IDENTIFICATION OF COMMUNITY TYPES OF SE MONTANA AS TARGETS FOR MINE RECLAMATION[1]

T. Weaver[2] and Ken Aho

Abstract. Vegetation of the northern plains has been disturbed by coal mines (> 50 square miles in Montana) and will be disturbed at increasing rates. 1) Reclamation managers often seek to re-vegetate with native vegetation. Such re-vegetation requires identification of major community types, characterization of these communities (as a basis for species choice and planting), and characterization of their environments (as a basis for siting, i.e. to determine what community to install on a particular site or to design a site for a particular community. 2) Ecologists from Montana State University, Montana Department of Environmental quality, and SE Montana coal mines attacked this problem cooperatively. We ordinated and classified pre-mine data to separately identify and characterize communities of three mine sites. We were unable to create a quantitative regional classification by analysis of vegetation data pooled across the sites, because differences in sampling methods between the mines yielded incompatible data. Therefore we used an alternative method, classical relevé analysis (tabling), to integrate quantitative single-mine classifications. 3) Regional communities identified include wide-ranging types [shortgrass prairie (BOGR/STCO), foothills prairie (AGSP), sage steppe **(**ARTR), pine savanna (PIPO)], localized types [skunk brush (RUTR), slope-toe snowberry (SYOC), riparian, wetland] and Agropyron old-fields. While the types identified dominate the landscape of SE Montana, more sampling (especially of riparian and dry/erosive sites) will likely identify more types by addition of un-sampled communities or subdivision of types recognized. 4) Species of interest are discussed, i.e. natives easy and hard to establish and the exotics likely to require most management.

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[2] Professor, Ecology Department, Montana State University, Bozeman MT 59717 tWeaver@montana.edu; [3] Research Associate, Montana State University, Bozeman MT 59717. kAho@montana.edu.

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Introduction

Coal has been removed from the Fort Union formation of Montana and adjacent states since the 1920s and is being removed in increasing quantities. To date over fifty square miles have been directly disturbed by coal mining in Montana (S. Regele, personal communication). In mine reclamation, pits are refilled and the surfaces are graded to pre-mine contours and replanted. Land managers often want to revegetate post-mine surfaces with communities similar to pre-mine communities.

To facilitate installation of natural communities on disturbed sites in SE Montana, we have identified and described pre-mine vegetation types of three mine sites (Absaloka (A), Rosebud (R), and Spring Creek (S); Aho et al. 2005, Aho et al. 2006a). These types represent vegetation typical of the southeast Montana coal mine region (Fort Union Formation; Fig. 1; USGS, 1999). Most general vegetation types appeared at more than one mine; these recurrent types were: short-grass prairie (A, R), foothills grassland (A,S), sage (R, S), skunkbrush (S, R), ponderosa pine (A,R, S), slope toe snowberry (A,R,S), riparian (A), wetland (A), and old field (A,R, S). The recurrence demonstrates the existence of regional types/ continuum segments.

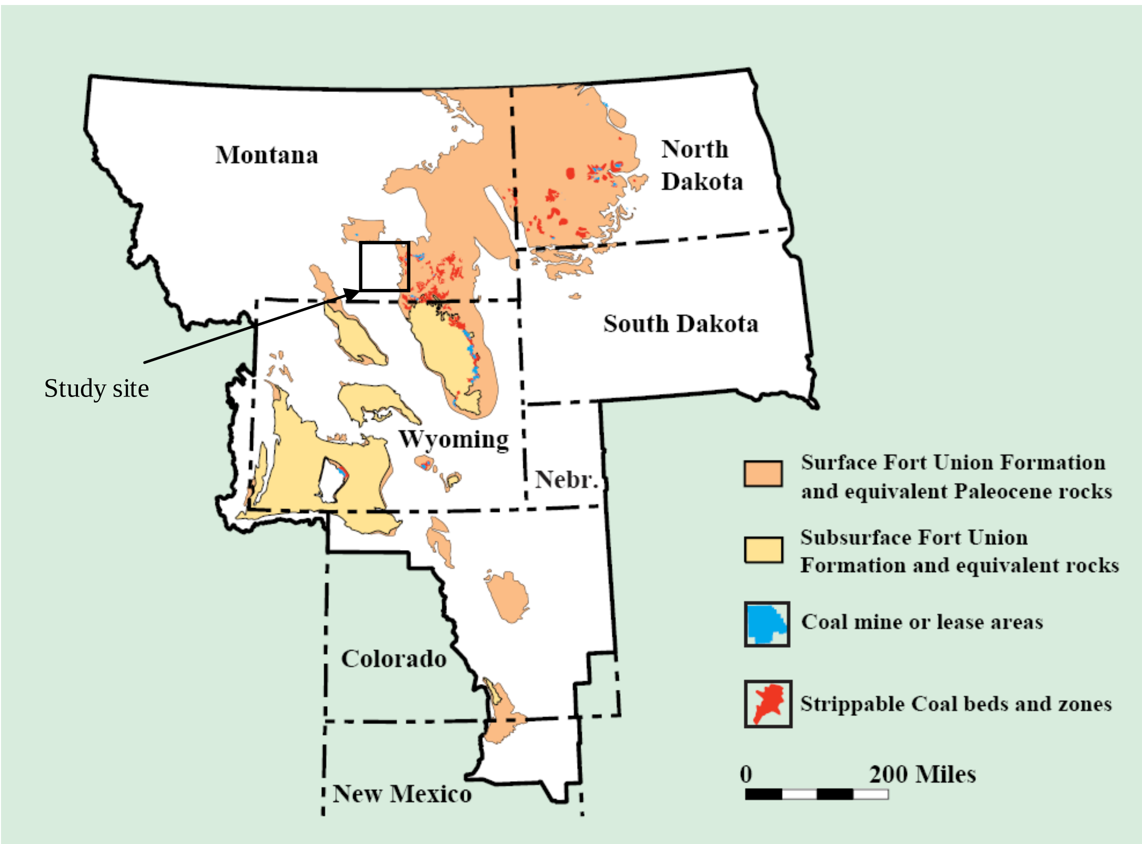

Figure 1. Location of Fort Union formation relative to the study site (USGS, 1999).

The objects of this paper are 1) to demonstrate the existence of regional types by showing that communities from different areas (mines) fall into a few cross-region (cross-mine) types, the members of which are more like each other than like members of the other types, 2) to quantitatively describe the composition of each regional type as a basis for seed-mix design, 3) to identify species which may be especially successful/unsuccessful in reclamation plantings and 4) to identify weeds which may need management. We will also hypothesize environmental differences (causes) responsible for the distribution of the regional types in SE Montana landscapes as a basis for choice of community types for particular sites in the post-mine landscape or for creation of sites intended to support particular communities.

Methods

The coal mine region of Montana lies in the southeastern sixth of the state. The zonal vegetation is Kuchler's BOGR-STCO (#64) and eastern Ponderosa pine (#16) types. Their climates are very similar (Weaver, 1980). Substrates for both are derived from unglaciated sandstone-shale layers of the Fort Union formation (Veseth and Montagne, 1980). The ponderosa type occupies the rockier substrates.

We studied pre-mine vegetation of three well-separated sites considered representative of the mineable surfaces of the region. The locations and climates of these sites are described/compared in Table 1.

Pre-mine vegetation was sampled at each (mine) site as part of the permitting process. The vegetation was stratified into subjective types. Multiple plots (5-36/ type indicated in Table 3.) of various shape and size (i.e., Absaloka = one 0.01 acre circular quadrat, Rosebud = clusters of forty 20 x 50 dm quadrats, and Spring Creek = clusters of two 1 x 0.5 m quadrats; Table 1) were well distributed in each subjective type. Species in the field layer were listed, each with an ocular estimate of its cover, i.e. the vertical projection of its crown onto the ground below. Thus the sampling involved very different versions of the Daubenmire (1959) method. Concentration on the understory surely underestimated plant cover in shrub and tree layers above the primary sampling plane. As a result our classification is based on vegetation in the field layer and not the overstory.

The vegetation of each site was separately ordinated/classified to discover and describe its structure. The sampling methods described above guaranteed inclusion of the major types at each site. Vegetation samples (plots) were graphically juxtaposed in 2-3 dimensional space using NMDS ordination (Kruskal and Wish, 1978). Vegetation samples were classified with hieracrchical agglomerative clustering using flexible-β = -0.25 linkage (Lance and Williams, 1967). Sample distances for ordination and classification were calculated using the Bray-Curtis index (Faith et al., 1987). Hierarchical classification trees were optimally pruned to identify the optimal number of types needed to adequately represent aggregations in the data. The pruning was based on a consensus of nine analytical methods described by Aho et al. (2006b) and Aho (2006).

While the identification of vegetation types at a particular site will be useful to revegetation of that site, a regional classification could be applied (as a standard) across environments of the broader region. It might be applied, for example, to unstudied mines (e.g. Decker or Big Sky) or across samples taken by different contractors at different times, different mines, or different mine segments. To create such a classification, one might identify regional types in two ways: 1) by juxtaposing species lists (tabling) and comparing apparently similar community types which were identified *separately* at the three sites (by use of cluster analysis discussed above), or (2) by creating a grand quantitative classification, by using the same ordination/cluster analysis on data from all three mines *simultaneously*. Because the data from the three mines was gathered in different ways, combining it in cluster analysis (i.e. method 2 above) seemed questionable. And indeed, tests of this method clustered plots by mine (i.e. by sampling method) and obscured recognition of regional types. Thus we chose method 1 to recognize/describe regional types.

Table 1. Description of the three mine sites studied: location, climate, data set, methods, and some non-comparable summary statistics.

	Absaloka	Rosebud	Spring Creek
Location			
Latitude	45° 48' 16''	45° 53' 4''	45° 6' 35''
Longitude	107° 2' 59''	106° 37' 30''	106° 59' 29''
Elevation, m	1117	992	1197
Elevation, ft	3630	3225	3889
Precipitation (inches)[1]			
Average Annual (Jan-Dec)	13.89	15.07	9.68
Average 1 water yr. (Oct-Sept)	13.78	15.11	9.29
Average 2 water yr. (Oct-Sept)	27.06	30.21	18.6
Average 1 yr. spr precip. (Mar-Jun)	6.62	7.81	5.03
Average 2 yr. spr precip. (Mar-Jun)	13.13	15.61	9.78
Sample			
Year	1992	1982-1983	1993
Mine unit	Tract 3E	Area C	Carbone Area
Precip. (ave, 2 water yr sampled)	29.5''	33.6-27.4''	20.9''
Sampling method			
Number of Plots	153	113	242
Sample description	0.01 acre circle	(20) 2x5dm quadrats	(1) 5x10dm quadrat
Number of samples per plot	1	2	2
Total plot area (m^2)	40.5	4.0	1.0
Whole area veg characteristics (NC[2])			
Average vegetation cover	87.4	80	54.6
Richness/Diversity			
Species richness (total)	273	173	151
Species per plot (average)	39.9	24.6	11.2
Shannon-Wiener diversity (average)[3]	2.07	2.24	1.41
Simpson's diversity (average)[3]	0.77	0.83	0.62

[1] Aho and Weaver (2005) showed that vegetation cover and production are better correlated with precipitation over a two year than a one year period.

[2] Due to different sampling methods, cover, richness and diversity measures are not comparable. They are included here to illustrate the biases of sampling methods, see discussion.

[3] Diversity measures were drawn from MacArthur and MacArthur (1961) and Simpson (1949).

In the strategy used, diagnostic tabling, we assumed that a type identified at one site is real, whether it occurs at other sites or not. Thus, we have listed the regional types found and grouped the mine-specific examples (= members) of each regional type. The regional type-list forms the heading for our association (relevé) tables (Table 3-7), with regional types (several broad columns) indicated in row one and communities component of each regional type (single columns) grouped under their heading and identified by their mine site (row 2) and the within-mine/within-community code (row 3). (For reference to the underlying reports (Aho et al., 2006a) the codes in row three are translated in Appendix 6). All species found at any of the three mines are listed in the first column (Appendix 1-5). The matrix is filled with presence data for each species x community so that each community is elaborately described in its column. Each presence entry includes the species constancy (% of the sample sites containing the species) and cover (the average cover of the species across the samples in the type/site). Inspection of the tables should simultaneously verify the regional types (by showing greater within-type than between-type similarity) and demonstrate variation among samples of a regional type gathered at different mines (i.e. show differences in adjacent columns due to differences in propagule availability, environments or sampling methods).

Tables are sorted to identify patterns in the data set. 1) Examples of regional community types identified at single mines (Absaloka, Rosebud, and Spring Creek) were grouped and ordered within (A,R,S) to facilitate examination of between mine variation. The regional types were ordered (L to R) on a hypothetical water gradient, i.e. grass, sage, *Rhus*, pine, slope-toe, riparian, and sodden. One might rearrange major columns (representing gradient positions- - none were moved) or minor columns (representing the mines in arbitrary order- - some were moved) to clarify/demonstrate emerging patterns. 2) Species in the vertical list were ordered according to their presumed water requirements, i.e. with xeric species first and hydric species last. The list was repeatedly re-sorted to improve the demonstration of water tolerances, i.e. to gather species occurring only in dry grasslands at the top and those only occurring in sodden environments at the bottom. 3) In ordering species by water requirement we discovered species that favored particular communities or groups of communities. Species with similar requirements were grouped within the water (vertical) gradient as responders (indicators) of water or other unidentified factors. That is, species are grouped into groups ('unions', Lippma, 1939; Daubenmire, 1968) which tend to stay together regardless of vegetation/ community type. 4) Within vegetation type *similarities* are emphasized by grouping species with this tendency to occur together regardless of vegetation type. And between community *differences* are emphasized by comparing the communities union-by-union, that is with respect to unions shared or not shared. While communities could be compared species-by-species, comparing by unions is both easier and more consistent with the age old observation that unions (or communities) are better predictors of their environments than single species are.

Results

The Unions

Ten unions-- groups of species which tend to co-occur regardless of community type -- were recognized. They are listed below (Table 2) with character species, presumptive environment, communities where they are common or absent, and an alphabetic designator. The unions are listed in order of moisture available in their presumptive environments, as determined by rainfall, soil texture, rockiness, and free water.

Table 2. Principle unions[1] of SE Montana steppe/ savanna vegetation identified in the examination of three representative sites (Absaloka, Rosebud, and Spring Creek). Each of the eight native vegetation types to be described is comprised of one or more of the unions described[2].

Union	Union name	Character species	Environment, presumptive	Communities occupied, 1-8
A	Grassland, dry	*Plantago patagonica* *Liatris punctata* *Opuntia fragilis*	Zonal shortgrass prairie	1 & 2 absent in 3-9
B	Grassland, well drained	*Agropyron spicatum* *Stipa comata*	Soils well drained	1-6 absent in 7,8,9
C	Grassland, clay	*Agropyron smithii* *Stipa viridula*	Soils less permeable	1,2,5,6 weak in 2.4,7&8
D	Pine/grass weeds	*Collomia linearis* *Filago arvensis*	Dry sites	1,2,6 absent in 3,4,7,8,9
E	Mixed grass	*Bouteloua curtipendula* *Andropogon scoparius* *Cerastium arvensis*	Moister sites	1,2,5,6 absent in 7,8, and 9
F	Sage	*Artemisia tridentata*	Soils deep & dry	3, 4, possibly 6,7 rare in 1,3,7,8,9
G	*Rhus*	*Rhus trilobata* *Pinus ponderosa*	Soils moist/well drained	5,6 rare elsewhere, esp. 9
H	Snowberry	*Symphoricarpos occid.* *Rosa woodsii*	Soils moist, low permeability	5,6,7,8 rare in 1,2,3
I	Riparian wood	*Ribes, Prunus,* *Crategus, Urtica*	Draw bottom	8,9 absent 1-7
J	Wet	*Spartina pecinata* *Hordeum jubatum* *Scirpus americana*	Soils sodden	9 absent 1-8

[1] A union is a 'functional group' a group of species that commonly appear together.

[2]To clarify the 'union concept', communities 1&2 both contain union A.
Community 1 also contains unions B, C, D, and E.

Near-climax native communities

Ten regional vegetation types (1-9b) are displayed across row one of the association/relevé table (Appendix 1). Rows two and three identify examples of regional communities by their mine (row two: Absaloka=A, Rosebud=R, and Spring Creek=S) and within mine 'local community' (1, 2, etc). Note, then, that we have pooled communities identified both at different sites and as distinct within mine-sites examples of the somewhat broader regional types. The communities are listed from the driest grasslands (left) through *Agropyron spicatum*, sagebrush, *Rhus* without or with pine, run-in, and riparian to at least seasonally sodden sites. The last regional-type (9a and 9b) describes vegetation of old fields once seeded to either *Agropyron cristatum* or *A. intermedium*.

As noted above, each community is composed of several species consorting in one or more unions, i.e. groups of species that tend to occur together across multiple vegetation types (Lippma, 1939; Daubenmire, 1968). Important species in the regional flora are listed in column 1of the releve table (Appendix 1), and those comprising each union are grouped within the list (groups A-J). The unions are summarily described in Table 2. Less important species - - those present, but having a constancy of 30% in no community- - are listed, by community type, in Appendix 5, because, while they are not discussed, they may suggest relationships between local communities and between local and regional communities.

<u>Shortgrass prairie</u>. Dry grasslands (type #1, STCO; Appendix 1) are the normal (zonal, Daubenmire 1968) grassland of the region (Kuchler, 1964, type 64 & Mueggler and Stewart, 1980, STCO/BOGR) against which all the other types will be compared. Two communities were recognized at Absaloka, three were recognized at Rosebud, there were none at Spring Creek (Appendix 1). Since there is no overstory (unions F-I) the aspect is grassy. Character species come from unions B & C, i.e. *Bouteloua gracilis, Stipa comata,* and *Agropyron smithii*. Species of dry union A (including *Plantago, Opuntia,* and *Liatris*) are well represented, but provide little cover. Despite its dry environment, mixed grasses (union E) may be present. Unions D (pine/grass weeds) and the moister unions (F-J) are poorly represented. The Rosebud communities apparently have poorer representation of unions A (dryland forbs) and C (less permeable soils), D (pine/grass weeds), and E (mixed grass) than the Absaloka communities.

<u>Foothills prairie.</u> *Agropyron spicatum* grasslands (type #2, AGSP; Appendix 1) found at Absaloka and Spring Creek correspond to Kuchler's (1964, type 63) foothills prairie or to the *Agropyron spicatum* types of Mueggler and Stewart (1980). Due to the absence of shrubs its appearance is grassy and due to the presence of *Agropyron spicatum, Stipa comata* and *Phlox hoodii*, it appears "bunchier" than the shortgrass prairie. The dominant grasses are from union B (*Agropyron spicatum*/ well drained), those from union C (*Agropyron smithii/ Stipa viridula*/ clay) are present but with little cover, and the dry-site forbs of union A (*Opuntia, Liatris*) are present as in the shortgrass prairie. Mixed grasses (E) are more important than in the short grass prairie. And species of the pine/grass (D), shrub (F-H) and wetland (I-J) unions are still few. While the Spring Creek community apparently has fewer species, mostly with less cover, the difference is probably due to differences in sample techniques or precipitation.

<u>Sage steppe.</u> The *Artemisia tridentata/ Agropyron spicatum* community (type#3, ARTR; Appendix 1) parallels Kuchler's sage steppe (1964, type 55) or the ARTR-AGSP type of Mueggler and Stewart (1980) sage steppe. It was well represented at Rosebud and Spring Creek, but absent at Absaloka (Appendix 1). The character species, *Artemisia tridentata*, gives it a gray shrubby aspect in contrast with the grassier plains and foothill prairies. The understory is dominated by grasses of the *Agropyron* union (B, well drained) with some *Agropyron smithii.* The type is very species poor, essentially lacking unions A, D, E, and G-J. The absent species may be excluded by allelopathic terpenes (Weaver and Klarich, 1977) or shrub preempted water. Competition for water seems less likely because shrubs and trees of other types (*Rhus* or pine communities) do not exclude them. Compared to the Rosebud community, cover and

constancies are somewhat lower at one Spring Creek community and much lower at the other (Appendix 1).

Skunkbrush vegetation. The *Rhus trilobata/ Agropyron spicatum* community (type #4, *Rhus*; Appendix 1), is regionally common (Mueggler and Stewart, 1980, RUTR-AGSP), but occurs on gravelly sites too small to map at a regional scale (Kuchler, 1964). It was well represented at Spring Creek (two communities) and Rosebud (three communities), but was absent from Absaloka (Appendix 1). Its aspect is determined by clones of the 'greener-than-sage' shrub (*Rhu*s, G), sometimes with sage or pine. Three herbaceous unions- - both the better drained (*Agropyron spicatum,* B) and clayier (*Stipa viridula/Agropyron smithii,* C) unions of the plains and the mixed grass union (*Andropogon/Bouteloua curtipendula,* D) are represented in the understory. The pine/grass (D), sage (F), run-in/riparian (H), and wetland (I,J) unions are poorly represented. The Spring Creek communities, once again, seem depauperate.

Pine skunkbrush savanna. The *Pinus ponderosa* regional-type (type #5, PIPO; Appendix 1), mapped by Kuchler (1964, type 16), is similar to the *Rhus* type and belongs to the grassy sub-series of Pfister et al (1977). It has a pine overstory (G union), a *Rhus/Symphoricarpos* (G/H) shrub layer, and an understory dominated by a full grass compliment (B/C). Dry grass herbs (union A) and pine/grass (D) and the mixed grass (E) unions appear as in the grasslands (types #1& #2) of the Absaloka mine but are progressively less well represented at the Rosebud and Spring Creek sites (Appendix 1). *Rhus* (G) is complemented by *Symphoricarpos* (H) and *Festuca* (E) of moister Absaloka sites. Riparian/wetland plants (I-J) are absent. Pine communities are likely moister (and/or more fire sheltered) than *Rhus* communities, and thus might be expected to include a lesser component of the dry grass union (C); the contrary is so, perhaps because pine transpiration creates dry micro-environments by draining sites near the trees (cf Weaver et al., 2001.).

Run-in vegetation. Slope-toe sites with rock-free fine textured soils are commonly occupied by a grassy matrix of *Agropyron smithii, Stipa viridula*, and *Artemisia cana* (union C) sometimes overtopped by clones of *Rhus* (G) and/or *Symphoricarpos* (H) and sometimes supporting pine trees (G). While this land-form/ vegetation type (type #6, S-TOE= slope-toe; Appendix 1) is everywhere present in SE Montana (we found it at Absaloka, Rosebud, and Spring Creek), units of it are too small to appear on regional maps (Kuchler, 1964) or western Montana (Mueggler and Stewart, 1980). Dry grassland (A), pine/grassland (D), and mixed grass (E) unions are absent- - as is the sage union (F), except at Spring Creek. A few wetland plants (I) stray upward from the riparian to moister micro-sites. No flood-plants (J) are present. The Absaloka/Rosebud/Spring Creek communities are more similar in the run-in environment than in other regional types. Still, run-in communities of the Absaloka mine have more dry grassland herbs (A) than do her sister mines, Rosebud and Spring Creek (Appendix 1).

Riparian. While riparian communities are seen at all three mines, the type was only sampled at Absaloka. This community (type #7, RIPR= riparian; Appendix 1) represents vegetation of the uppermost reaches of prairie streams (Lessica, 1989), not the cottonwood forests of Kuchler (1964, type # 98). Its aspect is determined by tall mesic shrubs such as *Ribes aureum, Crategus succulenta, Prunus americana*, and *Ribes setosum* (union I). A third of the stands contain *Fraxinus pennsylvanica.* Union C is weakly represented in the understory. Thus, plants of all but the mesic (H) and wet (I) unions were absent.

Wetland. Coarse grasses characterize these seasonal to permanent wetlands (type #8, SODD= sodden; Appendix 1); examples are *Hordeum jubatum, Spartina pectinata, Equisetum laevigatum* and even *Scirpus americanus* (union J). The type was sampled only at Absaloka, where two communities were found. The second community has relatively high and constant cover of union I (e.g. *Spartina, Hordeum,* and all of the *Scirpus* found). The first community contains both this wetland union (J, with lesser dominance) and a weak representation of shrubs from two more mesic unions (*Ribes aureum,* I and *Symphoricarpos,* H). It is apparently ecotonal between the riparian and sodden environments. The weediness of the ecotonal type may be due to disturbance of animals crossing it to water. If draws are searched more wetland types of restricted distribution may be found (Hansen et al., 1995).

Old field. Old fields (type #9, FIELD; Appendix 1) seeded to either *Agropyron cristatum* (9b) or *Agropyron intermedium* (9a) were present at all three sites. These most likely occupy the former dry grassland (type #1) and slope-toe (type #6) sites. Despite the passage of perhaps 60-80 years (D. Myran, personal communication) the types/ grasses seeded are little invaded by either exotics or natives. While there is a considerable literature on this type, our description may be the most complete.

Weeds of native vegetation

While there is no intention to include exotics in reclamation seed mixes, they will surely colonize and require management. Thus, we outline weed distribution among the vegetation types/ environments studied. Exotic distribution parallels that of natives, but is less complex. We think of three possible reasons for the simpler distribution. 1) As generalists/opportunists weeds have broad tolerances and range widely on environmental (e.g. water) gradients, perhaps with greater range-of-size (plastic) variation than natives. 2) As a result of their shorter North American history they have not adapted to coexist with particular native species or been adapted to by native species; thus they exhibit less community integration. And 3), because their species number is smaller than that of native species, patterns among them are harder to recognize.

The association (relevé) table (Appendix 2) suggests that exotic/weed unions have a broader than native tolerance range. The weed unions correspond roughly to those outlined in Appendix 1, and so are labeled in parallel, despite some imperfect matches. Unions A,B, and C are range weeds. Unions I and J are restricted to riparian and sodden sites. There are no clear members of D (absent in shrubland and slope toes) or E (absent in sage and slope toes). Membership in union F (split among moister and drier sites) is vague, as it is for natives (Appendix 1-2).

Dry grassland exotics (cf union A) are few and include *Alyssum alyssoides* and *Artemisia dracunculus.* Their evolution in dry sites at the Eurasian site of their origin/evolution probably pre-adapted them for growth in dry grasslands of N America.

Relative to natives, a larger fraction of weeds are broadly distributed, and thus must have broad tolerance ranges (cf. union B, Appendix 1, 2). *Bromus japonicus, Bromus tectorum,* and *Tragopogon dubius* are examples. We offer two hypotheses for their success. First, these weeds succeed by being generalist opportunists and thus benefit from having broad tolerance ranges. Second, disturbed sites colonizable by them exist in every vegetation type. The second mechanism must be less important because these weedy species are often important and they occupy more space than does any micro-environment disturbance (e.g. prairie dog burrows) we can imagine.

Several species are important in relatively moist sites, but exist in drier communities by occupying moist micro-environments. These include *Agropyron cristatum* and *Medicago sativa* (cf. union H).

In contrast to the three preceding broad ranging weed-unions, a union with a similar number of species appears only on wetter sites (cf. I-J unions). These surely also arrived pre-adapted: they evolved on Eurasian wet sites and their physiologic (rather than allelopathic) strategies have worked well in N. America. This group includes *Cirsium arvense, Arctium minus, Chenopodium album,* and *Bromus inermis*.

<u>Old field and reclamation communities</u>

Old fields were seeded (D. Myran, personal communication) to *Agropyron cristatum* in the 1940-1950's (Soil Conservation Service/ NRCS revegetation) and to *Agropyron intermedium* in the 1960's (USDA Soil bank program). Some of these fields were included in pre-mine sampling and many remain in SE Montana.

<u>Invaders of old fields.</u> Natives establishing in old fields (Appendix 3) must be both adapted to the old field environment and hearty enough to overcome the competition/allelopathy of the well established *Agropyrons*. If seeded into newly created dry reclamation sites, they should establish easily.

Successful old field invaders in SE Montana come from unions which occupy dry grasslands or grassland/shrublands. These include (Appendix 3) union A (*Opuntia fragilis and Cirsium undulatum*), union B (*Stipa comata, Koeleria cristata, Gaura coccinia* and *Guterizia sarothre*), union C (*Agropyron smithii, Artemisia cana, Heterotheca villos*a, and Ratibida *columinifera*), union D (*Aristida purpurea*) and union E (*Ambrosia pilostachya*). Some of these plants are obviously more desirable than others.

Helianthus petiolaris (union G) is the only successful invader from mesic or wet unions. It may enter disturbed microsites by exuding allelochemics and/or survive on water from soil horizons little occupied by grass roots.

No native plants from slope-toes (union H, *Symphoricarpos*), riparian (union I, *Ribes*), or sodden sites (union J, *Spartina*) persist in old fields (Appendix 3).

Compared to natives, a larger fraction of the exotics succeeded in old fields (Appendix 3). The invaders included the weeds of driest grasslands (union A, *Alyssum alyssoides*), general grasslands (union B, *Bromus japonicus* and *Tragopogon dubius*). They also came from the slope-toe union (H or its exotic parallel) which contributed no natives. Examples of toe-slope weeds/exotics invading old fields include *Poa pratensis, Taraxacum officinale,* and *Melilotus officinale*.

Three species associated with old fields do not appear in natural vegetation. They are *Agropyron intermedium, Convolvulus arvensis,* and *Poa compressa.* They were surely introduced in farming and apparently persist, but without dispersing out of the old fields.

<u>Old field failures.</u> While species present in old fields planted to *Agropyrons* will likely establish well in plantings (Appendix 3), those not establishing in old fields (Appendix 4) may be difficult to establish in reclamation if establishment is retarded by the physical environment. The difficulty will be less if their exclusion is due to competition or allelopathic interaction with the *Agropyrons* (*A. cristatum, A. intermedium*) not included in new plantings. The difficulty will also be less if the absence is due to a failure to disperse into large fields, a correctable deficiency.

Surprising failures include major grassland plants of union A (*Calamovilfa longifolia* and *Calamagrostis montanensis*), union B (*Bouteloua gracilis, Carex pennsylvanica,* and *Carex filifolia*) and union C (*Artemisia ludoviciana*), all well adapted to one-time range sites. The same is true for *Artemisia tridentata* (union F). Because these plants are well adapted to the physical environment, their failure must be due to failure to disperse, lack of mycorrhizae lost in farming, or competition/allelopathy of the *Agropyrons*.

Failures which perform best in the somewhat moister *Rhus*/pine environments of union D (*Arabis hoelbelli* and *Collomia linearis*) and union E (*Andropogon scoparius, Festuca idahoensis,* and *Yucca glauca*) are more likely excluded from drier old field sites by lack of water, but they may also be affected by poor dispersal or competition/ allelopathy. The same is true for union G (*Rhus trilobata* and *Pinus ponderosa*) and union H (*Symphoricaros occidentalis* and *Rosa woodsii*).

Plants of union I (*Ribes aureum* and *Crategus succulenta*) and union J (*Spartina pectinata, Equisetum laeviigatum,* and *Scirpus americana* would undoubtedly be excluded from old fields by lack of water - - whether or not they disperse into fields or interact with the *Agropyron*s.

With or without weak dispersal/competition, exotics of the moist site unions, union I (*Cirsium arvense, Phleum pretense, Rumex crispus*) and union J (*Arcticum minus* and *Bromus inermis*) would as likely be excluded by lack of water as are the I-J union natives.

Discussion

Ten vegetation types were identified (listed) from the Absaloka, Rosebud, and Spring Creek sites (Table 2). Four of these are widespread, mapped (e.g. Kuchler, 1964), and are relatively well understood: shortgrass prairie, foothills prairie, sage brush steppe, and eastern ponderosa pine. Skunkbrush, run-in, and prairie-draw (our 'riparian'), and wetland vegetation are less extensive, unmappable at a regional scale, and less understood. Ironically, wetland vegetation, the most azonal and perhaps the smallest, is the most studied of these azonal types. Old field vegetation is vast and little studied.

Since most communities recognized represent intuitively obvious and/or informally recognized types, they likely represent 'targets' to be used for native reclamation types. Some landforms, e.g. the dry grasslands, have been extensively sampled at all three mines, so we are unlikely to identify more types on them. In contrast, additional types may be found in less studied environments. For example, more extensive sampling of riparian areas, unsampled at two mines despite their presence there, will likely yield more types. Similarly, badlands, where they exist, probably contain undescribed communities for which reclamation may or may not be attempted.

The phrase 'target for native reclamation types' recognizes two facts. 1) Some land may be reclaimed with non-native vegetation types. And, 2) if reclamation with natives is the objective, initial seedlings will be relatively simple and the communities will evolve (succeed) by addition (natural or engineered) of species over long periods of time.

While representative communities for a regional-type are usually sampled (or are known of) at several mines, detailed community descriptions (e.g. Appendix 1) vary considerably among them. For example, species richness was lower at Spring Creek than at Rosebud and much lower than at Absaloka (except, mysteriously, in the slope-toe community). We suggest three causes, not mutually exclusive. 1) The environment (climate/soil) might be different. Or history (e.g. grazing) might have been different. If so, natural variation in community composition is demonstrated. 2) Abnormal rainfall levels (> 1 SD from the mean) can modify the expression of a given stand/vegetation type (Aho and Weaver, 2005). However, because rainfall in the biennium of sampling was within one standard deviation of the mean at all three mines, we cannot attribute the difference to differences in weather.

The most likely cause of between mine differences (#3) is variation in sampling methods. Such differences in methods and sampling teams have giant effects on results and mandate great caution in comparing data sets (Grieg-Smith, 1964). Specifically, we attribute most of the between mine variation in presence data to differences in quadrat sizes and most of the variation in cover to the lack of calibration of 'ocular' cover measurement among the mines. a) *Species richness* within any type varies among mines, usually dropping from Absaloka through Rosebud to Spring Creek. This is expected because richness drops with declining plot size (Whittaker, 1975). Using the Whittaker approximation to predict richness of Spring Creek communities ($1m^2$ per plot) and Rosebud communities ($4m^2$ per plot) from Absaloka data ($40.5\ m^2$ per plot) we would expect no species at Spring Creek and (0.38 x # Absaloka species) at Rosebud. The low, but higher than expected number of species actually found at Spring Creek and Rosebud might be due to two factors. The vegetation may be so homogeneous, especially in the slope-toe type, that most species are captured in a plot of $1\text{-}2m^2$. In addition, use of dispersed subplots of the $1\text{-}2m^2$ sample probably contributes to capture of more species than would be found in a single plot of the specified area. b) *Species constancy* within any type varies among the mines, apparently falling from Absaloka through Rosebud to Spring Creek. This is expected because, when a larger plot is used, it captures more of the species present than would be caught with a smaller plot. c) *Cover* may also vary systematically between the mines because, while within mine samples were gathered by one sampler/method, between mine cover samples were not calibrated one against the other. d) Because *diversity* is calculated from records of species present and their numbers, differences in sampling that affect the number of species recorded in a plot (e.g. plot size) invalidate any comparison of diversity (richness, Shannon-Weiner, or Simpson, cf. Table 1) across mines.

An alternate method for identifying regional community types is to pool samples across the mine areas and classify. We did so, determined an optimal number of types, and examined the classification's underlying hierarchical structure. The number of community types per mine declined (seemingly impossible) and the stands tended to be grouped by mine, rather than community. Thus, the similarity of climate, weather, and sampling methods within mines seems to impose a structure on the data which overrides variation among regional types obvious to both ranchers and ecologists.

We identified groups of species (unions) which seem to occur together regardless of community. These proved useful in community description. Information on the physical environment or community (competition/allelopathy) characteristics each requires/indicates is largely unavailable.

We speculated on physical environments occupied by individual community types and controlling differences in their distributions. Some of the hypotheses generated will be investigated in a follow-up project. Its objectives are to identify, for common reclamation environments, the (native) community most likely to succeed. And since, with equivalent management, there is a 1:1 relationship between ‘climax’ vegetation and its environment, to describe the environment needed to support establishment of a given vegetation type.

Our samples included exotics (weeds), as well as natives. This data (Appendix 2) can be used to 1) determine what exotics are likely to enter a given environment/vegetation type and 2) determine how successful they will be in that vegetation type, i.e. whether they might eventually damage the type or merely occupy disturbed sites in that type. Note that a species that only colonizes local disturbance (e.g. gopher diggings) may spread into adjacent sites if natives are weakened (e.g. by excessive grazing or trampling). The impact of specific weeds can be estimated from Appendix 2. We conclude that weeds of drier sites have the potential to invade widely, may persist, and may decline in density and stature if natives establish and out-compete them (succession). Observation of old field succession discussed below, show that while such succession may proceed, it may require decades or centuries.

Old fields planted to *Agropyron cristatum* (1950’s) or *A. intermedium* (1960’s) are described as type 9a/b in Appendix 1. While the resultant *Agropyron* vegetation was surely simple- - due to the elimination of most natives and exotics by long cultivation- - natives and exotics are entering these communities (Appendix 1-3). We offer six observations. 1) Invaders of *A. cristatum* and *A. intermedium* communities are virtually identical (Appendix 3). Possible exceptions, all of which do best in *A. cristatum* fields, include *Plantago argyrea, Artemisia cana*, and *Taraxacum officinale*. Thus, while *A. cristatum* may be allelopathic, neither *Agropyron* is more competitive/allelopathic than the other. 2) The proportion of weedy species invading old fields is greater than the proportion of invading natives (Appendix 1-3). This may indicate either that after 50 years, old fields are in an early stage of succession dominated by native/non-native early seral species. Or it may indicate that, as a group, exotics are better adapted to the environment (unlikely) or better pre-adapted to coexistence with *A. cristatum/A. intermedium*. 3) Native invaders of old fields (Appendix 3), are usually members of unions A,B, and C (those of dry grasslands, grasslands with well drained soils, and grasslands with finer textured soils). We offer two non-exclusive explanations. First, seed is available because the plants were on site at the time of seeding or it is available from nearby relic vegetation. Second, these plants are adapted to sites which they originally occupied. Reciprocally, native/exotic plants of mesic to wet sites are absent because they are ill adapted to dry old field environments. 4) Native plants establishing in old fields (Appendix 3) should be especially easy to establish in reclamation sites, but the variety is disappointing. 5) Natives which establish well in old fields may have evolved their capacity in a similar role, that is, repairing micro-disturbance within the community. Reciprocally those which don’t invade old fields could be late seral species which require prior presence of host or mycorrhizal species. 6) Natives and exotics that don’t invade old fields (Appendix 4) probably need special treatment to establish on dry reclamation sites. Their failure to establish in *Agropyron cristatum/ A. intermedium* sites may be due to lack of dispersal, physical requirements, symbionts, or intolerance of the *Agropyrons*. The names of the most important of these species are bolded in Appendix 4.

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Appendix 1. Presence of primary NATIVE species in vegetation types of three SE Montana mines. Terms/symbols are defined below table. Species constancies >50% shaded. Species mentioned in the text are bolded.

	Vegetation type	1 STCO					2 AGSP		3 ARTR			4 RHTR					5 PIPO				6 S-TOE			7 RIPR	8 SODD		9a AGIN		9b AGCR		
	Mine, (A,R, or S)	A	A	R	R	R	A	S	R	S	S	S	S	R	R	R	A	A	R	S	A	R	S	A	A	A	A	S	S	A	R
	Intra-mine community	1	2	1	2	3	1	1	1	1	2	1	2	1	2	3	1	2	1	1	1	1	1	1	1	2	1	1	1	1	1
	Number of plots	32	24	5	24	28	14	31	11	36	8	78	14	4	9	8	12	14	11	10	10	8	30	10	11	6	6	8	27	14	5
A	Asclepias verticillata	1A	2A	..	..	..	4A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Astragalus lotiflorus	++	3A	..	..	..	3A	..	..	..	..	..	..	..	..	..	..	++	..	..	++	..	..	..	..	..	4A	..	..	4A	..
	Astragalus plattensis	5A	2A	..	..	..	..	++	..	..	1A	+A	..	..	..	..	..	++	..	..	++	..	..	..	..	..	1A	..	..	++	..
	Plantago patagonica	9A	8A	..	..	..	4A	++	..	++	..	..	..	..	..	..	++	5A	..	..	..	..	1A	..	..	..	1A	..	++	2A	..
	Opuntia fragilis	7A	7A	1A	1A	1A	6A	..	+A	..	..	..	..	..	..	..	1A	3A	..	..	++	..	..	..	..	..	8A	..	..	6A	..
	Lygodesmia juncea	6A	6A	5A	2A	4A	4A	..	++	..	..	..	..	..	1A	..	1A	4A	++	..	1A	2A	..	..	..	..	4A	..	..	4A	1A
	Psoralea esculenta	3A	4A	..	++	..	5A	++	+A	..	..	+A	..	..	..	..	..	1A	..	+A	..	..	..	..	..	..	..	..	..	++	..
	Calylophus serrulatus	++	5A	..	+A	2A	4A	..	+A	..	1A	..	..	2A	..	1A	..	1A	1A	..	..	1A	..	..	..	..	..	..	..	..	..
	Cirsium undulatum	5A	4A	1A	1A	1A	6A	1A	+A	+A	1A	+A	1A	..	..	..	1A	2A	++	..	2A	1A	..	..	..	..	8A	..	..	6A	1A
	Liatris punctata	8A	8A	..	+A	3A	7A	..	+A	+A	..	..	..	..	3A	..	3A	4A	3A	1A	++	..	..	..	..	..	1A	..	..	2A	..
	Calamagrostis montan.	2A	5A	3B	1A	4A	4A	..	++	..	..	..	..	2A	5A	1A	4A	3A	..	+A	..	..	..	..	..	..	..	..	..	..	..
	Psoralidium tenuiflora	6A	5A	..	+A	+A	6A	1A	+A	1A	..	2A	+A	..	1A	..	4A	3A	+A	1A	2A	1A	..	..	..	..	1A	..	..	2A	..
	Calamovilfa longifolia	2A	4B	5C	1A	6C	5A	..	..	..	1A	+A	..	4A	2A	2A	1A	4A	4A	..	++	2A	..	..	..	..	..	..	+A	1A	..
	Plantago argyraea	..	..	3A	9A	8A	..	+A	3A	..	..	..	..	..	..	4A	..	..	+A	..	..	1A	..	..	..	..	..	..	..	..	5A
	Echinacea angustifolia	7A	6A	..	2A	1A	9B	..	4A	..	..	..	..	2A	4A	3A	3A	1A	4A	..	1A	1A	..	..	..	..	4A	..	..	1A	..
	Hedeoma hispidum	7A	4A	1A	4A	2A	2A	..	2A	+A	..	..	..	..	..	1A	..	2A	..	..	..	1A	..	..	..	..	1A	..	..	2A	..
	Vulpia octoflora	7C	7C	5A	4A	6A	7A	++	2A	++	..	..	..	..	..	2A	2A	4A	++	..	..	..	..	..	..	..	4A	..	..	4B	1A
B	Poa secunda	9C	8C	..	6C	7A	9A	4A	6A	3A	2A	2A	..	..	2A	3A	9A	7B	+A	2A	3A	2A	4A	..	..	..	3A	..	3A	3A	3A
	Sphaeralcea coccinea	9A	7A	7A	8A	5A	7A	6A	7A	2A	..	2A	5A	2A	2A	6A	1A	4A	4A	1A	2A	1A	2A	..	..	..	4A	..	3A	4A	5A
	Carex filifolia	+A	1A	..	2B	9D	8C	1A	4B	+A	4C	1B	..	..	9C	4B	2A	++	1A	3A	..	1B	..	..	..	..	..	..	..	..	..
	Agropyron spicatum	2A	1A	..	2B	6C	9D	7D	9D	6D	6A	9D	9D	9C	9D	9D	5C	1A	9D	9D	++	1A	1A	..	..	..	3A	..	..	++	1A
	Gutierrezia sarothrae	6A	6A	1A	5B	5B	9C	2A	9C	2A	2A	6B	2A	2A	8C	7A	2A	2A	6B	7B	++	1A	+A	..	..	..	9C	..	..	7C	5B
	Phlox hoodii	4A	4A	..	7A	4A	9B	5B	9B	3B	2B	5B	+A	4A	8A	8A	4A	2A	2A	4B	..	..	2A	..	..	..	..	..	++	..	..
	Koeleria cristata	9A	9B	9A	8D	9C	9B	2A	9D	4B	1A	4B	1A	2A	9C	9C	5A	9A	5A	6A	++	3B	4B	..	..	..	6A	..	1A	4A	5A
	Stipa comata	9D	9D	9D	9D	9D	9D	9D	6B	2C	3A	3B	4D	7A	7C	4C	9B	9C	7B	4B	3A	3B	2B	..	..	..	4A	..	1A	7A	1A
	Artemisia frigida	5A	4A	1A	8C	6B	9A	6C	6A	1A	1A	3A	3A	4A	2A	3A	3A	3A	2A	+A	++	3A	+A	..	..	..	3A	..	+A	2A	5B
	Carex pensylvanica	8C	9D	9E	1A	4C	7A	+A	..	+A	..	+A	..	9D	3B	3C	6B	8C	3A	..	5B	..	..	..	..	..	1A	..	..	..	..
	Bouteloua gracilis	8B	7B	7A	8C	9D	7A	2B	6B	+A	2C	+A	..	..	4A	6A	++	4A	2A	+A	..	3A	..	..	..	..	..	..	..	..	..
	Psoralea argophylla	8B	8A	5A	5A	6A	9A	2A	5A	1A	2A	1A	1A	4A	2A	3A	8A	9B	2A	+A	6A	1A	..	..	++	..	1A	..	..	3A	3A
	Gaura coccinea	9A	8A	7A	7A	5A	9A	1A	3A	1A	1A	2A	2A	..	5A	2A	4A	5A	4A	+A	2A	4A	+A	..	..	..	8A	..	..	9A	1A
C	**Artemisia cana**	8D	4A	9D	6C	2A	5A	1A	2A	1A	2C	1A	..	7B	3A	4B	3A	6B	1A	++	8B	6C	3C	3A	++	..	1A	..	5D	2A	..
	Stipa viridula	9C	4A	3B	7C	2B	4A	+B	9D	1A	..	1A	2A	4A	7B	6A	6C	5A	1A	+A	9D	6C	8D	1A	2A	1A	3A	..	1C	2A	3A
	Achillea millefolium	8B	6A	5A	4A	2A	7A	..	6B	1A	..	1A	+A	9B	6B	7A	9A	9A	1A	3A	9A	9C	1A	5A	1A	1A	6A	1A	+A	4A	1A
	Agropyron smithii	9D	9D	9D	9D	8D	9C	4B	9D	4C	4C	3A	4B	4A	5B	9C	5A	9C	8B	..	9D	9D	9E	1A	5C	1A	..	..	4C	++	5A
	Artemisia ludoviciana	5A	9A	5C	3A	1A	5A	+A	..	+A	..	+A	+A	7A	3A	3A	5A	8A	..	..	5A	7A	2A	++	1A	..	1A	..	+A	1A	..
	Rosa arkansana	4A	7A	5C	2A	2A	4A	..	1A	..	..	..	..	4A	4A	3A	3A	7A	2A	..	5A	2A	++	2A	2A	..	4A	..	..	1A	1A
	Aster falcatus	7A	5A	..	2A	2A	7A	..	1A	+A	..	+A	+A	2A	6A	3A	6A	7A	++	..	8A	..	1A	++	..	..	4A	..	..	2A	..
	Solidago missouriensis	2A	4A	1A	1A	3A	4A	..	..	..	..	+A	..	9A	5A	1A	2A	6A	1A	3A	3A	1A	..	..	..	..	..	..	..	..	..
	Ratibida columnifera	9A	6A	..	1A	1A	7A	..	++	..	..	..	..	..	..	1A	6A	6A	..	..	8A	..	..	++	++	..	8A	..	..	7A	..
	Solidago mollis	1A	2A	3A	+A	1A	1A	..	..	++	..	+A	..	..	..	..	..	3A	++	..	5A	1A	+A	++	++	..	..	..	..	1A	..
	Heterotheca villosa	7A	9A	..	+A	2A	6A	+A	..	..	..	..	..	..	..	..	4A	7A	2A	..	3A	..	..	..	..	..	4A	..	..	6A	..
D	Arabis holboellii	2A	3A	..	++	+A	1A	..	..	+A	..	++	..	..	1A	..	5A	3A	..	..	..	..	..	..	..	..	..	..	++	1A	..
	Astragalus missouriensis	++	3A	..	..	++	7A	+A	..	+A	..	+A	..	..	..	..	4A	4A	..	..	++	..	..	..	..	..	1A	..	..	4A	..
	Filago arvensis	6A	3A	..	..	..	++	..	..	..	..	..	..	..	..	..	1A	4A	..	..	..	..	++	..	..	..	3C	..	..	2A	..
	Erigeron divergens	3A	4A	..	..	..	++	..	..	..	..	..	..	..	..	..	5A	3A	..	..	..	..	..	..	..	..	..	..	..	1A	..

Appendix 1 cont.

	Vegetation type	1 STCO					2 AGSP		3 ARTR			4 RHTR					5 PIPO				6 S-TOE			7 RIPR	8 SODD		9a AGIN		9b AGCR		
	Mine, (A,R, or S)	A	A	R	R	R	A	S	R	S	S	S	S	R	R	R	A	A	R	S	A	R	S	A	A	A	A	S	S	A	R
	Collomia linearis	4A	2A	3A	+A	..	..	..	..	..	..	..	..	..	..	..	7A	4A	..	..	++	..	..	..	++	..	..	..	..	..	..
	Aster oblongifolius	++	..	..	..	..	4A	..	..	..	..	..	..	..	..	..	2A	++	..	..	..	..	..	..	..	..	3A	..	..	1A	..
	Andropogon hallii	+A	4A	..	..	1A	4A	..	..	..	..	..	..	..	..	..	1A	2A	..	..	++	..	..	..	..	..	..	..	..	++	..
	Asclepias viridiflora	++	4A	..	..	++	4A	..	..	..	..	..	..	..	..	..	++	1A	..	..	++	..	..	..	..	..	..	..	..	1A	..
	Artemisia campestris	+A	2A	..	+A	++	4A	..	..	..	..	++	..	..	..	..	..	1A	..	..	..	..	..	..	..	..	..	..	..	++	..
	Lithospermum incisum	6A	8A	3A	1A	5A	6A	..	1A	..	..	..	..	..	..	1A	3A	7A	..	..	++	..	..	..	..	..	1A	..	..	3A	3A
	Aristida purpurea	6A	6A	1A	1B	1A	4A	+A	..	+A	1A	+A	..	..	..	..	3A	3A	+A	+A	..	1A	..	..	..	..	4A	..	..	5A	3A
E	Astragalus adsurgens	++	1A	3A	+A	+A	++	..	4A	+A	..	1A	..	4A	4B	2A	2A	1A	3A	6B	..	..	..	..	..	..	..	..	..	..	..
	Cerastium arvense	4A	4B	3B	1A	2A	4A	++	2A	+A	..	+A	..	9A	5A	2A	9B	8C	1A	..	4A	2A	..	..	..	..	1A	..	..	+A	..
	Bouteloua	5B	9C	..	+A	+A	9C	..	..	..	..	..	..	4A	3B	2B	7A	9C	8D	..	2A	..	..	..	..	..	1A	..	..	2A	..
	Ambrosia psilostachya	5A	5A	..	2A	1A	2A	1A	..	..	..	+A	4C	..	1A	1A	++	4A	..	..	..	1A	..	..	++	1A	8A	..	..	7A	1A
	Antennaria parvifolia	4A	4A	..	1A	1A	6A	..	++	..	..	..	..	2A	3A	2A	9A	7A	++	..	1A	..	..	..	..	..	3A	..	..	2A	..
	Yucca glauca	1A	3A	..	1A	2B	4A	1A	+A	+A	..	1A	+A	2A	6C	3A	3A	2A	6A	1A	..	..	..	..	..	..	1A	..	..	1A	..
	Dalea purpurea	4A	5A	1A	++	1A	9A	3B	+A	+A	1A	2A	2A	..	2A	3A	4A	5A	++	1A	1A	..	..	..	..	..	..	..	..	2A	..
	Penstemon albidus	3A	7A	..	..	..	9A	..	..	..	..	..	..	..	..	1A	2A	4A	++	..	..	..	..	..	..	..	..	..	..	1A	..
	Andropogon	1A	4A	..	..	3B	6B	..	..	..	..	+A	..	..	3A	2A	3A	3A	6C	..	..	..	..	..	..	..	..	..	..	..	..
	Festuca idahoensis	2A	3A	..	..	..	++	..	++	..	..	+A	..	7D	..	..	9D	9D	..	+A	3A	..	..	..	..	..	..	..	..	..	..
	Crepis acuminata	..	2A	1A	..	+A	..	..	1A	..	..	++	..	..	4A	1A	7A	5A	..	..	1A	..	..	..	..	..	..	..	..	..	..
F	Solidago nemoralis	++	1A	..	..	..	2A	..	..	..	..	..	..	4A	2A	1A	2A	++	..	..	..	..	..	..	..	..	..	..	..	..	..
	Calochortus nuttallii	2A	1A	..	++	++	4A	..	..	..	..	..	..	..	..	1A	2A	++	..	..	++	..	+A	..	..	..	..	..	..	..	..
	Muhlenbergia cuspidata	..	++	..	+A	1A	3A	..	..	..	..	..	..	..	2A	4B	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..
	Polygala alba	1A	++	..	+A	2A	4A	..	+A	..	..	..	..	..	..	1A	++	..	..	..	++	..	..	..	..	..	..	..	..	++	..
	Oxytropis lambertii	++	2A	..	..	..	4A	+A	+A	..	1A	+A	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	++	..
	Zigadenus venenosus	1A	2A	..	..	++	4A	1A	+A	..	..	+A	..	..	1A	1A	..	++	..	..	++	..	..	..	..	..	..	..	..	..	..
	Astragalus gracilis	++	++	1A	+A	4A	2A	..	2A	..	..	..	..	..	1A	..	++	++	+A	..	..	..	..	..	..	..	..	..	..	++	1A
	Comandra umbellata	++	..	..	+A	++	++	..	1A	+A	1A	2A	..	2A	3A	4A	..	..	1A	4A	..	..	..	..	..	..	..	..	..	..	..
	Oxytropis sericea	..	++	..	..	+A	2A	..	..	++	..	+A	..	4A	1A	..	..	..	..	3A	++	..	..	..	..	..	4A	..	..	++	..
	Campanula rotundifolia	++	..	..	..	+A	++	..	..	+A	..	++	+A	4A	2A	..	++	..	++	..	++	..	..	..	..	..	..	..	..	..	..
	Artemisia tridentata	..	..	..	+A	1A	++	4B	9D	9D	6A	8C	4B	..	2A	1A	..	..	+A	9C	..	..	5D	..	..	..	..	..	1B	..	..
	Aster campestris	..	..	..	2A	1A	..	+A	2A	++	..	..	1A	2A	4A	3A	..	..	2A	..	..	..	..	..	..	..	..	..	..	..	1A
	Stephanomeria	..	..	..	..	..	..	+A	..	+A	2A	2A	..	..	..	..	..	..	..	4A	..	..	..	..	..	..	..	..	..	..	..
G	Juniperus scopulorum	..	..	..	..	..	..	..	..	1A	..	2A	..	..	1A	3C	2A	++	+A	9A	++	..	..	..	..	..	..	..	..	..	..
	Amelanchier alnifolia	..	..	..	..	..	..	..	..	..	..	..	..	4A	2A	1A	..	..	..	..	++	..	..	++	..	..	..	..	..	..	..
	Linum lewisii	1A	..	..	1A	1A	..	++	4A	1A	1A	1A	2A	4A	5A	6A	1A	..	2A	+A	3A	1A	..	2A	1A	..	1A	..	..	..	..
	Rhus trilobata	+A	1A	3C	1A	1B	2A	3A	..	3A	4A	6A	7D	9B	8C	9D	5A	2A	9C	7A	2A	3C	+A	+A	..	..	..	..	..	..	..
	Pinus ponderosa	..	+A	..	..	..	2A	..	..	1A	1A	2A	..	4A	1A	..	9E	9D	2A	9E	5D	..	..	+A	..	..	..	..	..	..	..
	Astragalus flexuosus	++	1A	..	..	..	++	..	..	..	..	..	..	..	..	..	4A	3A	..	..	1A	..	..	..	..	..	..	..	..	..	..
	Andropogon gerardii	++	2A	..	..	..	..	..	..	..	..	..	..	..	..		2A	1A	..	..	2A	..		..	..	2A	..	..	..	..	..
	Helianthus petiolaris	++	++	..	..	+A	..	..	..	..	..	..	..	..	..	..	++	++	..	..	..	..	..	1A	++	..	8A	..	..	5A	..
	Astragalus agrestis	..	1A	..	..	..	..	..	..	..	..	++	..	..	..	..	4A	2A	..	..	6A	..	..	..	1A	..	..	..	..	..	..
H	Prunus virginiana	..	++	..	+A	..	..	..	..	++	..	..	..	..	3A	2A	1A	..	+A	..	5A	2C	..	8D	1A	..	..	..	..	..	..
	Symphoricarpos	2A	1A	..	+A	+A	1A	..	..	..	..	..	..	9C	4A	3B	7B	6C	2A	..	9E	8E	++	9D	3A	3A	..	..	..	++	..
	Rosa woodsii	..	++	..	..	..	..	++	..	1A	..	+A	++	..	..	1B	..	..	..	2A	6B	6D	++	6D	2A	4A	..	..	..	..	..
	Lactuca oblongifolia	++	..	3A	1A	+A	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	2A	3A	..	4A	2A	..	..	..	..	..	..
	Symphyotrichum	..	..	..	1A	1A	..	..	++	..	..	..	..	..	1A	..	..	..	..	..	..	..	..	++	1A	6A	..	..	..	..	..

Appendix 1 cont.

	Vegetation type	1 STCO					2 AGSP		3 ARTR			4 RHTR					5 PIPO				6 S-TOE			7 RIPR	8 SODD		9a AGIN		9b AGCR		
	Mine, (A,R, or S)	A	A	R	R	R	A	S	R	S	S	S	S	R	R	R	A	A	R	S	A	R	S	A	A	A	A	S	S	A	R
I	Agropyron trachycaulum	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	2A	1A	..	5B	4A	9D	..	..	..	..	..
	Ribes aureum	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3C	2C	..	9D	2A	..	..	..	..	..	..
	Urtica dioica	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	1A	..	6C	2A	1A	..	..	..	..	..
	Crataegus succulenta	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	1A	..	5D	++	..	..	..	..	..	..
	Carex praegracilis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	+A	5D	3A	..	..	..	..	..
	Prunus americana	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2A	..	..	5D	++	..	..	..	..	..	..
	Ribes setosum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	5A	++	..	..	..	..	..	..
	Viola canadensis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	4C	..	1A	..	..	..	..	..
J	**Fraxinus pennsylvanica**	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	3D	..	..	..	..		..	..
	Elymus virginicus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4B	..	..	..	..	..	..	..
	Shepherdia argentea	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2D	..	..	..	..	..	..	..
	Acer negundo	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2C	..	..	..	..	..	..	..
	Polygonum convolvulus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5B	++	..	..	..	..	..	..
	Galium aparine	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	6C	..	..	..	..	..	..	..
	Ambrosia trifida	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4B	2A	3A	..	..	..	..	..
	Spartina pectinata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	6C	9E	..	..	..	..	..
	Cirsium flodmanii	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	3A	9A	..	..	..	..	..
	Equisetum laevigatum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	2A	8A	..	..	..	..	..
	Carex pellita	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	++	9E	..	..	..	..	..
	Hordeum jubatum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	7C	9D	1A	..	..	..	..
	Carex nebraskensis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2C	6C	..	..	..	..	..
	Oenothera villosa	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	4A	..	..	..	..	..
	Eleocharis palustris	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	4D	..	..	..	..	..
	Iva xanthifolia	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4A	..	..	..	++	..
	Scirpus americanus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6C	..	..	..	..	..
	Epilobium ciliatum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8B	..	..	..	..	..
	Ambrosia artemisiifolia	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3A	..	..	..	..	..

Terms used in Appendix 1-5. **Vegetation types** are short grass prairie (1, STCO), foothills prairie (2, AGSP), sage (3, ARTR), *Rhus* (4, RHTR), pine (5, PIPO), slope-toe (6, S-TOE), riparian (7, RIPR), sodden (8, SODD), and old fields (9, FIELD). **Mines** are Absaloka (A), Rosebud (R), and Spring Creek (S). **Presence** is expressed in each cell as a two symbol code, constancy is indicated by the first symbol, while cover is indicated by the second symbol. For constancy: 0% = ".", 0-10% = +, 10-20% = 1, 20-30% = 2, 30-40% = 3, 40-50% = 4, 50-60% = 5, 60-70% = 6, 70-80% = 7, 80-90% 8, 90-100% = 9. For cover: 0% = ".", 0-0.01% = +, 0.01-1% = A, 1-2% = B, 2-5% = C, 5-25% = D, >25% = E. **Shaded presence cells** indicate important species, i.e. those with constancy $\geq$ 50%. **Primary** refers to species having greater than 30% constancy (occupying greater than 30% of the stands in at least one vegetation type at one mine). **Secondary** species have less than 30% constancy in all communities observed; they are listed in Appendix 5.

Appendix 2. Presence of primary EXOTICS in vegetation types of three SE Montana mines. Terms are defined below table. Species constancies >50% shaded. Species mentioned in text are bolded in table.

	Vegetation type	1 STCO					2 AGSP		3 ARTR			4 RHTR					5 PIPO				6 S-TOE			7 RIPR	8 SODD		9a AGIN		9b AGCR		
	Mine, (A,R, or S)	A	A	R	R	R	A	S	R	S	S	S	S	R	R	R	A	A	R	S	A	R	S	A	A	A	A	S	S	A	R
	Intra-mine community	1	2	1	2	3	1	1	1	1	2	1	2	1	2	3	1	2	1	1	1	1	1	1	1	2	1	1	1	1	1
	Number of plots	32	24	5	24	28	14	31	11	36	8	78	14	4	9	8	12	14	11	10	10	8	30	10	11	6	6	8	27	14	5
A	Verbascum thapsus	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Salsola iberica	..	++	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Artemisia dracunculus	9B	8C	7B	4A	5B	5A	+A	+A	++	1A	+A	..	..	..	1A	1A	4A	..	+A	1A	1A	..	..	++	..	1A	..	..	3A	1A
	Alyssum alyssoides	2A	2A	..	1A	2A	4A	3A	3A	2A	1A	1A	+A	..	..	..	++	++	..	+A	..	..	4A	..	++	..	8A	4A	2A	4A	7C
B	**Bromus japonicus**	9D	9C	9D	9D	9D	9B	6A	9D	4A	1A	3A	5A	4A	6A	9C	9A	9B	7A	4A	9C	8C	8A	9D	9C	3A	9C	7A	4A	9C	5A
	Bromus tectorum	3B	5A	5B	4C	3B	++	3A	1A	+A	1A	+A	6C	..	2A	2A	4A	4A	2A	..	++	1A	1A	6D	5C	..	3A	..	..	4B	1A
	Tragopogon dubius	9A	8A	9A	4A	5A	8A	5A	7A	2A	..	2A	+A	2A	8A	3A	9A	7A	1A	5A	9A	4A	4B	6A	9C	4A	3A	4A	1A	6A	1A
C	Poa pratensis	4B	3C	9D	7D	3B	++	..	3A	..	1A	..	..	2A	1A	3A	4B	4A	1A	..	9E	9E	1A	9D	9E	9D	9A	..	+A	7B	3A
	Taraxacum officinale	3A	3A	3A	7A	3A	1A	+A	3A	1A	..	+A	1A	..	3A	1A	6A	3A	++	2A	3A	6A	3B	5C	9C	6A	..	1A	1A	2A	7A
	Camelina microcarpa	4A	2A	1A	2A	1A	6A	..	2A	..	..	++	+A	..	1A	..	++	2A	++	..	++	..	1A	1A	5A	..	3A	..	..	2A	..
	Melilotus officinalis	2A	2A	3A	4B	2B	1A	1A	4A	+A	..	+A	7E	..	3A	3A	..	1A	1A	..	1A	4C	3B	5A	9B	6A	8A	4A	3C	9B	5D
D,E,G	No species																														
H	Lactuca serriola	4A	3A	..	..	..	2A	..	..	..	..	..	..	..	..	..	4A	2A	..	..	6A	1A	..	7C	9D	8A	3A	..	..	2A	..
	Agropyron cristatum	1A	4A	..	1A	1A	4A	+A	+C	+A	..	..	..	..	..	..	..	3A	..	..	..	1A	+A	3A	6A	1A	4C	2C	9E	9E	9E
	Medicago sativa	1A	1A	..	+A	+A	++	..	+A	..	..	..	..	..	1A	..	1A	++	..	..	4A	..	..	2A	9D	4A	1A	..	..	3B	1A
	Sisymbrium altissimum	4A	2A	..	+A	++	3A	..	..	..	..	..	2A	..	..	..	..	2A	++	..	..	..	..	4B	9A	4A	..	..	..	3A	..
F	Convolvulus arvensis	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+B	..	..	++	1A	..	6A	2A	..	4D	3C
	Poa compressa	+A	++	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	1A	..	..	1A	..	+A	..	1A	..	8A	..	..	3A	1A
	Sisymbrium loeselii	..	..	..	+A	..	..	..	..	++	1A	..	+A	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..
	Alyssum desertorum	..	..	..	..	..	..	2A	..	++	..	+A	4A	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..
	Dactylis glomerata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1C	..	..	..	..	..	..	..
	Agropyron intermedium	..	..	..	..	..	..	..	..	+A	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	2A	..	9E	9E	+A	4C	1A
	Agropyron repens	..	..	..	..	..	..	..	..	..	1D	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Kochia scoparia	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..
I	**Cirsium arvense**	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+A	++	1A	..	4B	6D	9B	..	..	..	..	..
	Phleum pratense	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	3D	5D	1A	..	..	..	..	..
	Cirsium vulgare	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	+A	..	1A	..	..	..	..	..
	Descurainia sophia	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	5A	9C	3A	..	..	..	..	..
	Thlaspi arvense	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	5A	6A	1A	..	..	..	..	..
	Rumex crispus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	5A	2A	3A	..	..	..	..	..
J	**Arctium minus**	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4B	++	..	..	..	..	..	..
	Bromus inermis	..	..	..	++	..	..	..	+A	..	..	..	..	..	..	..	..	++	..	..	..	..	..	1A	6D	1A	..	..	..	..	..
	Atriplex hortensis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4A	..	..	..	..	..	..
	Chenopodium album	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	++	..	..	..	5A	4A	3A	..	++	1A	..
	Melilotus albus	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3A	..	..	..	..	1A	..

Terms used in Appendix 1-5. **Vegetation types** are short grass prairie (1, STCO), foothills prairie (2, AGSP), sage (3, ARTR), *Rhus* (4, RHTR), pine (5, PIPO), slope-toe (6, S-TOE), riparian (7, RIPR), sodden (8, SODD), and old fields (9, FIELD). **Mines** are Absaloka (A), Rosebud (R), and Spring Creek (S). **Presence** is expressed in each cell as a two symbol code, constancy is indicated by the first symbol, while cover is indicated by the second symbol. For constancy: 0% = ".", 0-10% = +, 10-20% = 1, 20-30% = 2, 30-40% = 3, 40-50% = 4, 50-60% = 5, 60-70% = 6, 70-80% = 7, 80-90% 8, 90-100% = 9. For cover: 0% = ".", 0-0.01% = +, 0.01-1% = A, 1-2% = B, 2-5% = C, 5-25% = D, >25% = E. **Shaded presence cells** indicate important species, i.e. those with constancy $\geq$ 50%. **Primary** refers to species having greater than 30% constancy (occupying greater than 30% of the stands in at least one vegetation type at one mine). **Secondary** species have less than 30% constancy in all communities observed; they are listed in Appendix 5.

Appendix 3. Species likely to establish easily on dry reclamation sites. These species established naturally in *Agropyron cristatum/ A. intermedium* fields over the last 50-60 years. Old field responses and species mentioned in text bolded. Constancies > 50% shaded.

	Vegetation type	1 STCO					2 AGSP		3 ARTR			4 RHTR					5 PIPO				6 S-TOE			7 RIPR	8 SODD		9a AGIN		9b AGCR		
	Mine, A,R, or S	A	A	R	R	R	A	S	R	S	S	S	S	R	R	R	A	A	R	S	A	R	S	A	A	A	A	S	S	A	R
	Intra-mine community	1	2	1	2	3	1	1	1	1	2	1	2	1	2	3	1	2	1	1	1	1	1	1	1	2	1	1	1	1	1
	Number of plots	32	24	5	24	28	14	31	11	36	8	78	14	4	9	8	12	14	11	10	10	8	30	10	11	6	6	8	27	14	5
	PLANTED																														
	Agropyron cristatum	1A	4A	..	1A	1A	4A	+A	+C	+A	..	..	..	..	..	..	..	3A	..	..	..	1A	+A	3A	6A	1A	4C	2C	9E	9E	9E
	Agropyron	..	..	..	..	..	..	..	..	+A	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	2A	..	9E	9E	+A	4C	1A
	NATIVES																														
A	Astragalus lotiflorus	++	3A	..	..	..	3A	..	..	..	..	..	..	..	..	..	..	++	..	..	++	..	..	..	..	..	4A	..	..	4A	..
	Plantago patagonica	9A	8A	..	..	..	4A	++	..	++	..	..	..	..	..	..	++	5A	..	..	..	..	1A	..	..	..	1A	..	++	2A	..
	Opuntia fragilis	7A	7A	1A	1A	1A	6A	..	+A	..	..	..	..	..	..	..	1A	3A	..	..	++	..	..	..	..	..	8A	..	..	6A	..
	Lygodesmia juncea	6A	6A	5A	2A	4A	4A	..	++	..	..	..	..	..	1A	..	1A	4A	++	..	1A	2A	..	..	..	..	4A	..	..	4A	1A
	Cirsium undulatum	5A	4A	1A	1A	1A	6A	1A	+A	+A	1A	+A	1A	..	..	..	1A	2A	++	..	2A	1A	..	..	..	..	8A	..	..	6A	1A
	Liatris punctata	8A	8A	..	+A	3A	7A	..	+A	+A	..	..	..	..	3A	..	3A	4A	3A	1A	++	..	..	..	..	..	1A	..	..	2A	..
	Psoralidium tenuiflora	6A	5A	..	+A	+A	6A	1A	+A	1A	..	2A	+A	..	1A	..	4A	3A	+A	1A	2A	1A	..	..	..	..	1A	..	..	2A	..
	Plantago argyraea	..	..	3A	9A	8A	..	+A	3A	..	..	..	..	..	..	4A	..	..	+A	..	..	1A	..	..	..	..	..	..	..	..	5A
	Echinacea angustifolia	7A	6A	..	2A	1A	9B	..	4A	..	..	..	..	2A	4A	3A	3A	1A	4A	..	1A	1A	..	..	..	..	4A	..	..	1A	..
	Hedeoma hispidum	7A	4A	1A	4A	2A	2A	..	2A	+A	..	..	..	..	..	1A	..	2A	..	..	..	1A	..	..	..	..	1A	..	..	2A	..
	Vulpia octoflora	7C	7C	5A	4A	6A	7A	++	2A	++	..	..	..	..	..	2A	2A	4A	++	..	..	..	..	..	..	..	4A	..	..	4B	1A
B	Poa secunda	9C	8C	..	6C	7A	9A	4A	6A	3A	2A	2A	..	..	2A	3A	9A	7B	+A	2A	3A	2A	4A	..	..	..	3A	..	3A	3A	3A
	Sphaeralcea coccinea	9A	7A	7A	8A	5A	7A	6A	7A	2A	..	2A	5A	2A	2A	6A	1A	4A	4A	1A	2A	1A	2A	..	..	..	4A	..	3A	4A	5A
	Agropyron spicatum	2A	1A	..	2B	6C	9D	7D	9D	6D	6A	9D	9D	9C	9D	9D	5C	1A	9D	9D	++	1A	1A	..	..	..	3A	..	..	++	1A
	Gutierrezia sarothrae	6A	6A	1A	5B	5B	9C	2A	9C	2A	2A	6B	2A	2A	8C	7A	2A	2A	6B	7B	++	1A	+A	..	..	..	9C	..	..	7C	5B
	Koeleria cristata	9A	9B	9A	8D	9C	9B	2A	9D	4B	1A	4B	1A	2A	9C	9C	5A	9A	5A	6A	++	3B	4B	..	..	..	6A	..	1A	4A	5A
	Stipa comata	9D	9D	9D	9D	9D	9D	9D	6B	2C	3A	3B	4D	7A	7C	4C	9B	9C	7B	4B	3A	3B	2B	..	..	..	4A	..	1A	7A	1A
	Artemisia frigida	5A	4A	1A	8C	6B	9A	6C	6A	1A	1A	3A	3A	4A	2A	3A	3A	3A	2A	+A	++	3A	+A	..	..	..	3A	..	+A	2A	5B
	Psoralea argophylla	8B	8A	5A	5A	6A	9A	2A	5A	1A	2A	1A	1A	4A	2A	3A	8A	9B	2A	+A	6A	1A	..	..	++	..	1A	..	..	3A	3A
	Gaura coccinea	9A	8A	7A	7A	5A	9A	1A	3A	1A	1A	2A	2A	..	5A	2A	4A	5A	4A	+A	2A	4A	+A	..	..	..	8A	..	..	9A	1A
C	**Artemisia cana**	8D	4A	9D	6C	2A	5A	1A	2A	1A	2C	1A	..	7B	3A	4B	3A	6B	1A	++	8B	6C	3C	3A	++	..	1A	..	5D	2A	..
	Stipa viridula	9C	4A	3B	7C	2B	4A	+B	9D	1A	..	1A	2A	4A	7B	6A	6C	5A	1A	+A	9D	6C	8D	1A	2A	1A	3A	..	1C	2A	3A
	Achillea millefolium	8B	6A	5A	4A	2A	7A	..	6B	1A	..	1A	+A	9B	6B	7A	9A	9A	1A	3A	9A	9C	1A	5A	1A	1A	6A	1A	+A	4A	1A
	Agropyron smithii	9D	9D	9D	9D	8D	9C	4B	9D	4C	4C	3A	4B	4A	5B	9C	5A	9C	8B	..	9D	9D	9E	1A	5C	1A	..	..	4C	++	5A
	Artemisia ludoviciana	5A	9A	5C	3A	1A	5A	+A	..	+A	..	+A	+A	7A	3A	3A	5A	8A	..	..	5A	7A	2A	++	1A	..	1A	..	+A	1A	..
	Rosa arkansana	4A	7A	5C	2A	2A	4A	..	1A	..	..	..	..	4A	4A	3A	3A	7A	2A	..	5A	2A	++	2A	2A	..	4A	..	..	1A	1A
	Aster falcatus	7A	5A	..	2A	2A	7A	..	1A	+A	..	+A	+A	2A	6A	3A	6A	7A	++	..	8A	..	1A	++	..	..	4A	..	..	2A	..
	Ratibida columnifera	9A	6A	..	1A	1A	7A	..	++	..	..	..	..	..	..	1A	6A	6A	..	..	8A	..	..	++	++	..	8A	..	..	7A	..
	Heterotheca villosa	7A	9A	..	+A	2A	6A	+A	..	..	..	..	..	..	..	..	4A	7A	2A	..	3A	..	..	..	..	..	4A	..	..	6A	..
D	Astragalus	++	3A	..	..	++	7A	+A	..	+A	..	+A	..	..	..	..	4A	4A	..	..	++	..	..	..	..	..	1A	..	..	4A	..
	Filago arvensis	6A	3A	..	..	..	++	..	..	..	..	..	..	..	..	..	1A	4A	..	..	..	..	++	..	..	..	3C	..	..	2A	..
	Aster oblongifolius	++	..	..	..	..	4A	..	..	..	..	..	..	..	..	..	2A	++	..	..	..	..	..	..	..	..	3A	..	..	1A	..
	Lithospermum incisum	6A	8A	3A	1A	5A	6A	..	1A	..	..	..	..	..	..	1A	3A	7A	..	..	++	..	..	..	..	..	1A	..	..	3A	3A
	Aristida purpurea	6A	6A	1A	1B	1A	4A	+A	..	+A	1A	+A	..	..	..	..	3A	3A	+A	+A	..	1A	..	..	..	..	4A	..	..	5A	3A
E	Bouteloua curtipendula	5B	9C	..	+A	+A	9C	..	..	..	..	..	..	4A	3B	2B	7A	9C	8D	..	2A	..	..	..	..	..	1A	..	..	2A	..
	Ambrosia	5A	5A	..	2A	1A	2A	1A	..	..	..	+A	4C	..	1A	1A	++	4A	..	..	..	1A	..	..	++	1A	8A	..	..	7A	1A
	Antennaria parvifolia	4A	4A	..	1A	1A	6A	..	++	..	..	..	..	2A	3A	2A	9A	7A	++	..	1A	..	..	..	..	..	3A	..	..	2A	..
	Dalea purpurea	4A	5A	1A	++	1A	9A	3B	+A	+A	1A	2A	2A	..	2A	3A	4A	5A	++	1A	1A	..	..	..	..	..	..	..	..	2A	..

Appendix 3 cont.

	Vegetation type	1 STCO					2 AGSP		3 ARTR			4 RHTR					5 PIPO				6 S-TOE			7 RIPR	8 SODD		9a AGIN		9b AGCR		
	Mine, (A,R, or S)	A	A	R	R	R	A	S	R	S	S	S	S	R	R	R	A	A	R	S	A	R	S	A	A	A	A	S	S	A	R
F	Oxytropis sericea	..	++	..	..	+A	2A	..	..	++	..	+A	..	4A	1A	..	..	..	..	3A	++	..	..	..	..	..	4A	..	..	++	..
G	Helianthus petiolaris	++	++	..	..	+A	..	..	..	..	..	..	..	..	..	..	++	++	..	..	..	..	..	1A	++	..	8A	..	..	5A	..
H-J	No species																														
	EXOTICS																														
A	Artemisia dracunculus	9B	8C	7B	4A	5B	5A	+A	+A	++	1A	+A	..	..	..	1A	1A	4A	..	+A	1A	1A	..	..	++	..	1A	..	..	3A	1A
	Alyssum alyssoides	2A	2A	..	1A	2A	4A	3A	3A	2A	1A	1A	+A	..	..	..	++	++	..	+A	..	..	4A	..	++	..	8A	4A	2A	4A	7C
F	Oxytropis sericea	..	++	..	..	+A	2A	..	..	++	..	+A	..	4A	1A	..	..	..	..	3A	++	..	..	..	..	..	4A	..	..	++	..
G	Helianthus petiolaris	++	++	..	..	+A	..	..	..	..	..	..	..	..	..	..	++	++	..	..	..	..	..	1A	++	..	8A	..	..	5A	..
B	**Bromus japonicus**	9D	9C	9D	9D	9D	9B	6A	9D	4A	1A	3A	5A	4A	6A	9C	9A	9B	7A	4A	9C	8C	8A	9D	9C	3A	9C	7A	4A	9C	5A
	Bromus tectorum	3B	5A	5B	4C	3B	++	3A	1A	+A	1A	+A	6C	..	2A	2A	4A	4A	2A	..	++	1A	1A	6D	5C	..	3A	..	..	4B	1A
	Tragopogon dubius	9A	8A	9A	4A	5A	8A	5A	7A	2A	..	2A	+A	2A	8A	3A	9A	7A	1A	5A	9A	4A	4B	6A	9C	4A	3A	4A	1A	6A	1A
C	**Poa pratensis**	4B	3C	9D	7D	3B	++	..	3A	..	1A	..	..	2A	1A	3A	4B	4A	1A	..	9E	9E	1A	9D	9E	9D	9A	..	+A	7B	3A
	Taraxacum officinale	3A	3A	3A	7A	3A	1A	+A	3A	1A	..	+A	1A	..	3A	1A	6A	3A	++	2A	3A	6A	3B	5C	9C	6A	..	1A	1A	2A	7A
	Camelina microcarpa	4A	2A	1A	2A	1A	6A	..	2A	..	..	++	+A	..	1A	..	++	2A	++	..	++	..	1A	1A	5A	..	3A	..	..	2A	..
	Melilotus officinalis	2A	2A	3A	4B	2B	1A	1A	4A	+A	..	+A	7E	..	3A	3A	..	1A	1A	..	1A	4C	3B	5A	9B	6A	8A	4A	3C	9B	5D
D,G	Lactuca serriola	4A	3A	..	..	..	2A	..	..	..	..	..	..	..	..	..	4A	2A	..	..	6A	1A	..	7C	9D	8A	3A	..	..	2A	..
	Agropyron cristatum	1A	4A	..	1A	1A	4A	+A	+C	+A	..	..	..	..	..	..	..	3A	..	..	..	1A	+A	3A	6A	1A	4C	2C	9E	9E	9E
	Medicago sativa	1A	1A	..	+A	+A	++	..	+A	..	..	..	..	..	1A	..	1A	++	..	..	4A	..	..	2A	9D	4A	1A	..	..	3B	1A
	Sisymbrium altissimum	4A	2A	..	+A	++	3A	..	..	..	..	..	2A	..	..	..	..	2A	++	..	..	..	..	4B	9A	4A	..	..	..	3A	..
F	**Convolvulus arvensis**	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+B	..	..	++	1A	..	6A	2A	..	4D	3C
	Poa compressa	+A	++	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	1A	..	..	1A	..	+A	..	1A	..	8A	..	..	3A	1A
	Agropyron intermedium	..	..	..	..	..	..	..	..	+A	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	2A	..	9E	9E	+A	4C	1A
I	No species																														
J	Chenopodium album	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	++	..	..	..	5A	4A	3A	..	++	1A	..

Terms used in Appendix 1-5. **Vegetation types** are short grass prairie (1, STCO), foothills prairie (2, AGSP), sage (3, ARTR), *Rhus* (4, RHTR), pine (5, PIPO), slope-toe (6, S-TOE), riparian (7, RIPR), sodden (8, SODD), and old fields (9, FIELD). **Mines** are Absaloka (A), Rosebud (R), and Spring Creek (S). **Presence** is expressed in each cell as a two symbol code, constancy is indicated by the first symbol, while cover is indicated by the second symbol. For constancy: 0% = ".", 0-10% = +, 10-20% = 1, 20-30% = 2, 30-40% = 3, 40-50% = 4, 50-60% = 5, 60-70% = 6, 70-80% = 7, 80-90% 8, 90-100% = 9. For cover: 0% = ".", 0-0.01% = +, 0.01-1% = A, 1-2% = B, 2-5% = C, 5-25% = D, >25% = E. **Shaded presence cells** indicate important species, i.e. those with constancy ≥ 50%. **Primary** refers to species having greater than 30% constancy (occupying greater than 30% of the stands in at least one vegetation type at one mine). **Secondary** species have less than 30% constancy in all communities observed; they are listed in Appendix 5.

Appendix 4. Old field failures: species needing special treatment for establishment in dry reclamation sites. Failure to establish in *Agropyron cristatum/ A. intermedium* sites may be due to lack of dispersal, physical requirements, symbionts, or intolerance of the *Agropyrons*. Species constancies > 50% shaded. Species mentioned in the test are bolded. Terms/symbols explained below table.

	Vegetation type	1 STCO					2 AGSP		3 ARTR			4 RHTR					5 PIPO				6 S-TOE			7 RIPR	8 SODD		9a AGIN		9b AGCR		
	Mine, A,R, or S	A	A	R	R	R	A	S	R	S	S	S	S	R	R	R	A	A	R	S	A	R	S	A	A	A	A	S	S	A	R
	Intra-mine community	1	2	1	2	3	1	1	1	1	2	1	2	1	2	3	1	2	1	1	1	1	1	1	1	2	1	1	1	1	1
	Number of plots	32	24	5	24	28	14	31	11	36	8	78	14	4	9	8	12	14	11	10	10	8	30	10	11	6	6	8	27	14	5
	PLANTED																														
	Agropyron	..	..	..	..	..	..	..	..	+A	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	2A	..	9E	9E	+A	4C	1A
	Agropyron cristatum	1A	4A	..	1A	1A	4A	+A	+C	+A	..	..	..	..	..	..	..	3A	..	..	..	1A	+A	3A	6A	1A	4C	2C	9E	9E	9E
	NATIVES																														
A	Asclepias verticillata	1A	2A	..	..	..	4A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Astragalus plattensis	5A	2A	..	..	..	..	++	..	..	1A	+A	..	..	..	..	..	++	..	..	++	..	..	..	..	..	1A	..	..	++	..
	Psoralea esculenta	3A	4A	..	++	..	5A	++	+A	..	..	+A	..	..	..	..	..	1A	..	+A	..	..	..	..	..	..	..	..	..	++	..
	Calylophus serrulatus	++	5A	..	+A	2A	4A	..	+A	..	1A	..	..	2A	..	1A	..	1A	1A	..	..	1A	..	..	..	..	..	..	..	..	..
	Calamagrostis mont.	2A	5A	3B	1A	4A	4A	..	++	..	..	..	..	2A	5A	1A	4A	3A	..	+A	..	..	..	..	..	..	..	..	..	..	..
	Calamovilfa longifolia	2A	4B	5C	1A	6C	5A	..	..	..	1A	+A	..	4A	2A	2A	1A	4A	4A	..	++	2A	..	..	..	..	..	..	+A	1A	..
B	**Carex filifolia**	+A	1A	..	2B	9D	8C	1A	4B	+A	4C	1B	..	..	9C	4B	2A	++	1A	3A	..	1B	..	..	..	..	..	..	..	..	..
	Phlox hoodii	4A	4A	..	7A	4A	9B	5B	9B	3B	2B	5B	+A	4A	8A	8A	4A	2A	2A	4B	..	..	2A	..	..	..	..	..	++	..	..
	Carex pensylvanica	8C	9D	9E	1A	4C	7A	+A	..	+A	..	+A	..	9D	3B	3C	6B	8C	3A	..	5B	..	..	..	..	..	1A	..	..	..	..
	Bouteloua gracilis	8B	7B	7A	8C	9D	7A	2B	6B	+A	2C	+A	..	..	4A	6A	++	4A	2A	+A	..	3A	..	..	..	..	..	..	..	..	..
C	**Artemisia ludoviciana**	5A	9A	5C	3A	1A	5A	+A	..	+A	..	+A	+A	7A	3A	3A	5A	8A	..	..	5A	7A	2A	++	1A	..	1A	..	+A	1A	..
	Solidago missouriensis	2A	4A	1A	1A	3A	4A	..	..	..	..	+A	..	9A	5A	1A	2A	6A	1A	3A	3A	1A	..	..	..	..	..	..	..	..	..
	Solidago mollis	1A	2A	3A	+A	1A	1A	..	..	++	..	+A	..	..	..	..	..	3A	++	..	5A	1A	+A	++	++	..	..	..	..	1A	..
D	**Arabis holboellii**	2A	3A	..	++	+A	1A	..	..	+A	..	++	..	..	1A	..	5A	3A	..	..	..	..	..	..	..	..	..	..	++	1A	..
	Erigeron divergens	3A	4A	..	..	..	++	..	..	..	..	..	..	..	..	..	5A	3A	..	..	..	..	..	..	..	..	..	..	..	1A	..
	Collomia linearis	4A	2A	3A	+A	..	..	..	..	..	..	..	..	..	..	..	7A	4A	..	..	++	..	..	..	++	..	..	..	..	..	..
	Andropogon hallii	+A	4A	..	..	1A	4A	..	..	..	..	..	..	..	..	..	1A	2A	..	..	++	..	..	..	..	..	..	..	..	++	..
	Asclepias viridiflora	++	4A	..	..	++	4A	..	..	..	..	..	..	..	..	..	++	1A	..	..	++	..	..	..	..	..	..	..	..	1A	..
	Artemisia campestris	+A	2A	..	+A	++	4A	..	..	..	..	++	..	..	..	..	..	1A	..	..	..	..	..	..	..	..	..	..	..	++	..
E	Astragalus adsurgens	++	1A	3A	+A	+A	++	..	4A	+A	..	1A	..	4A	4B	2A	2A	1A	3A	6B	..	..	..	..	..	..	..	..	..	..	..
	Cerastium arvense	4A	4B	3B	1A	2A	4A	++	2A	+A	..	+A	..	9A	5A	2A	9B	8C	1A	..	4A	2A	..	..	..	..	1A	..	..	+A	..
	Yucca glauca	1A	3A	..	1A	2B	4A	1A	+A	+A	..	1A	+A	2A	6C	3A	3A	2A	6A	1A	..	..	..	..	..	..	1A	..	..	1A	..
	Penstemon albidus	3A	7A	..	..	..	9A	..	..	..	..	..	..	..	..	1A	2A	4A	++	..	..	..	..	..	..	..	..	..	..	1A	..
	Andropogon	1A	4A	..	..	3B	6B	..	..	..	..	+A	..	..	3A	2A	3A	3A	6C	..	..	..	..	..	..	..	..	..	..	..	..
	Festuca idahoensis	2A	3A	..	..	..	++	..	++	..	..	+A	..	7D	..	..	9D	9D	..	+A	3A	..	..	..	..	..	..	..	..	..	..
	Crepis acuminata	..	2A	1A	..	+A	..	..	1A	..	..	++	..	..	4A	1A	7A	5A	..	..	1A	..	..	..	..	..	..	..	..	..	..
F	Solidago nemoralis	++	1A	..	..	..	2A	..	..	..	..	..	..	4A	2A	1A	2A	++	..	..	..	..	..	..	..	..	..	..	..	..	..
	Calochortus nuttallii	2A	1A	..	++	++	4A	..	..	..	..	..	..	..	..	1A	2A	++	..	..	++	..	+A	..	..	..	..	..	..	..	..
	Muhlenbergia cuspidata	..	++	..	+A	1A	3A	..	..	..	..	..	..	..	2A	4B	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..
	Polygala alba	1A	++	..	+A	2A	4A	..	+A	..	..	..	..	..	..	1A	++	..	..	..	++	..	..	..	..	..	..	..	..	++	..
	Oxytropis lambertii	++	2A	..	..	..	4A	+A	+A	..	1A	+A	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	++	..
	Zigadenus venenosus	1A	2A	..	..	++	4A	1A	+A	..	..	+A	..	..	1A	1A	..	++	..	..	++	..	..	..	..	..	..	..	..	..	..
	Astragalus gracilis	++	++	1A	+A	4A	2A	..	2A	..	..	..	..	..	1A	..	++	++	+A	..	..	..	..	..	..	..	..	..	..	++	1A
	Comandra umbellata	++	..	..	+A	++	++	..	1A	+A	1A	2A	..	2A	3A	4A	..	..	1A	4A	..	..	..	..	..	..	..	..	..	..	..
	Campanula rotundifolia	++	..	..	..	+A	++	..	..	+A	..	++	+A	4A	2A	..	++	..	++	..	++	..	..	..	..	..	..	..	..	..	..
	Artemisia tridentata	..	..	..	+A	1A	++	4B	9D	9D	6A	8C	4B	..	2A	1A	..	..	+A	9C	..	..	5D	..	..	..	..	..	1B	..	..
	Aster campestris	..	..	..	2A	1A	..	+A	2A	++	..	..	1A	2A	4A	3A	..	..	2A	..	..	..	..	..	..	..	..	..	..	..	1A
	Stephanomeria	..	..	..	..	..	..	+A	..	+A	2A	2A	..	..	..	..	..	..	..	4A	..	..	..	..	..	..	..	..	..	..	..

Appendix 4 cont.

	Vegetation type	1 STCO					2 AGSP		3 ARTR			4 RHTR					5 PIPO				6 S-TOE			7 RIPR	8 SODD		9a AGIN		9b AGCR		
	Mine, A,R, or S	A	A	R	R	R	A	S	R	S	S	S	S	R	R	R	A	A	R	S	A	R	S	A	A	A	A	S	S	A	R
G	**Juniperus scopulorum**	..	..	..	..	..	..	..	..	1A	..	2A	..	..	1A	3C	2A	++	+A	9A	++	..	..	..	..	..	..	..	..	..	..
	Amelanchier alnifolia	..	..	..	..	..	..	..	..	..	..	..	..	4A	2A	1A	..	..	..	..	++	..	..	++	..	..	..	..	..	..	..
	Linum lewisii	1A	..	..	1A	1A	..	++	4A	1A	1A	1A	2A	4A	5A	6A	1A	..	2A	+A	3A	1A	..	2A	1A	..	1A	..	..	..	..
	Rhus trilobata	+A	1A	3C	1A	1B	2A	3A	..	3A	4A	6A	7D	9B	8C	9D	5A	2A	9C	7A	2A	3C	+A	+A	..	..	..	..	..	..	..
	Pinus ponderosa	..	+A	..	..	..	2A	..	..	1A	1A	2A	..	4A	1A	..	9E	9D	2A	9E	5D	..	..	+A	..	..	..	..	..	..	..
	Astragalus flexuosus	++	1A	..	..	..	++	..	..	..	..	..	..	..	..	..	4A	3A	..	..	1A	..	..	..	..	..	..	..	..	..	..
	Andropogon gerardii	++	2A	..	..	..	..	..	..	..	..	..	..	..	..		2A	1A	..	..	2A	..		..	..	2A	..	..	..	..	..
	Astragalus agrestis	..	1A	..	..	..	..	..	..	..	..	++	..	..	..	..	4A	2A	..	..	6A	..	..	..	1A	..	..	..	..	..	..
H	Prunus virginiana	..	++	..	+A	..	..	..	..	++	..	..	..	..	3A	2A	1A	..	+A	..	5A	2C	..	8D	1A	..	..	..	..	..	..
	Symphoricarpos occident.	2A	1A	..	+A	+A	1A	..	..	..	..	..	..	9C	4A	3B	7B	6C	2A	..	9E	8E	++	9D	3A	3A	..	..	..	++	..
	Rosa woodsii	..	++	..	..	..	..	++	..	1A	..	+A	++	..	..	1B	..	..	..	2A	6B	6D	++	6D	2A	4A	..	..	..	..	..
	Lactuca oblongifolia	++	..	3A	1A	+A	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	2A	3A	..	4A	2A	..	..	..	..	..	..
	Symphyotrichum ericoides	..	..	..	1A	1A	..	..	++	..	..	..	..	..	1A	..	..	..	..	..	..	..	..	++	1A	6A	..	..	..	..	..
I	Agropyron trachycaulum	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	2A	1A	..	5B	4A	9D	..	..	..	..	..
	Ribes aureum	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3C	2C	..	9D	2A	..	..	..	..	..	..
	Urtica dioica	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	1A	..	6C	2A	1A	..	..	..	..	..
	Crataegus succulenta	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	1A	..	5D	++	..	..	..	..	..	..
	Carex praegracilis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	+A	5D	3A	..	..	..	..	..
	Prunus americana	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2A	..	..	5D	++	..	..	..	..	..	..
	Ribes setosum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	5A	++	..	..	..	..	..	..
	Viola canadensis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	4C	..	1A	..	..	..	..	..
J	**Spartina pectinata**	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	6C	9E	..	..	..	..	..
	Cirsium flodmanii	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	3A	9A	..	..	..	..	..
	Equisetum laevigatum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	2A	8A	..	..	..	..	..
	Carex pellita	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	++	9E	..	..	..	..	..
	Galium aparine	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	6C	..	..	..	..	..	..	..
	Fraxinus pennsylvanica	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	3D	..	..	..	..	..	..	..
	Elymus virginicus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4B	..	..	..	..	..	..	..
	Shepherdia argentea	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2D	..	..	..	..	..	..	..
	Acer negundo	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2C	..	..	..	..	..	..	..
	Polygonum convolvulus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5B	++	..	..	..	..	..	..
	Ambrosia trifida	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4B	2A	3A	..		..	..	..
	Hordeum jubatum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	7C	9D	1A	..	..	..	..
	Carex nebraskensis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2C	6C	..	..	..	..	..
	Oenothera villosa	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	4A	..	..	..	..	..
	Eleocharis palustris	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	4D	..	..	..	..	..
	Iva xanthifolia	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4A	..	..	..	++	..
	Scirpus americanus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6C	..	..	..	..	..
	Epilobium ciliatum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8B	..	..	..	..	..
	Ambrosia artemisiifolia	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3A	..	..	..	..	..
	EXOTICS																														
A	Verbascum thapsus	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Salsola iberica	..	++	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
B-E	No species																														
H	Sisymbrium loeselii	..	..	..	+A	..	..	..	..	++	1A	..	+A	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..
F	Alyssum desertorum	..	..	..	..	..	..	2A	..	++	..	+A	4A	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..
	Dactylis glomerata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1C	..	..	..	..	..	..	..
	Agropyron repens	..	..	..	..	..	..	..	..	..	1D	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Kochia scoparia	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..

Appendix 4 cont.

	Vegetation type	1 STCO					2 AGSP		3 ARTR			4 RHTR					5 PIPO				6 S-TOE			7 RIPR	8 SODD		9a AGIN		9b AGCR		
	Mine, A,R, or S	A	A	R	R	R	A	S	R	S	S	S	S	R	R	R	A	A	R	S	A	R	S	A	A	A	A	S	S	A	R
I	**Cirsium arvense**	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+A	++	1A	..	4B	6D	9B	..	..	..	..	..
	Phleum pratense	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	3D	5D	1A	..	..	..	..	..
	Cirsium vulgare	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	+A	..	1A	..	..	..	..	..
	Descurainia sophia	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	5A	9C	3A	..	..	..	..	..
	Thlaspi arvense	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	5A	6A	1A	..	..	..	..	..
	Rumex crispus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	5A	2A	3A	..	..	..	..	..
J	**Arctium minus**	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4B	++	..	..	..	..	..	..
	Bromus inermis	..	..	..	++	..	..	..	+A	..	..	..	..	..	..	..	..	++	..	..	..	..	..	1A	6D	1A	..	..	..	..	..
	Atriplex hortensis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4A	..	..	..	..	..	..
	Melilotus albus	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3A	..	..	..	..	1A	..

Terms used in Appendix 1-5. **Vegetation types** are short grass prairie (1, STCO), foothills prairie (2, AGSP), sage (3, ARTR), *Rhus* (4, RHTR), pine (5, PIPO), slope-toe (6, S-TOE), riparian (7, RIPR), sodden (8, SODD), and old fields (9, FIELD). **Mines** are Absaloka (A), Rosebud (R), and Spring Creek (S). **Presence** is expressed in each cell as a two symbol code, constancy is indicated by the first symbol, while cover is indicated by the second symbol. For constancy: 0% = ".", 0-10% = +, 10-20% = 1, 20-30% = 2, 30-40% = 3, 40-50% = 4, 50-60% = 5, 60-70% = 6, 70-80% = 7, 80-90% 8, 90-100% = 9. For cover: 0% = ".", 0-0.01% = +, 0.01-1% = A, 1-2% = B, 2-5% = C, 5-25% = D, >25% = E. **Shaded presence cells** indicate important species, i.e. those with constancy ≥ 50%. **Primary** refers to species having greater than 30% constancy (occupying greater than 30% of the stands in at least one vegetation type at one mine). **Secondary** species have less than 30% constancy in all communities observed; they are listed in Appendix 5.

Appendix 5 Presence of secondary (<30% constancy) native and exotic species in vegetation types of three SE Montana mines. Important species bolded in table. Horizontal lines segregate species which occur in many, few, three, two, and one community.

Vegetation type	1 STCO					2 AGSP		3 ARTR			4 RHTR					5 PIPO				6 S-TOE			7 RIPR	8 SODD		9a AGIN		9b AGCR		
Mine, A,R, or S	A	A	R	R	R	A	S	R	S	S	S	S	R	R	R	A	A	R	S	A	R	S	A	A	A	A	S	S	A	R
Intra-mine community	1	2	1	2	3	1	1	1	1	2	1	2	1	2	3	1	2	1	1	1	1	1	1	1	2	1	1	1	1	1
Number of plots	32	24	5	24	28	14	31	11	36	8	78	14	4	9	8	12	14	11	10	10	8	30	10	11	6	6	8	27	14	5
Solidago rigida	++	1A	..	..	+A	++	..	..	..	..	..	..	..	1A	..	1A	1A	++	..	1A	1A	+A	..	..	..	..	..	..	..	..
Gaillardia aristata	++	++	..	..	++	..	..	..	..	..	..	..	2A	1A	..	1A	1A	..	..	1A	..	..	..	..	..	..	..	..	..	..
Phacelia linearis	1A	2A	1A	..	..	..	..	..	..	..	++	..	2A	1A	1A	++	++	..	..	..	..	..	..	..	..	..	..	..	++	..
Glycyrrhiza lepidota	++	1A	..	..	..	++	..	..	..	..	..	..	..	..	..	++	1A	..	..	1A	1A	..	+A	2A	1A	..	..	..	..	..
Arabis glabra	++	..	..	..	..	++	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	++	..	..	..	..	..	..	..
Lepidium densiflorum	++	++	..	2A	++	++	..	++	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..	..	1A
Carex stenophylla	+A	+A	..	..	..	1A	+A	..	+A	..	+A	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	+A	..	..
Antennaria microphylla	..	..	..	..	+A	..	+A	..	+A	..	+A	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..
Draba reptans	++	++	..	++	++	..	..	++	..	..	++	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..
Astragalus purshii	++	..	..	..	1A	1A	..	..	++	..	+A	..	..	..	..	1A	++	2A	+A	..	..	..	..	..	..	..	..	..	..	..
Leucocrinum montanum	1A	1A	..	1A	1A	2A	..	+A	..	..	..	..	2A	..	..	..	++	+A	..	..	..	..	..	..	..	..	..	..	..	..
Dalea candida	++	..	..	..	++	2A	+A	..	+A	2C	+A	..	..	..	..	..	++	2A	+A	..	..	..	..	..	..	1A	..	..	..	..
Juniperus horizontalis	..	..	..	..	+A	..	..	..	+A	..	1C	..	2A	..	1A	..	..	..	1A	++	..	..	..	..	..	..	..	..	..	..
Allium textile	..	++	..	..	+A	1A	..	..	+A	..	..	..	..	2A	2A	1A	..	..	+A	++	..	..	..	..	..	..	..	..	..	..
Agropyron dasystachyum	1A	++	..	..	..	+A	+A	..	1B	..	+A	..	2A	2A	..	..	1A	..	+A	..	1A	..	++	..	..	..	..	..	..	..
Erigeron pumilus	++	++	..	..	..	2A	..	..	+A	..	+A	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..	..	..	..	..
Crepis occidentalis	++	..	..	..	..	..	..	..	++	..	++	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..
Sisymbrium loeselii	..	..	..	+A	..	..	..	..	++	1A	..	+A	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..
Krascheninnikovia lanata	..	..	..	..	+A	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	+A	..	..
Senecio canus	..	..	..	..	1A	..	..	..	..	..	+A	+A	..	1A	1A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Apocynum androsaemifolium	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Danthonia spicata	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	++	..	..	..	..	..	..	..	..	..	..
Epilobium brachycarpum	++	++	..	..	..	..	..	..	..	..	..	..	..	..	..	2A	1A	..	..	++	..	..	..	..	..	..	..	..	..	..
Penstemon gracilis	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2A	2A	..	..	++	..	..	..	..	..	..	..	..	..	..
Silene antirrhina	++	++	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Viola nuttallii	++	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..
Arnica sororia	+A	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+C	..	..	..	..	..	..	..	..	..	..	..	..	..
Coryphantha vivipara	++	++	..	..	..	++	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..	..	..	..	..	..	..
Tradescantia occidentalis	..	2A	..	..	..	++	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	1A	..
Mirabilis linearis	++	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..
Brickellia eupatorioides	++	++	..	..	..	..	+A	..	..	..	+A	..	..	..	..	++	..	..	..	++	..	..	..	..	..	..	..	..	..	..
Astragalus crassicarpus	..	++	..	1A	+A	++	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A
Machaeranthera pinnatifida	++	..	..	..	+A	1A	..	..	..	..	..	..	..	..	1A	..	++	..	..	..	..	..	..	..	..	..	..	..	++	..
Euphorbia robusta	..	..	..	..	..	++	..	..	..	..	+A	..	..	..	1A	..	++	..	+A	..	..	..	..	..	..	..	..	..	..	..
Lesquerella alpine	..	..	..	..	..	..	+A	++	+A	1A	2A	..	..	2A	..	..	..	+A	1A	..	..	..	..	..	..	..	..	..	..	..
Geum triflorum	..	..	..	..	..	1A	..	..	..	..	+A	..	2A	1A	1A	1A	2A	..	..	..	..	..	..	..	..	..	..	..	..	..
Opuntia polyacantha	..	..	..	..	..	..	1A	..	+A	..	+A	..	..	..	..	..	..	..	+A	..	..	+A	..	..	..	..	..	..	..	..
Atriplex confertifolia	..	..	..	..	..	..	..	..	+A	1A	++	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Appendix 5 cont.

Vegetation type	1 STCO					2 AGSP		3 ARTR			4 RHTR					5 PIPO				6 S-TOE			7 RIPR	8 SODD		9a AGIN		9b AGCR		
Mine, A,R, or S	A	A	R	R	R	A	S	R	S	S	S	S	R	R	R	A	A	R	S	A	R	S	A	A	A	A	S	S	A	R
Machaeranthera grind.	..	..	..	..	..	..	..	..	+A	..	1A	..	..	2A	1A	..	..	+A	1A	..	..	..	..	..	..	..	..	..	..	..
Oryzopsis hymenoides	..	..	..	..	..	..	..	..	+A	2B	+A	..	..	..	1A	..	..	+A	+A	..	..	..	..	..	..	..	..	..	..	..
Ribes cereum	..	..	..	..	..	..	..	..	..	..	++	..	..	..	1A	..	..	+A	++	..	..	..	..	..	..	..	..	..	..	..
Thermopsis rhombifolia	..	..	..	..	..	..	..	..	..	..	..	..	2A	1A	2A	1A	++	+A	..	..	..	..	..	..	..	..	..	..	..	..
Toxicodendron rydbergii	..	..	..	..	..	..	..	..	..	..	..	..	2A	..	1A	++	..	..	..	1A	1A	..	1A	..	..	..	..	..	..	..
Agrostis stolonifera	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..
Elymus elymoides	..	++	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..
Tradescantia bracteata	..	..	1A	++	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Musineon divaricatum	..	..	..	++	++	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Lomatium macrocarpum	..	..	..	+A	..	..	..	2A	..	..	..	..	..	2A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Ipomopsis congesta	..	..	..	..	++	..	..	..	..	..	+A	..	..	1A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Eriogonum flavum	..	..	..	..	..	++	..	..	+A	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Iva axillaries	..	..	..	..	..	..	+A	..	..	..	+A	1A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Asclepias pumila	..	..	..	..	..	..	++	..	..	..	+A	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Erigeron ochroleucus	..	..	..	..	..	..	+A	..	..	..	+A	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..	..	..	..	..
Machaeranthera canescens	..	..	..	..	..	..	..	..	..	..	..	..	..	2A	1A	..	..	1A	..	..	..	..	..	..	..	..	..	..	..	..
Galium boreale	..	..	..	..	..	..	..	..	..	..	..	..	2A	..	1A	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..
Besseya wyomingensis	..	..	..	..	..	..	..	..	..	..	..	..	2A	2A	..	..	..	..	..	1A	..	..	..	..	..	..	..	..	..	..
Symphyotrichum leave	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	1A	..	..	1A	..	..	..	..	..	..	..
Maianthemum stellatum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	1A	..	..	1A	..	..	..	..	..	..	..
Cirsium vulgare	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	+A	..	1A	..	..	..	..	..
Antennaria neglecta	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	++	..	..	..	..	..	..	..	..	..	..	..	..	..
Apocynum cannabinum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1C	..	..	..	..	..	..
Agropyron elongatum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A
Microsteris gracilis	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..
Agoseris glauca	..	++	..	..	..	..	..	..	..	..	..	..	2A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Salsola iberica	..	++	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Silene drummondii	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..
Lomatium orientale	..	..	..	+A	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Castilleja sessiliflora	..	..	..	..	++	1A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Penstemon eriantherus	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..
Atriplex gardneri	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..	..	..
Phacelia hastate	..	..	..	..	..	..	..	..	..	1A	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Agropyron repens	..	..	..	..	..	..	..	..	..	1D	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Oenothera cespitosa	..	..	..	..	..	..	..	..	..	1A	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Hedeoma drummondii	..	..	..	..	..	..	..	..	++	..	1A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Symphoricarpos alba	..	..	..	..	..	..	..	..	++	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Physaria didymocarpa	..	..	..	..	..	..	..	..	++	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Townsendia hookeri	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..
Chrysothamnus viscidiflorus	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..	..	..	..	..
Populus deltoides	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	2D	..	..	..	..	..	..
Arabis hirsute	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Astragalus barrii	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Astragalus bisulcatus	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Kochia scoparia	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..
Balsamorhiza sagittata	..	..	..	..	..	..	..	..	..	..	..	..	2A	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Mahonia repens	..	..	..	..	..	..	..	..	..	..	..	..	2C	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..
Collinsia parviflora	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	++	..	..	..	..	..	..	..
Elymus Canadensis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..	+A	..	..

Appendix 5 cont.

Vegetation type	1 STCO					2 AGSP		3 ARTR			4 RHTR					5 PIPO				6 S-TOE			7 RIPR	8 SODD		9a AGIN		9b AGCR		
Mine, A,R, or S	A	A	R	R	R	A	S	R	S	S	S	S	R	R	R	A	A	R	S	A	R	S	A	A	A	A	S	S	A	R
Polygonum amphibium	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+A	1B	..	..	..	..	..
Helianthus annuus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	1A	..
Physalis longifolia	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	++	..
Verbena bracteata	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Verbascum thapsus	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Conyza Canadensis	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Euphorbia spathulata	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Triodanis leptocarpa	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Triodanis perfoliata	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Coryphantha missouriensis	..	..	1A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Euphorbia glyptosperma	..	..	..	1A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Potentilla glandulosa	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Lappula redowskii	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Delphinium bicolor	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Sarcobatus vermiculatus	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Malva parviflora	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Erodium cicutarium	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Helianthus maximiliani	..	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Euphorbia esula	..	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Fragraria vesca	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Picradeniopsis oppositifolia	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Chenopodium pratericola	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Lupinus polyphyllus	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Haplopappus armerioides	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Chaenactis douqlasii	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Cornus stolonifera	..	..	..	..	..	..	..	..	..	..	..	..	2A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Potentilla arguta	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..
Oenothera nuttallii	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..	..	..	..
Bromus anomalus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Fragaria virginiana	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..
Geranium carolinianum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..	..	..	..
Bromus marginatus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2A	..	..	..	..	..	..	..	..	..
Convolvulus sepium	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..	..	..
Elymus cinereus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..	..
Ranunculus abortivus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..
Chorispora tenella	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..
Chenopodium fremontii	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..
Erysimum cheiranthoides	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..
Osmorhiza longistylis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	..	..
Dactylis glomerata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1C	..	..	..	..	..	..	..
Scrophularia lanceolata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..
Salix bebbiana	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+C	..	..	..	..	..	..	..
Lithophragma parviflora	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..
Mertensia oblongifolia	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..
Nepeta cataria	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..
Ribes americanum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+A	..	..	..	..	..	..	..
Nothocalais cuspidata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..
Polygonum ramosissimum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..

Appendix 5 cont.

Vegetation type	1 STCO					2 AGSP		3 ARTR			4 RHTR					5 PIPO				6 S-TOE			7 RIPR	8 SODD		9a AGIN		9b AGCR		
Mine, A,R, or S	A	A	R	R	R	A	S	R	S	S	S	S	R	R	R	A	A	R	S	A	R	S	A	A	A	A	S	S	A	R
Geum macrophyllum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..	..
Salix amygdaloides	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2B	..	..	..	..	..	..
Plantago major	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	..
Salix exigua	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..	..
Beckmannia syzigachne	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..
Polygonum aviculare	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..	..	..	..	..	..
Juncus dudleyi	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..
Asclepias speciosa	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..
Atriplex patula	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..
Juncus torreyi	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..
Elyhordeum macounii	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..
Ranunculus cymbalaria	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..
Bidens vulgate	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..
Mentha arvensis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..
Rorippa tenerrima	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..
Epilobium palustre	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1A	..	..	..	..	..
Chenopodium leptophyllum	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	++	..

Terms used in Appendix 1-5. **Vegetation types** are short grass prairie (1, STCO), foothills prairie (2, AGSP), sage (3, ARTR), *Rhus* (4, RHTR), pine (5, PIPO), slope-toe (6, S-TOE), riparian (7, RIPR), sodden (8, SODD), and old fields (9, FIELD). **Mines** are Absaloka (A), Rosebud (R), and Spring Creek (S). **Presence** is expressed in each cell as a two symbol code, constancy is indicated by the first symbol, while cover is indicated by the second symbol. For constancy: 0% = ".", 0-10% = +, 10-20% = 1, 20-30% = 2, 30-40% = 3, 40-50% = 4, 50-60% = 5, 60-70% = 6, 70-80% = 7, 80-90% 8, 90-100% = 9. For cover: 0% = ".", 0-0.01% = +, 0.01-1% = A, 1-2% = B, 2-5% = C, 5-25% = D, >25% = E. **Shaded presence cells** indicate important species, i.e. those with constancy $\geq$ 50%. **Primary** refers to species having greater than 30% constancy (occupying greater than 30% of the stands in at least one vegetation type at one mine). **Secondary** species have less than 30% constancy in all communities observed; they are listed in Appendix 5.

Appendix 6. Key for comparing community designations in this document to community designations in Aho et al. (2006a).

Vegetation type[1]	1 STCO					2 AGSP		3 ARTR			4 RHTR					5 PIPO				6 S-TOE			7 RIPR	8 SODD		9a AGIN		9b AGCR		
Mine, A,R, or S[2]	A	A	R	R	R	A	S	R	S	S	S	S	R	R	R	A	A	R	S	A	R	S	A	A	A	A	S	S	A	R
Intra-mine community[3] labels from this document	1	2	1	2	3	1	1	1	1	2	1	2	1	2	3	1	2	1	1	1	1	1	1	1	2	1	1	1	1	1
Aho et al. (2006)a Community labels	2a.2	2a.1	1a	1b	1c	2a.3	2c	1d	2b	2a	2e	2d	4c	4a	4b	2b.2	2b.1	4d	2f	3a.1	3	1	3a.2	3a.3	3b	1b	3b	3a	1a	2

[1]The vegetation types discussed throughout this paper are Stipa comata (STCO), Agropyron spicatum (AGSP), Artemisia tridentata (ARTR), etc.

[2]Mines are Absaloka (A), Rosebud (R), and Spring Creek (S).

[3]Classification of plots at a mine sometimes yielded 2-3 subtypes which we pooled as part of a single 'regional type' . For example, the Absaloka mine had two STCO subtypes; these are labeled 1&2 here and 2a.2&2a.1 in Aho et al 2006.