological site should include all of the states that occurred historically under historical disturbance regimes (historical states), and other states produced as a result of recent (post-European settlement) anthropogenic influences including introduction of exotic species (anthropogenic states). Past influences of Native Americans are incorporated as part of the historical states. Some ecological site descriptions have not included descriptions of the full range of historical states and transitions, so these may need further development for some MLRAs. A full state and transition model for an ecological site should include descriptions of all of the states that occurred historically as well as any currently common states produced by anthropogenic influences (for example, see fig. 1).

Use of ecological sites as defined by NRCS assures that ecosystem services are being considered in equivalent locations having similar abiotic environments. For example, two loamy ecological sites within the same MLRA and precipitation zone should have the potential of supporting similar states with similar potential productivity and thus have the potential to contribute similar ecosystem services. The services they are producing at any time will be determined by the existing plant community occurring at that time, but the potential of loamy sites should basically be the same. A saline upland ecological site in the same MLRA and precipitation zone would have different plant communities or states associated with it than the loamy ecological site, as the different soil properties favor the occurrence of different plant species and support different productivity, growth rates, and other factors. While both may contribute some similar ecosystem services, such as contributing to the habitat of a certain species, they are

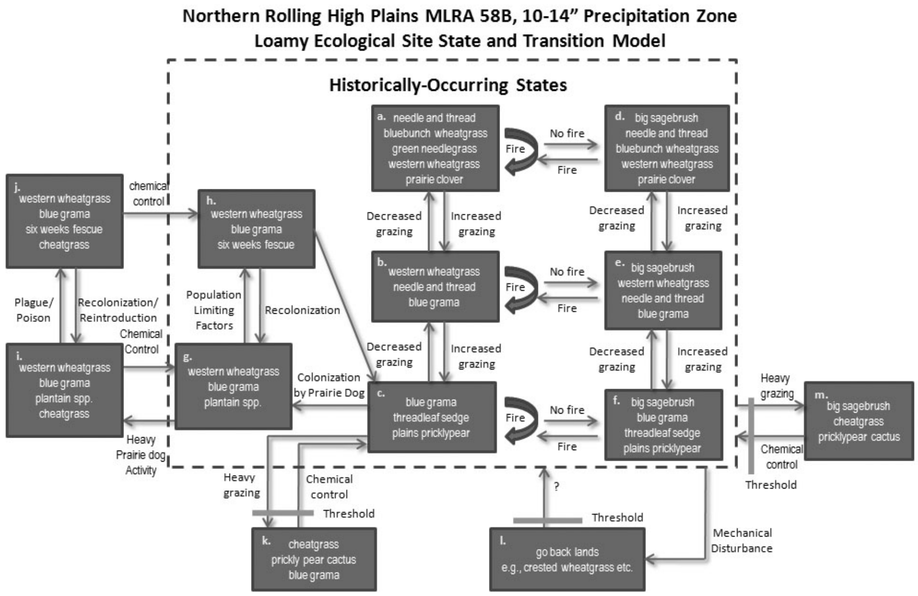

Figure 1–State and transition model for loamy ecological sites within the 10-14” precipitation zone of MLRA 58B, the Northern Rolling High Plains. States identified outside of the dashed box did not occur historically but rather are the result of recent anthropogenic changes.

inherently different in their compositions, productivity, and other factors. For any one ecosystem service, such as habitat for one species of interest, it may be possible to measure the contribution of existing conditions for that one ecosystem service. However, other ecosystem services provided by the site, for example grazing productivity, will be inherently different, so that if the goal is to produce a system that tracks equivalent credit or debit units for a suite of ecosystem services, then use of ecological sites can help assure that equivalent services are capable of being provided. Other ecological classifications could serve a similar function. However, other systems are not currently available within the sagebrush biome that consider underlying site potential with the same level of development, mapping, and acceptance by potential users as the NRCS ecological site classification system.

Ecological sites within an MLRA and precipitation zone have been described by NRCS in its ESD process (http://esis.sc.egov.usda.gov/). While ESDs have been prepared for many MLRAs within the sagebrush biome, others are still being prepared. NRCS has indicated that completing the ESDs is a high priority, and these should be available in the near future. Where ESDs are lacking, developers can produce their own descriptions of ecological sites if they have the appropriate knowledge of the ecology of the area. Each ESD provides descriptions of the site, its plant compositions and productivity, soils, and an array of other characteristics. In areas where soils have been mapped, the specific ecological sites occurring on an impact or mitigation area will also be available on a map. In areas where soils have not been mapped, on-site sampling will be needed to determine the specific ecological sites of the impact and mitigation areas based on the soils present in these areas.

Ecological integrity (Karr 2004) refers to an ecosystem's completeness, including the presence of all appropriate components (e.g., species), structures (e.g., heights of vegetation) and processes (e.g., nutrient cycling or disturbance response). Complete ecosystems possess ecological integrity because they support a biota that is the product of evolutionary and biogeographic processes with minimal changes from human impacts (Karr 2004). Ecological integrity has been a policy objective in several national and bi-national laws and agreements, including the U.S. Water Quality Amendments of 1972 (Clean Water Act), the Great Lakes Water Quality Agreement between the United States and Canada, and the National Wildlife Refuge System Improvement Act of 1997 (Noss 2004).

ESDs generally provide the information needed to develop descriptions of historical and anthropogenic states. Historical plant communities occurred as a result of disturbance regimes that influenced the composition, structure, and processes of each community. Various historical states typically occurred on any given ecological site. Various additional anthropogenic states that did not occur historically may now occur as a result of human activities over the past 100+ years. Descriptions of the historical states that occurred for each ecological site can be used to provide a baseline reference for comparison. Ecological integrity at a site must be evaluated and quantified relative to an identified reference or baseline to allow an interpretation of its existing and potential future quality for ecosystem services. Historical states define the native ecosystem diversity that occurred within a landscape or MLRA, and provide the best reference for use as baseline conditions for ecological integrity.

Existing Conditions

In addition to the ecological site, the conditions for the existing plant communities occurring on each impact or mitigation site will need to be described through field sampling. The composition of the plant community as well as other potential measures such as its structure should be sampled and quantified. Measures that are important for assessing the value of the area for animal species of concern should also be included in this sampling. The existing condition can then be rated as to its ecological integrity in comparison to a reference condition using tools such as a similarity index (NRCS 2003).

Planned development activities (resulting in debit units) may be evaluated as to the reduction of ecosystem services associated with the loss of the level of existing ecological integrity to a site, potentially going to zero. Mitigation activities (resulting in credit units) may be designed to maintain or increase the ecological integrity of a site and thus its level of ecosystem services. In addition to the ecological site information identified above, information on the existing characteristics of the vegetation at a site is required to complete this evaluation. On each site, the amount of each plant community and its underlying ecological site provide the basis for the determination of level of ecological integrity. The existing community characteristics are evaluated relative to a reference condition generated from the ESD information to produce a value for the existing ecological integrity, which is then further evaluated relative to landscape context (described below).

Off-site mitigation areas that have equivalent ecological sites could be improved by restoring these areas to conditions that more closely resemble one of the historical states or other desired plant communities based on reference information. The more dissimilar the off-site mitigation area is to the desired plant communities (i.e., high levels of exotic species, low diversity of native species), the greater the potential gain in mitigation value through restoration. Numerous ecosystem services could be increased, including better soil stabilization, improved water quality, increases in grazing land health, and increased quality of fish and wildlife habitat.

Extent of Change

The mitigation metric should measure the change in conditions of plant communities indexed in relation to the historical state or other desired plant community selected as a reference condition. The baseline reference provides a description of the conditions that could be considered optimum in value for a given site, with a possible score of 1 on a 0.1 – 1.0 scale. The existing conditions are then evaluated in relation to this reference condition. If an historical state is desired for use as a baseline reference for calculating credit or debit units, the specific historical state to be used will need to be selected from those that occurred for specific ecological site. Suggestions for making this selection are discussed below in the description of the example.

The metric for a site would evaluate the quality of the existing plant communities at the site in comparison to the reference, and then quantify gains or losses to this quality from impacts or mitigation. For example, a completely degraded site, perhaps dominated by invasive species might score a 0.1 in reference to an identified baseline plant community for a specific ecological site. Impacting this site would not generate a large number of debit units. Mitigation to improve a degraded site to more closely resemble a specified historical state might get partway towards this goal in 3 years, resulting in a 0.6 score for ecological integrity. Each acre improved by this amount would then receive a benefit of the acre times the increase in value, so that in this example, 10 acres increased from 0.1 to 0.6 on a certain ecological site would result in 5 units of improvement (10 acres times 0.5 gain in quality) for each year that the improved condition was maintained. These might offset impacts to other areas of the same ecological site disturbed by energy production or other impacts. In another example, if an existing site had a value of 0.9, and was impacted by an energy development, a large number of debit units might be created. If such a site in an off-site mitigation location was identified and maintained in a high quality condition when it might have decreased to a 0.6 without specific mitigation efforts, then a gain of 0.3 times the area might be identified for each year that the site is maintained in the better condition.

Landscape Context

An important need in determining mitigation metrics is to determine how landscape features influence ecosystem services at a site. The same ecological site and plant community occurring in an impact site or mitigation site may not have the same value or produce the same wildlife benefits through mitigation due to these landscape effects. For example, a development site might be located in mule deer (*Odocoileus hemionus*) winter range. An off-site mitigation site may be identified that has the same ecological site and even existing plant community as the development site, but not be in a mule deer wintering area. The site within the wintering area would be considered of higher conservation value because of this function, even though the site conditions were the same.

Locations of sites important to wildlife species may be identified in two ways. Important habitat for distributions of species of interest may be known and mapped, and this information then used in determining the value of a particular site. Alternatively and more widely used, important sites in a landscape context can be evaluated using habitat modeling. A method of evaluating landscape context is to rely on the expected impacts or benefits for selected wildlife species that are likely to be produced by either impacts or mitigation actions. Models of habitat quality that include landscape components for selected species of concern could be used to evaluate declines in habitat quality in the development area compared to potential gains in habitat quality for these same species in the mitigation area. Using derivations of habitat suitability index (HSI) models (US Fish and Wildlife Service 1981) that operate at landscape scales, the influence of amounts of specific habitat conditions and their impacts from various developments can be modeled. Further refinements to these models may produce more targeted results. For example, Roloff and Haufler (1997, 2002) developed a habitat-based approach to species viability that provides for the estimation of numbers of home ranges of varying quality for a species in an area to project gains or losses in numbers as a result of development or mitigation activities. Beck and Suring (2008) evaluated the various types of habitat models currently in use in landscape analyses. Through such methods, spatial influences of landscape context can be used as modifiers of the credit or debit units calculated for a specific site.

An important question for evaluating landscape context is which species and how many species of concern should be used as indicators of landscape effects? It would seem desirable to include a number of species within any landscape, but the exact number and which species would need to be determined. If multiple species are used, how should the changes in their habitat qualities be combined to determine the overall landscape context? For example, if off-site mitigation is shown to improve conditions for two sage-brush-associated species but to decrease conditions for another species, how should these be evaluated in the landscape context? Should the net gains and losses of all species be averaged, or are some species more important and therefore receive a higher weighting in the analysis of landscape context? These are policy decisions that need to be determined for the actual application of this mitigation metric system.

The landscape context serves to further adjust the credit or debit units calculated from the site analyses. The site level analysis determines the base level of units. The landscape context then further modifies this level depending on the resulting expected gains or losses to wildlife populations. For example, an impact site might reduce ecological integrity by 50 debit units (e.g. 100 acres of 0.5 quality reduced to 0.0 quality). A landscape evaluation may then determine that this area supported habitat quality of 0.8 for two species of concern which would drop to a quality of 0.4 with the development. To offset this reduction, a mitigation site that was 100 acres of 0.3 quality would need to be increased to an ecological integrity of 0.8, and be shown to improve habitat quality for the two species by an equivalent increase.

Timing and Duration of Change

Key determinants of the amount of credit or debit units attributed to an activity include expected annual changes, and the total amount of cumulative change (positive or negative) anticipated from the action over some period of time (e.g., 20 years), compared to the conditions that would be expected over the same period without the action. Note that under this approach, "preservation" of existing habitat does not gain any credit units unless it eliminates some expected deterioration in condition. "Change" here is intended to refer to changes in the ecosystem services or values provided by the affected areas. As a practical matter, such changes are likely to be inferred from changes in the vegetative characteristics of the affected areas as modified by the landscape level analysis of changes in the use of the area by sagebrush-associated wildlife. These changes need to be evaluated in the context of the extent to which they may impact the flow of services over time relative to the reference condition. In measuring "change" in plant communities, the metric would quantify the amount of change in the plant community over some specified period of time measured in years.

In the sagebrush ecosystem, the impacts of development activities on ecosystem services and species of concern will often be immediate, but they may not always be permanent (e.g., well pads and associated roads can be removed after they are no longer in use). Conversely, the benefits of conservation activities on ecosystem services or species of concern will often be neither immediate (e.g., restoring sagebrush at dry sites will take many years), nor permanent. Thus, the timing and duration of impacts and conservation activities need to be taken into account when quantifying credits or debits.

SAGEBRUSH BIOME MITIGATION METRIC EXAMPLE

The above discussion provides a general description of the mitigation metric framework. An example of the application of these concepts is presented here.

Site evaluation and quantification of ecological integrity

The first level of assessment in the mitigation metrics is at the ecological site. The metrics evaluate the ecological integrity of a site (impact or mitigation) in comparison to a reference community. Stated differently, ecological integrity can be linked to the maintenance or restoration of native sagebrush ecosystems because it is recognized that native ecosystems contain the appropriate plant species that are adapted to that specific location and that wildlife species assemblages have developed in response to these adaptations. Definition of a native ecosystem requires reference to what occurred in the area historically, which is typically considered those conditions that occurred prior to major perturbations brought about following European settlement.

ESDs (http://esis.sc.egov.usda.gov/) use state and transition models to define vegetation states that can occur across sites both historically and under current conditions. Unfortunately, many ESDs only describe one historical state termed the historical climax plant community (HCPC). The HCPC is then described relative to its composition and productivity of native species. However, there are typically multiple historical states that occurred across an ecological site within a landscape depending on the disturbance history of the landscape. For example, figure 1 displays a state and transition model that includes the range of historical states and other anthropogenic states for loamy soils in the Northern Rolling High Plains MLRA (58B) in a 10-14” precipitation zone.

Each historical state for an ecological site can be described in terms of the composition, structure, and processes for a specific historical plant community. For example, a post-fire state dominated by grasses and forbs, and further influenced by light, moderate, or heavy grazing regimes (three different states) might have occurred on a certain ecological site. Over time without fire, sagebrush would be expected to reestablish on the site, resulting in a state with sagebrush intermixed with grasses and forbs, the species of which would be influenced by the level of persistent grazing (fig. 1). A reference condition for each of these historical states can be described and used as a basis for comparison to any existing community through use of evaluation tools such as similarity indices. Table 1 provides a description of the compositions of the fire and grazing-influenced historical states included in the state and transition model for loamy sites depicted in figure 1. As a check, a local or regional team of experts may be convened to review the descriptions of historical states for use in mitigation metrics to assure that these descriptions are considered correct and supported by the local natural resource managers.

The proposed metric that addresses ecological integrity compares conditions of current plant communities at a site in relation to a historical state. Because various historical states may have occurred on an ecological site selected for specific mitigation activities, a specific historical state would need to be selected as the baseline reference. The selection of a reference historical state might use either of these approaches:

1. Evaluate which historical states currently have the lowest representation in the surrounding landscape relative to the amounts estimated to have occurred historically, and emphasize restoration of this state. Such under-represented states provide conditions that are most likely to be limiting to sagebrush-associated species in the landscape because these states are in the smallest amounts relative to their past availability. For example, sagebrush ecosystems in a selected area may have limited amounts of states that contain plant species that decline with grazing pressure, so that the historical states produced under light grazing conditions may be selected as the reference community.
2. Alternatively, a local or regional panel of experts could determine which historical state described for a site is the most important to be emphasized based on the assessment of the most desired vegetation conditions in the landscape either for anticipated ecosystem services or for the importance of that state to the habitat needs of one or more wildlife species of concern.

The existing conditions for the plant community at an impact or mitigation site are measured in the field (e.g., vegetation composition and structure). While a

Table 1–Descriptions of potential historical states occurring on loamy ecological sites in the 10 – 14” precipitation zone of the Northern Rolling High Plains Major Land Resource Area (58B). Letters for each historical state correspond to states shown in figure 1. Scientific names are listed in Appendix A.

Short-Fire Return Interval			
	Light Grazing (A)	**Moderate Grazing (B)**	**Heavy Grazing (C)**
Fire Return Interval	<25 years; avg. 5-15 years	<25 years; avg. 5-15 years	<25 years; avg. 10-20 years
Grazing	Intermittent, with rest periods	Variable, but mostly moderate	Mostly season long grazing
Primary Species	Needleandthread, green needlegrass, western wheatgrass, thickspike wheatgrass, bluebunch wheatgrass, white prairie clover, prairie coneflower, dotted blazing star, winterfat, Indian ricegrass, Cusick’s bluegrass, needleleaf sedge, American vetch, hawksbeard, biscuitroot, evening primrose	Western wheatgrass, needleandthread, Sandberg bluegrass, thickspike wheatgrass, blue grama, threadleaf sedge, western yarrow, Indian ricegrass, bluebunch wheatgrass, Cusick’s bluegrass, needleleaf sedge, prairie junegrass, prairie coneflower, white prairie clover, biscuitroot, scurfpea, rosy pussytoes, milkvetch, goldenweed, hawksbeard, textile onion, bluebells, scarlet globemallow, penstemon, common pepperweed	Blue grama, threadleaf sedge, plains pricklypear, prairie junegrass, common yarrow, rosy pussytoes, common pepperweed, western wheatgrass, thickspike wheatgrass, Sandberg bluegrass, scurfpea, milkvetch, penstemon, scarlet globemallow, stemless goldenweed, textile onion, bluebells, Hood’s phlox
Productivity	1,100 lbs/acre	900 lbs/acre	550 lbs/acre
Structure/Height	5-8	4-6	3-5
Long-Fire Return Interval			
	Light Grazing (D)	**Moderate Grazing (E)**	**Heavy Grazing (F)**
Fire Return Interval	>25 years	>25 years	>25 years
Grazing	Intermittent, with rest periods	Variable, but mostly moderate	Mostly season long grazing
Primary Species	Big sagebrush, needleandthread, green needlegrass, western wheatgrass, thickspike wheatgrass, bluebunch wheatgrass, white prairie clover, prairie coneflower, Indian ricegrass, Cusick’s bluegrass, needleleaf sedge, American vetch, hawksbeard, biscuitroot, dotted blazing star, evening primrose	Big sagebrush, western wheatgrass, needleandthread, Sandberg bluegrass, thickspike wheatgrass, blue grama, threadleaf sedge, western yarrow, winterfat, Indian ricegrass, bluebunch wheatgrass, Cusick’s bluegrass, needleleaf sedge, prairie junegrass, prairie coneflower, white prairie clover, biscuitroot, scurfpea, rosy pussytoes, milkvetch, goldenweed, hawksbeard, textile onion, bluebells, scarlet globemallow, penstemon, common pepperweed	Big sagebrush, blue grama, threadleaf sedge, plains pricklypear, prairie junegrass, common yarrow, rosy pussytoes, common pepperweed, western wheatgrass, thickspike wheatgrass, Sandberg bluegrass, scurfpea, milkvetch, penstemon, scarlet globemallow, stemless goldenweed, textile onion, bluebells, Hood’s phlox
Productivity	925 lbs/acre	750 lbs/acre	475 lbs/acre
Structure/Height	5-8” grasses; sagebrush up to 3’	4-6”; sagebrush up to 3’	3-5”; sagebrush up to 2.5’

standardized sampling methodology is not proposed here, the sampling methods used should be the same for both impact and mitigation sites. Various vegetation metrics could be used to help capture potential changes caused by impacts or mitigation actions. We suggest that a primary measurement would be the relative cover of each plant species. Productivity of each species could also be used, but it is more time consuming to sample, and is complicated by annual fluctuations in productivity based on weather patterns and the different growth rates of woody and herbaceous plants and grasses and forbs. Additional measures, such as vegetation heights, horizontal cover, or amounts of bare ground could all be potential indicators of existing conditions in comparison to an historical reference.

Baseline or reference conditions of historical states are described from information in the ESDs, with further development based on known or published information on the responses of plant species to different types or levels of disturbance. Development of such information may be reviewed by a local or regional panel of experts with knowledge of plant ecology and range dynamics for the area. Comparisons of existing plant communities can be made to these described historical states through the use of a similarity index (NRCS 2003). A value of an existing plant community may then be calculated for a site that represents the ecological integrity of the ecosystem for that site. From Table 1, the reference community that might be selected might be the light grazing, long fire return interval state for loamy sites in the Northern Rolling High Plains, 10-14" precipitation zone. Table 2 lists reference standards that might be established for this selected historical state as a reference community. Table 3 lists existing plant community compositions determined from field sampling of 3 specific locations that could serve as either impact or mitigation sites within this MLRA and precipitation zone. Table 4 displays the computed similarity index for ecological integrity of the existing plant communities at these three locations.

The similarity index used the reference community to define an "optimum" composition for desired conditions. The existing community composition is compared to this reference. For each reference standard, the existing community receives points for each percentage of relative cover for the identified native species groups in the reference state, up to the reference standard. Higher amounts than the reference standard of any one group do not add additional points.

The ecological integrity of the 3 example sites compared to the reference state is relatively low (table 4) ranging from 0.305 to 0.473. These values are based solely on cover of reference native species found at these sites. An additional modifier of ecosystem integrity might be the level of exotic species occurring on the sites. Figure 2 depicts a possible relationship that could be used to modify a site's ecological integrity based on the relative cover of exotic species sampled for a site. Using this relationship, the adjusted ecological integrity of the 3 sites is listed in table 5. Additional variables could be added to further define important features of a plant community that effectively contribute to the ability of a site to contribute ecosystem services, such as productivity of herbaceous vegetation, horizontal cover for selected wildlife species, or other measures.

Table 2–Reference standards for use in calculating a similarity index of ecological integrity for a loamy ecological site in the 10-14” Precipitation Zone of the Rolling High Plains Major Land Resource Area based on use of Historical State D described in table 1 (long-fire return x light grazing historical state) as the reference. Scientific names of species are listed in the Appendix A.

Reference component	Relative cover (%)	Standard (%)
Big sagebrush	10–30	20
Winterfat	1–10	5
Dominant grass (western wheatgrass)	10–40	25
Other native grasses (combined; needleandthread, green needlegrass, thickspike wheatgrass, bluebunch wheatgrass, Cusick’s bluegrass, Indian ricegrass, and needleleaf sedge)	25–60	40
Native forb species (combined; prairie clover, prairie coneflower, American vetch, biscuitroot, hawksbeard, evening primrose, and dotted blazing star)	5–20	10

These calculations reveal that the 3 sites generally had sufficient sagebrush to meet the desired level of this species identified in the reference state, although site 3 could be improved by slightly increasing the cover of sagebrush. However, all 3 sites had generally low levels of other native species, particularly the “other grass” species that are indicators of a light grazing regime state in this landscape. Further, the ecological integrity of the sites was dramatically reduced by the level of exotic species.

This example reveals how the quality of a specific location could be improved to gain credit units. By knowing what specific factors kept the site from receiving a higher ecological integrity rating, restoration treatments can be targeted to correct the problem. For example, all 3 sites were very deficient in grasses that decrease in the presence of grazing pressure. Efforts to increase the relative composition of these species on these sites, such as inter-seeding with these species or adjustment of current grazing regimes could be used as treatments to improve this condition. Similarly, all 3 sites lacked sufficient relative cover of native forbs expected for this plant community, so inter-seeding or other efforts to increase these forbs would be a good treatment to increase the ecological integrity index. Finally, for 2 of the 3 sites, the levels of exotics, especially cheatgrass, dramatically decreased the ecological integrity index for the site. Reduction of cheatgrass, possibly though use of selective herbicides, might be an additional mitigation treatment to increase the number of credit units.

Table 3–Relative cover of plant species for 3 example locations sampled within the 10-14” precipitation zone of the Northern Rolling High Plains Major Land Resource Area (58B). Scientific names of species listed in the Appendix.

	Site		
	1	2	3
Plant species	Relative cover (%)		
American vetch	0.0	0.4	0.0
Cheatgrass[a]	14.8	26.5	3.9
Big sagebrush	24.4	25.6	13.2
Blue grama	4.5	1.2	8.2
Sandberg bluegrass	25.8	6.3	1.9
Canadian horseweed	0.0	0.2	0.0
Common dandelion[a]	0.0	0.4	0.0
Common pepperweed	0.0	0.2	0.1
Desert madwort[a]	0.2	0.2	0.0
False pennyroyal	1.2	0.9	0.0
Knotweed	0.2	0.4	0.0
Narrowleaf four o'clock	0.0	0.2	0.0
Needle and thread	1.4	5.9	9.1
Needleleaf sedge	4.1	0.5	11.5
Plains pricklypear	1.2	0.9	1.4
Prairie junegrass	5.7	3.0	0.5
Prairie sagewort	0.2	0.0	0.5
Purple threeawn	0.5	1.2	0.5
Rosy pussytoes	0.0	0.2	0.0
Scarlet globemallow	0.7	0.0	0.5
Sixweeks fescue	3.6	3.0	10.1
Textile onion	0.0	0.2	0.0
Threadleaf sedge	0.0	3.3	0.0
Western wheatgrass	8.1	16.2	38.5
Wiinterfat	1.0	2.6	0.0
Wooly plantain	2.1	0.9	0.1
Yellow salsify[a]	0.2	0.0	0.0
Exotic species total	15.2	27.1	3.9

[a]Exotic species

Whether or not the actual weightings and standards used in this example are the preferred values, the example demonstrates how the mitigation metric framework can work at the site level to measure debit and credit units. The example also demonstrates how the determination of these units helps identify the potential management or restoration goals of a mitigation location. It also shows how the framework assures that equivalent ecological sites and resulting plant communities can be compared between impact and mitigation locations.

Table 4–Example calculation of a similarity index for ecological integrity of existing plant communities sampled on loamy sites in the 10-14” precipitation zone of the Northern Rolling High Plains Major Land Resource Area (58B). Scientific names of species are listed in the Appendix.

		Site					
		1		2		3	
Species group	Reference standard from table 2 (%)	Cover data (%)	Index score	Cover data (%)	Index score	Cover data (%)	Index score
Big sagebrush	20	24.4	0.200	25.6	0.200	13.2	0.132
Winterfat	5	1.0	0.010	2.6	0.026	0.0	0.000
Western wheatgrass	25	8.1	0.081	16.2	0.162	38.5	0.250
Other grasses for this historical state	40	1.4	0.014	5.9	0.059	9.1	0.091
Forbs for this historical state	10	0.0	0.000	0.4	0.004	0.0	0.000
Ecological Integrity Score			0.305		0.451		0.473

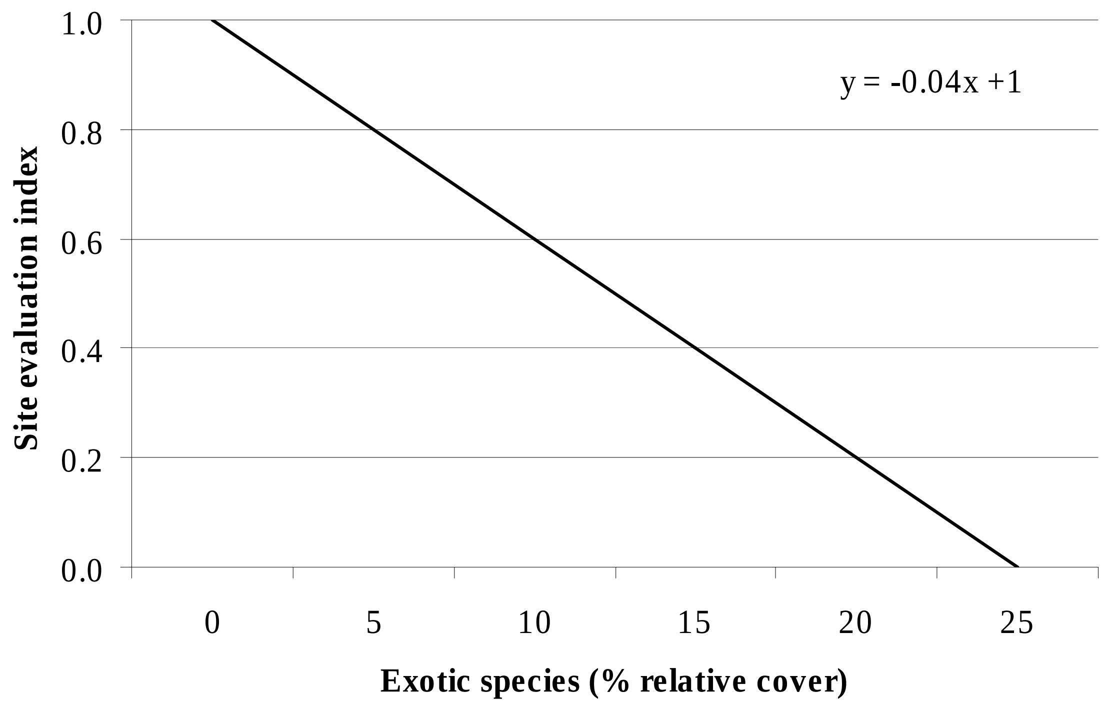

Figure 2. Graph of an example relationship between relative cover of exotic species at a site and the ecological integrity of the site. At 5% relative cover of exotic species, the integrity of a site would be reduced to 0.8 of its value, while at 25% relative cover of exotic species, the integrity of a site would be reduced to 0.

Table 5–Exotic species modifier for ecological integrity scores for example plant communities sampled in the 10-14" precipitation zone of the Northern Rolling High Plains Major Land Resource Area (58B). Similarity index scores are from table 3. Modifiers for levels of exotic species are from fig. 2.

	Site		
Site characteristic	1	2	3
Site similarity index score	0.305	0.451	0.473
Level of exotic species (%) (from table 3)	15.2	27.1	3.9
Ecological Integrity score modifier (from fig. 2)	0.392	0.0	0.844
Adjusted Ecological Integrity Score	0.12	0.0	0.399

Landscape Context

A goal of the mitigation metrics framework is to develop a process that promotes the mitigation of ecosystem services in the sagebrush biome, including maintaining or improving conditions for sagebrush-associated species. To address the needs of such species, analysis of impact or mitigation assessments are needed at the landscape level.

This is proposed to be accomplished through the use of habitat models for selected sagebrush-associated species.

Habitat models that can operate effectively and be endorsed by experts on sagebrush-associated species for use at the landscape level are not widely available at the present. While numerous habitat models exist for conservation planning at the landscape scale (Beck and Suring 2008), obtaining agreement for their use relating to energy developments in the sagebrush biome has proven to be a more complicated process. Here, we will not present the pros or cons of any specific models, but will discuss how models can serve to evaluate the landscape context for the mitigation metric framework. Models for use in the mitigation metric framework should be acceptable to the mitigation decision-making authority, identify the specific habitat information for evaluating the contribution of impact and mitigation sites, and provide a basis for delineation of the landscape to be used in the evaluation. Use of specific models will require maps of vegetation and other landscape attributes that provide the required input data of sufficient accuracy and detail to run the selected models. Availability of such maps and associated habitat variables are one of the most limiting features for running habitat models at landscape scales. Use of even the most sophisticated habitat models will be unlikely to produce accurate results if the quality of the underlying vegetation map including an assessment of its ability to provide the specific information required by the model is not addressed.

Various habitat models for sagebrush-associated species exist. Considerable attention has recently been directed at developing habitat or impact models for greater sage-grouse because of the concerns about the status of this species. Models for other sagebrush-associated species exist, but most lack the level of detail, testing, and data generation that has been directed at sage-grouse models. While selection of the specific species to be included in the landscape assessment will be determined by the mitigation-decision authority, we suggest that 5-10 sagebrush-associated species be used in evaluating the landscape context. These most often may include sage-grouse, pronghorn (*Antilocapra americana*), and mule deer because of the large home range requirements of these species and the public interest and concern about their status. Additional sagebrush-associated species that include a range of required sagebrush conditions or historical states should also be considered. An example of some of the habitat models available for use in the sagebrush biome is included in Rowland and others (2006).

The species and the habitat models selected for use in the landscape evaluation for mitigation metrics will determine the specific habitat variables that need to be considered. Those habitat variables that relate to vegetation characteristics should be identified, and the required information included in vegetation sampling conducted at potential development or mitigation sites. This will insure that the actual contributions of these sites to the habitat requirements of selected sagebrush-associated species is known and documented.

The area to be included in the landscape assessment will depend on the setting and the needs of the species selected for the landscape context. Some resident species have small home ranges, and their complete habitat needs can be assessed with a relatively small landscape context. Other resident species, including some populations of sage-grouse, mule deer, and pronghorn, will make seasonal movements and the assessment should include their entire annual home ranges. This will mean that the landscape for some evaluations will be quite large.

IMPLEMENTATION OF A MITIGATION METRICS FRAMEWORK

The mitigation metrics framework provides an index of ecosystem services provided per acre that can be used to determine the number of credit and debit units. The credits or debits are based on the ecological site classification system of NRCS. This classification system describes ESDs that occur within Precipitation Zones which then overlap with MLRAs. Credit and debit units are therefore defined for specific Ecological Sites within a Precipitation Zone and MLRA. This combination of areas then defines the minimum operational area for the mitigation metric system. This framework assures that credit and debit units are equal at the site level. The additional assessment at the landscape scale assures that credits and debits are also equal for species influenced by surrounding landscape factors.

There may be opportunities to provide mitigation benefits that do not correspond to this strict compliance of similar ecosystem services. For example, there may be advantages to addressing impacts occurring in one MLRA through off-site mitigation in an adjacent or nearby MLRA. In this case, the assumptions concerning the equality of ecosystem services may not hold. This should not preclude the consideration of such mitigation opportunities, but decisions to allow such trade-offs of credits and debit units should be made with the clear recognition that equivalency may not be achieved. Similarly, even within one MLRA, it may be desirable to mitigate impacts to one ecological site on a different ecological site. For example, impacts to a saline upland site might be more efficiently off-set and landscape context considerations better addressed by conducting mitigation in a loamy site that has higher productivity and greater diversity of plant species. However, in both of these examples, careful consideration should be given to the cumulative impacts that might be occurring to one particular ecological site, and sufficient consideration given to maintaining enough area of high ecological integrity for that site within the MLRA. If tradeoffs in types of sites are considered acceptable to a mitigation-decision authority, a general suggestion would be that sites with higher productivity or diversity of species should not be allowed to be mitigated through use of sites with a lower productivity or diversity of species.

An additional consideration is how area and quality may interact. Impacts to a very high quality site in terms of its existing ecological integrity theoretically could be off-set by increasing the ecological integrity of additional acres of sites with very low ecological integrity to a moderate level of integrity. While mathematically this may work, the biological response may be very different. The implications of such tradeoffs should be considered and may require additional standards so that cumulative impacts to high quality sites do not result in substantial reductions of these conditions.

As mentioned in the landscape context section, which species to consider and the number of species to consider in evaluating landscape influences is a determination that must be made. Further, the combined response of multiple species in the landscape assessment needs to be determined.

MONITORING

The scope of monitoring instituted in association with mitigation metrics will be up to the mitigation-decision authority determining appropriate mitigation standards. Monitoring is strongly recommended to track credit units that are expected following mitigation treatments. Some mitigation-decision authorities may require that the actual changes in plant communities be produced and documented prior to awarding credit units. Other mitigation authorities may acknowledge credits once treatments have been applied, while others may acknowledge credits with only a commitment to conduct restoration treatments. The mitigation metric framework provides a strong basis for developing a specific restoration treatment and monitoring program. The level and kind of monitoring may vary by individual project.

An effective monitoring program should be sufficiently flexible to allow modifications as new findings are produced, but require sufficient standardization to be credible and reproducible. We encourage use of an adaptive management design (Holling 1978), so that specific mitigation metrics can be continually evaluated and adjusted as needed to make them as accurate and effective as possible. Standard survey procedures or other previously established monitoring protocols based on sound science should be used in this process. Though the specific monitoring for each project may differ, some factors that may be important to monitor include vegetative responses to management, the presence of invasive species, and presence or abundance of species of concern.

CONCLUSIONS

The mitigation metrics framework described here provides a strong foundation for determining and measuring equivalency of mitigation credit and debit units at the site level. It also outlines a mechanism for incorporating a standardized method of evaluating landscape context and influences. The application at the site level is fairly straight-forward, and the information on ESDs and soils maps are available in many areas. Providing this information in remaining areas is a priority for NRCS. Even where the information is not available, the mitigation metrics can be efficiently developed and applied by knowledgeable experts.

Landscape context remains a larger challenge. Identifying which species to include, which species' models are acceptable, and developing the required data and maps to accurately run the models at the landscape scale can be difficult. This challenge is not unique to this mitigation metric framework. Rather, it is an over-arching concern for impact assessment and mitigation assessment within the sagebrush and other biomes.

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REFERENCES

Beck, J.L.; Suring, L.H. 2008. Wildlife habitat-relationships models: description and evaluation of existing frameworks. In: Millspaugh, J.J.; Thompson, F.R., III, eds. Models for planning wildlife conservation in large landscapes. New York, NY: Elsevier Science: (in press).

Friedel, M.H. 1991. Range condition assessment and the concept of thresholds: a viewpoint. Journal of Range Management. 44:422–426.

Haufler, J.B.; Suring, L.H. In Press. A metric system for evaluating off-site mitigation for ecosystem services and wildlife habitat in sagebrush ecosystems. In: Wambolt, C.L.; Frisina, M.R., comp. Wildland Shrub Symposium. Shrublands: wildlands and wildlife habitats. Proceedings RMRS-P-XX. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: xx–xx.

Holling, C.S., ed. 1978. Adaptive environmental assessment and management. New York, NY: John Wiley. 377 p.

Karr, J.R. 2004. Beyond definitions: maintaining biological integrity, diversity, and environmental health in National Wildlife Refuges. Natural Resources Journal. 44:1067–1092.

Laycock, W.A. 1991. Stable states and thresholds of range condition on North American rangelands: a viewpoint. Journal of Range Management. 44:427–433.

Noss, R.F. 2004. Some suggestions for keeping National Wildlife Refuges healthy and whole. Natural Resources Journal. 44:1093–1111.

Roloff, G.J.; Haufler, J.B. 2002. Modeling habitat-based viability from organism to population. In: Scott, M.J.; Heglund, P.J.; Morrison, M.L. [and others] eds. Predicting species occurrence. Washington, D.C.: Island Press: 673–686.

Roloff, G.J.; Haufler, J.B. 1997. Establishing population viability planning objectives based on habitat potentials. Wildlife Society Bulletin. 25:895–904.

Rowland, M.M.; Leu M.; Hanser, S. [and others] 2006. Assessment of threats to sagebrush habitats and associated species of concern in the Wyoming Basins. Version 2.0, March 2006, unpublished report on file at USGS Biological Resources Discipline, Snake River Field Station, 970 Lusk St., Boise, ID 83706.

USDA Natural Resources Conservation Service (NRCS). 2008. The PLANTS Database. (http://plants.usda.gov). Baton Rouge, LA: U.S. Department of Agriculture, Natural Resources Conservation Service.

USDA Natural Resources Conservation Service (NRCS). 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. USDA Handbook 296. Washington, D.C. 669 p.

USDA Natural Resources Conservation Service (NRCS). 2003. National range and pasture handbook. USDA Natural Resources Conservation Service 190-VI-NRPH. Washington, D.C.

U.S. Fish and Wildlife Service. 1981. Standards for the development of habitat suitability index models for use in the Habitat Evaluation Procedures. U.S. Fish and Wildlife Service, Division of Ecological Services, ESM 103, Washington, D.C.

APPENDIX

Scientific names of plant species referred to in this manuscript. Nomenclature follows the PLANTS database (NRCS 2008). Origin refers to N=native, I=introduced.

Family/ symbol	Scientific name	Common name	Origin
Apiaceae			
LOSP	*Lomatium* spp	biscuitroot	N
Asteraceae			
ACMI2	*Achillea millefolium*	common yarrow	N
ANRO2	*Antennaria rosea*	rosy pussytoes	N
ARFR4	*Artemisia frigida*	prairie sagewort	N
ARTR2	*Artemisia tridentata*	big sagebrush	N
COCA5	*Conyza canadensis*	Canadian horseweed	N
CRSP	*Crepis* spp.	hawksbeard	I
RASP	*Ratibida* spp.	prairie coneflower	N
STAC	*Stenotus acaulis*	stemless goldenweed	I
Boraginaceae			
MESP	*Mertensia* spp.	bluebells	N
Brassicaceae			
ALDE	*Alyssum desertorum*	desert madwort	I
LEDE	*Lepidium densiflorum*	common pepperweed	N
Cactaceae			
OPPO	*Opuntia polyacantha*	plains pricklypear	N
Chenopodiaceae			
KRLA2	*Krascheninnikovia lanata*	winterfat	N

Family/ symbol	Scientific name	Common name	Origin
Cyperaceae			
CADU6	*Carex duriuscula*	needleleaf sedge	N
CAFI	*Carex filifolia*	threadleaf sedge	N
Fabaceae			
ASSP	*Astragalus* spp.	milkvetch	N
DACA7	*Dalea candida*	white prairie clover	N
PSSP	*Psoralidium* spp.	scurfpea	N
VIAM	*Vicia americana*	American vetch	N
Lamiaceae			
HEHI	*Hedeoma hispida*	false pennyroyal	N
Liliaceae			
ALTE	*Allium textile*	textile onion	N
Malvaceae			
SPCO	*Sphaeralcea coccinea*	scarlet globemallow	N
Nyctaginaceae			
MILI3	*Mirabilis linearis*	narrowleaf four o'clock	N
Onagraceae			
OESP	*Oenothera* spp.	evening-primrose	N
Plantaginaceae			
PLPA2	*Plantago patagonica*	woolly plantain	N
Poaceae			
ACHY	*Achnatherum hymenoides*	Indian ricegrass	N
ANBR	*Annual brome*	cheatgrasses	I

Family/ symbol	Scientific name	Common name	Origin
ARPU9	*Aristida purpurea*	purple threeawn	N
BOGR2	*Bouteloua gracilis*	blue grama	N
BRTE	*Bromus tectorum*	cheatgrass	I
ELLA	*Elymus lanceolatus*	thickspike wheatgrass	N
NAVI4	*Nassella viridula*	green needlegrass	N
PASM	*Pascopyrum smithii*	western wheatgrass	N
POCU3	*Poa cusickii*	Cusick's bluegrass	N
POSE	*Poa secunda*	Sandberg bluegrass	N
PSSP6	*Pseudoroegneria spicata*	bluebunch wheatgrass	N
VUOC	*Vulpia octoflora*	sixweeks fescue	N
Polemoniaceae			
PHHO	*Phlox hoodii*	Hood’s phlox	N
Polygonaceae			
POSP	*Polygonum* spp.	knotweed	N
Santalaceae			
PESP	*Penstemon* spp.	penstemon	N