Appendix A Glossary of Terms

Blowouts: refers to ecological range sites with eroded surface pits reflecting the presence of abundant Solonetzic (hard pan) soils.

Chernozemic: Dominated by the accumulation of organic matter from the decomposition of grasses and forbs, typically of Grassland plant communities. Chernozemic soils have normal development of soil horizons (A, B, C) and the topsoil (Ah, Ap) is more than 10 cm thick.

Choppy Sandhills: Refers to ecological range sites characterized by loamy sand and sand soils with a duned land surface.

Clayey: refers to ecological range sites with clayey textured soils including: silty clay, sandy clay, clay and heavy clay. Generally >40% clay.

Climax: the final or stable biotic community in a successional series; it is self perpetuating and in equilibrium with the physical habitat.

Cultivar: is a plant variety which has undergone genetic restrictions through selection by plant breeders, and which has been registered by a certifying agency. **Native plant cultivars** in this report refer to cultivars produced from native grass species.

Decreaser: Highly productive, palatable plants that are dominant species in reference plant communities. They decrease in relative abundance as grazing pressure or disturbance related activity increases.

Ecological Range Site: A distinctive kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation. In a grassland environment, **range site** refers to a broader description of soil and landscape (e.g. loamy, clayey, sandy, choppy sand hills etc.), that might be further subdivided into ecological sites due to differences in plant community potential.

Ecological status: is the degree of similarity between the present plant community and the **reference plant community**.

Forb: Primarily broad-leaved flowering plants with net-like veins. For the purpose of simplifying identification, the category can be broadened to include those parallel-veined plants with brightly colored flowers such as orchids or lilies.

Graminoid: Refers to plants which have hollow, jointed stems and leaves in two rows (ranks). Flowers are usually perfect with seeds borne between two scales (palea and lemma). Commonly referred to as grasses and includes sedges.

Gravel: Ecological range sites dominated by gravels or cobbles (>50% coarse fragments). May be covered by a mantle with few gravels, up to 20 cm thick.

Grazing response: how the various kinds of plants on the range react when they are grazed. This may vary with soil and climate for any one species. Range plants are grouped as follows:

> **Grazing Response – Type 1 Species (Decreasers):** Species that decrease in relative abundance as disturbance increases. They tend to be palatable to grazing animals and are the dominant species in the reference plant community (climax vegetation). Highly productive, palatable plants that grow in the original climax vegetation stand. They are palatable to livestock, and will decrease on a range when exposed to heavy grazing pressures.

Grazing Response – Type 2 Species (Increaser – Type 1): Species that normally increase in relative abundance as the decreasers decline. They are commonly shorter, less productive species and more resistant to grazing and other disturbances. Type 1 increaser species increase at first but may decrease later as grazing or other disturbance pressures continue to increase. The increaser plants are normally shorter, lower producing and less palatable to livestock.

Grazing Response – Type 3 Species (Invaders): Invaders are introduced, non-native species and not normally components of the reference plant community (climax vegetation). They invade a site as the decreasers and increasers are reduced by grazing or other disturbances. Invaders may be annuals, herbaceous perennials, or shrubs and have some (or no) grazing value. They are never considered desirable or acceptable vegetation.

Grazing Response –Type 4 Species (Increaser – Type 2): Species that normally increase in relative abundance as the decreasers decline. They are commonly shorter, less productive species and more resistant to disturbance. Type 2 increaser species continue to increase in abundance with increasing disturbance pressures. When increaser type 2 species occur on a disturbed well site, we limit the amount of this cover that is considered desirable vegetation. The amount considered acceptable would be equal to the cover of the species found in the control or 5% whichever is greatest.

Increaser: Plant species that normally increase in relative abundance as the decreasers decline. They are commonly shorter, less productive species and more resistant to grazing and other disturbances.

Interim reclamation sites: refers to sites where the surface soil disturbance has been reduced and reclaimed following initial development activity to stabilize the soils and facilitate the recovery of the native plant communities during the operational phase.

Lentic: this term means *standing* or *still water* (i.e. lakes, wetlands and sloughs).

Limy: refers to ecological range sites with eroded or immature soils with free lime ($CaCO^3$) at the soil surface. Soils pH generally 7.5.

Loamy: refers to ecological range sites with medium to moderately –fine textured soils.

Lotic: this term means *flowing water* (i.e. streams or rivers).

Minimum Disturbance: As defined in the 2010 Reclamation Criteria-Native Grassland refers to minimum disturbance sites that have been reclaimed where construction practices have minimized the level of disturbance on the lease resulting in two different management zones (i.e. Undisturbed meaning the soils have not been stripped and replaced and Disturbed where the soils have been stripped and replaced).

Natural Subregion (NSR): Natural Subregions are subdivisions of a Natural Region, generally characterized by vegetation, climate, elevation, and latitudinal or physiographic differences within a given Region. There are 21 Natural Subregions in Alberta, four of which comprise the Grassland Natural Region.

Overflow: The ecological range site subject to water spreading and sheet flow. Typically on gentle inclines or terraces prone to stream overflow.

Ordination: refers to methods which graphically summarize complex species relationships by aligning observations in a pattern along multiple axes (dimensions) (McCune and Grace 2002).

Plant Community: refers to an assemblage of plants occurring together at any point in time, thus denoting no particular successional status. A mixture of plant species that interact with one another.

Rangeland: is land supporting indigenous or introduced vegetation that is either grazed or has the potential to be grazed and is managed as a natural ecosystem.

Rangeland Health: the ability of rangeland to perform certain key functions. Those key functions include: productivity, site stability, capture and beneficial release of water, nutrient cycling, and plant species diversity.

Reduced Soil Disturbance: refers to construction procedures and practices designed to reduce the area of impact to soil and native vegetation resources. It can refer to interim reclamation and recovery procedures which reduce the area of stripped and stored soils during the operational phase of an industrial development.

Reference Plant Community: is the term used for the potential natural community or climax community. It is the plant community that is the expression of the ecological site potential under light disturbance. It is used in range health assessment as the basis for comparison, hence the term "reference".

Riparian: is the term used to define the transitional area between the aquatic part of a lotic or lentic system and the adjacent upland system.

Restoration: the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Society for Ecological Restoration 2004).

Sands: refers to the ecological range site with very coarse textured soils and not on a duned landscape.

Sandy: refers to the ecological range site with sandy loam, moderately coarse textured soils.

Seral: refers to species or communities that are eventually replaced by other species or communities.

Shallow to Gravel: refers to ecological range sites characterized by soil with 20 to 50 cm of a sandy or loamy surface overlying a gravel or cobble-rich substrate.

Solonetzic: Dominated by hard-pan subsoil or B horizons that are hard when dry and a sticky mass of low permeability when wet. Solonetzic soils are high in sodium and typically have columnar or prismatic macro-structure.

Specified land: for the purpose of the 2010 reclamation criteria, the term Specified Land, means land that is being or has been used or held for or in connection with the construction, operation or reclamation of a well, battery or pipeline (excerpt from the Conservation and Reclamation Regulation (115/93) of the Alberta Environmental Protection and Enhancement Act (Alberta Government 2000).

Succession: the gradual replacement of one plant community by another, over time.

Successional pathways: describe the predictable pathway of change in the plant community as it is subjected to types and levels of disturbance over time.

Seral stages: are each step along a successional pathway. Seral stages begin at the pioneer stage of **early seral,** and progress upward in succession to **mid-seral,** then **late seral** and finally the climax or **reference plant community.**

Thin Breaks: refers to ecological range sites with areas of bedrock at or near the surface; largely vegetated. May include thin, eroded or immature soils on gentle to steep landscapes.

Appendix B Case Studies

B.1 Case Study of Express Pipeline

B.1.1 Why is Express Important?

The Express Pipeline Long-term Revegetation Monitoring Project (Express) provided industry and the Government of Alberta regulatory agencies with a unique opportunity to gather and process much needed data on the long term revegetation success of reclamation techniques used on native prairie. To obtain a pdf version of the entire document or an abridged edition highlighting the key learnings of the study, visit the Foothills Restoration Forum website at http://www.foothillsrestorationforum.ca/.

This section provides a summary of the findings associated with the assessment of reclamation techniques implemented on Express in the Mixedgrass Natural Subregion.

Express Pipeline, owned and operated by Kinder Morgan Canada Inc., is a 24 inch (610 mm) crude oil pipeline that extends from Kinder Morgan's tank farm near Hardisty, Alberta, south 434 kilometres to cross the United States border at Wildhorse, Alberta. The permanent right-of-way (RoW) is 20m wide and an additional 10m of temporary workspace was required for construction. At linear infrastructure crossings, on steep slopes and at water crossings, extra temporary workspace was also required.

Express crosses large contiguous tracks of native prairie along its alignment. Portions of the RoW cross native prairie in the Central Parkland, Northern Fescue, Mixedgrass and Dry Mixedgrass Natural Subregions of Alberta. The long term impact of pipeline construction and reclamation on native prairie ecosystems was an issue identified by stakeholders early in the planning process in 1994. ***Express Pipeline's regulatory commitment was to reclaim the RoW in native prairie areas with the goal of establishing a positive successional trend towards the native plant community present prior to construction*.** This was an early opportunity to demonstrate minimum disturbance practices in the Grassland Natural Region. To pursue this goal, native seed mixes were developed, specialized seeding equipment was used, and erosion control procedures were implemented. Revegetation trials such as natural recovery were implemented to test the response of unconventional revegetation techniques.

A five year post-construction monitoring program was conducted between 1997 and 2001. Monitoring sites included; a diversity of soil types and native rangeland plant communities, construction practices areas where spoil was stored directly on prairie vegetation and areas where construction vehicles were driven on the grass, and areas where disturbed soils were seeded or left to recover naturally. Each monitoring site includes a pair of observations including an undisturbed control and a treatment area on the RoW.

Over the years stakeholders and regulatory agencies recognized that further monitoring of Express could provide a valuable contribution to reclamation science regarding the long term performance of the cultivars and wild harvested seed used in the seed mixes, and the plant community succession of seeded sites and natural recovery trial sites. Additional monitoring in 2010, 14 years after construction, built on monitoring results collected in the initial five years.

B.1.2 Express Results –Mixedgrass Seed Mixes

The performance of each species in the seed mixes in terms of cover was tracked over time and compared to undisturbed native plant communities on the adjacent controls.

The expression and percent cover of seeded species over time on ten sites seeded to Solonetzic Soil Mix 4 is illustrated in Figure B1. The naturally occurring cover of these species on control sites in 2010 is also shown. Components of the seed mix are presented in Table B1.

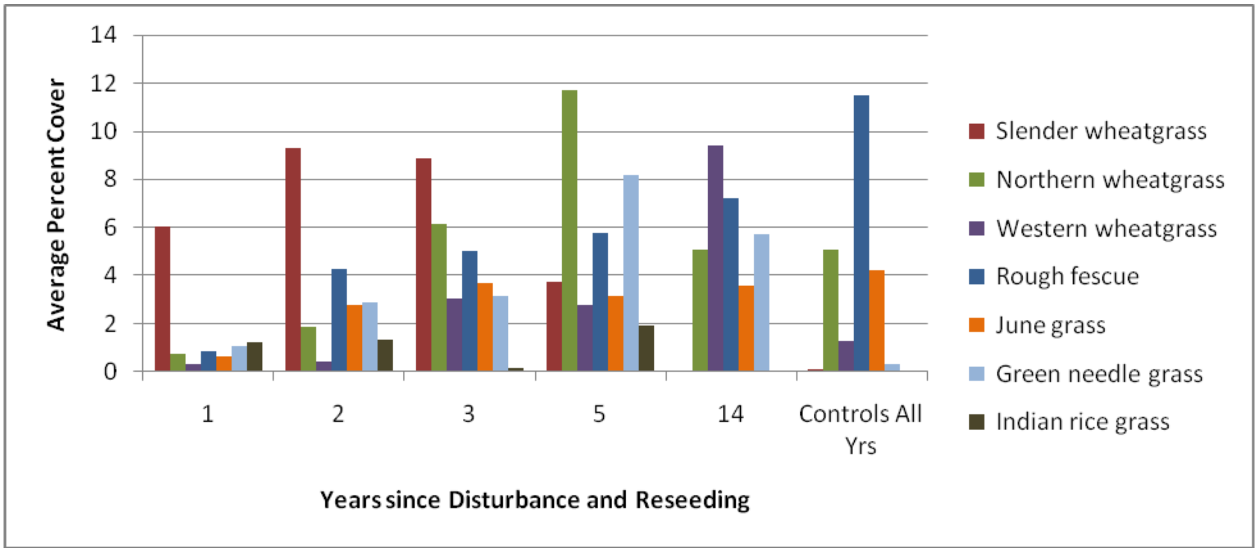
Wild-harvested Seed

- Establishment of wild harvested rough fescue from two sources (plains rough fescue Roes from the Hand Hills and likely foothills rough fescue Petherbridge from the Milk River Ridge) was very slow initially, but the average cover has increased slowly and steadily on ecological range sites with potential to support rough fescue. 14 years after seeding, average cover values of rough fescue on the seeded RoW are more than 50% of the average cover values on the controls.
- Wild harvested June grass performed well, reaching average cover values close to those of the controls by the third year. It performed comparatively better than the June grass cultivar used in the Dry Mixedgrass seed mix.

Cultivars

- The two slender wheatgrass cultivars, *Revenue* and *Adanac*, behaved as transition species, establishing in the early years and providing initial cover to stabilize soils, build litter and shelter other seedlings. Both cultivars have disappeared from the plant community after 14 years.
- Northern wheatgrass and streambank wheatgrass provided good cover during the first five years and have since declined to comparable average cover values to the controls. The seeded cultivars are more robust and taller than their natural counterparts.
- Western wheatgrass established early but has slowly increased over the 14 years and persists at seven fold higher cover than on the controls.
- Green needle grass is only present at low cover levels on a limited number of the native rangeland controls. The seeded cultivar provided good cover during the first five years, but is persisting well beyond natural cover levels (19 fold more) after 14 years. This grass cultivar is significantly taller and more robust than the surrounding native vegetation, creating persistent taller structure and differences in composition in the successional plant community.
- After 14 years, persistent cultivars which are still expanding or maintaining relative cover beyond levels on the controls are influencing the trajectory of plant community succession.

Figure B1 - Species Cover over Time for Rough Fescue - Mixedgrass Transition Seed Mix 2

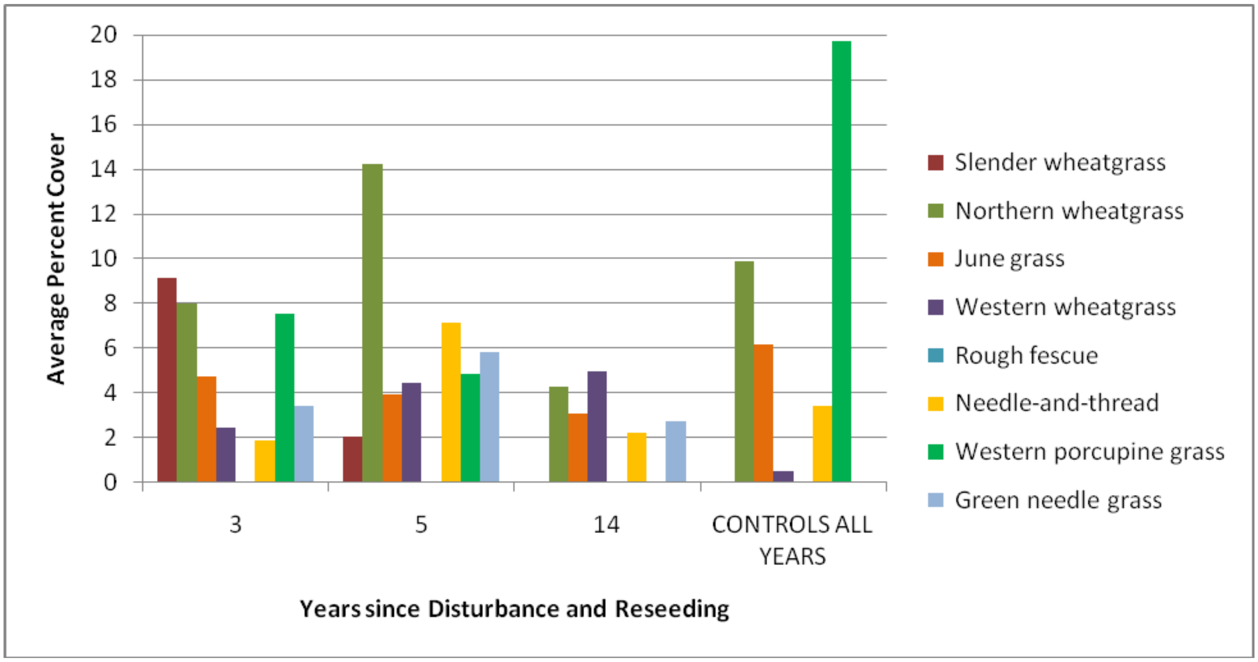


Average % Cover of Seeded Species for all Sites Seeded to Mix 2: Sites #s 4, 21, 22, 23, 25

Table B1 - Rough Fescue - Mixedgrass Transition Prairie (Express Seed Mix 2)

Species	seeds/g	PLS	est%	PLS/m2	plt/m2	kg/ha	%/wt	total kg
Streambank wheatgrass	344	92	25	60	15	1.9	16.3	664
Northern wheatgrass	345	92	25	24	6	0.8	6.5	265
Western wheatgrass	242	92	25	24	6	1.1	9.3	377
Slender wheatgrass *Revenue*	353	83	25	20	5	0.7	5.9	239
Slender wheatgrass *Adanac*	353	86	25	28	7	0.9	7.9	323
Green needle grass *Blight*	398	88	10	43	4	1.2	10.4	425
Indian rice grass	518	86	10	50	5	1.1	9.7	393
June grass *Gillespie*	3300	84	10	71	7	0.3	2.2	89
Plains rough fescue *Roes*	386	77	10	25	3	0.8	7.3	296
Rough fescue *Petherbridge*	386	77	10	85	8	2.9	24.6	1000
Totals				**429**	**66**	**12**	**100**	**4,069**

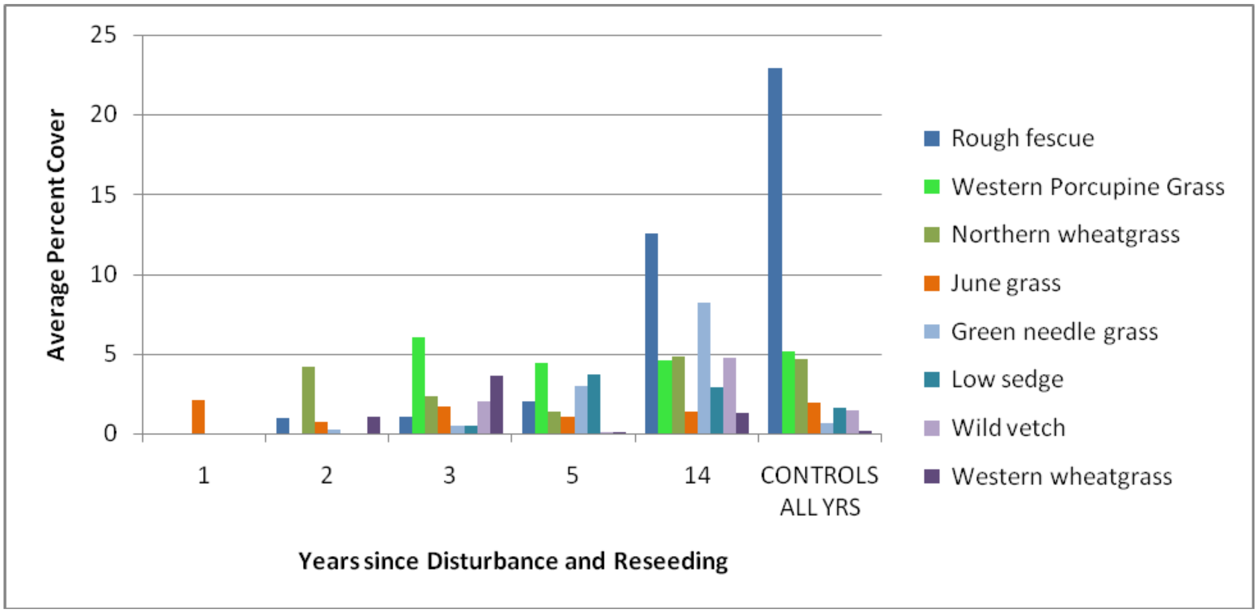
Figure B2 - Species Cover over Time for Seed Trial: Seed Mix 2* + Rough Fescue + Needle-and-thread 5:6:6



* See Table B1 for a list of species in Mix 2.

Includes sites 54 and 55: 5 kgs per ha seed mix 2 drill seeded; and then broadcast seeding of rough fescue 6 kgs per ha and needle-and-thread 6 kgs per ha; and then accu-rolled. No rough fescue or Indian rice grass was observed on or off RoW for sites 54 and 55.

Figure B3 - Species Cover over Time for Seed Trial: 100% Rough Fescue Seed



Average % cover of seeded Species for sites seeded to 100% rough fescue only: Site #s 53, 56, 57 Seeded to wild-harvested rough fescue only; at 12 kgs per ha with Accuroller and straw crimped.

B.1.3 Express Results – Mixedgrass Natural Recovery

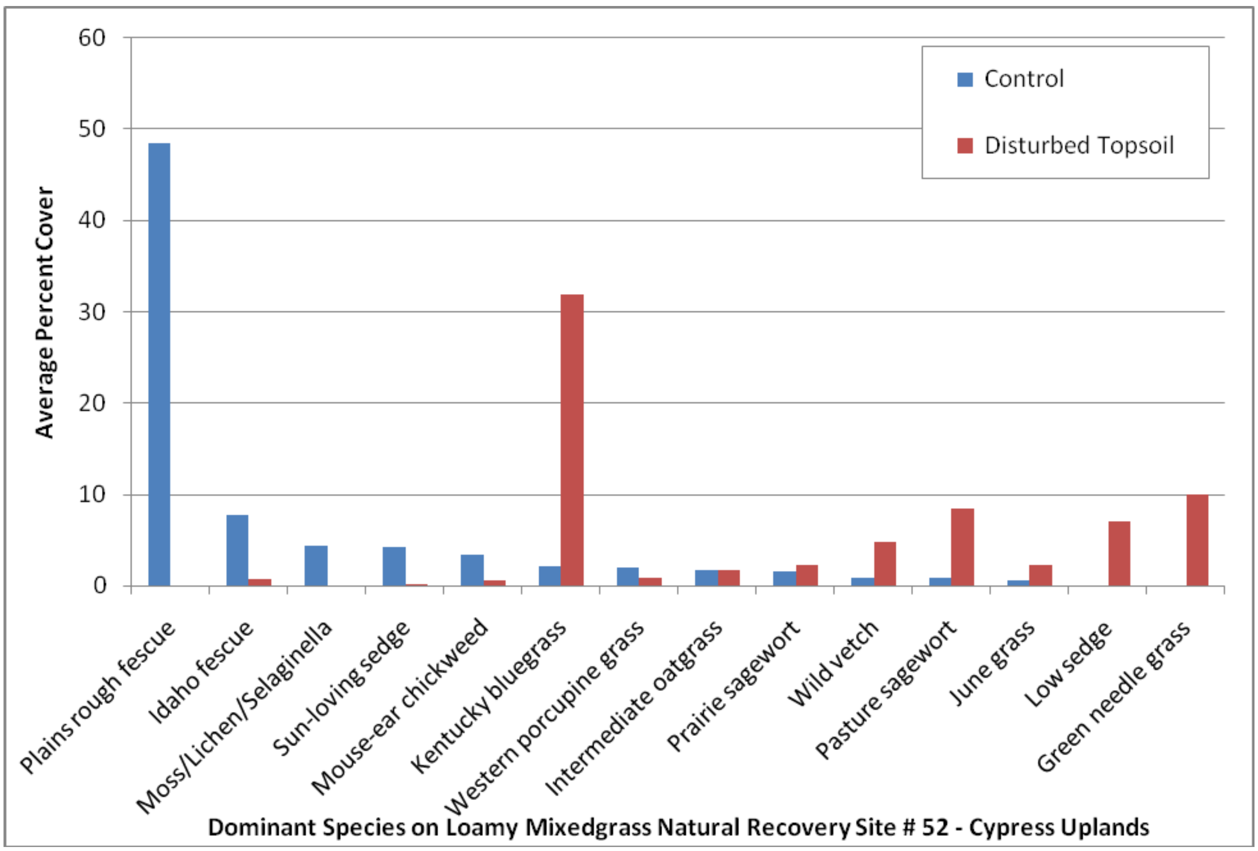
Natural recovery trials were established on Loamy soils in the Mixedgrass. Two sites were selected on relatively level terrain where site stability due to slopes was not an issue and soil exposure to wind erosion was minimized. Cultivars are absent from the reclaiming plant communities, which results in better potential to match off RoW communities in terms of composition and the structural characteristics of local plants.

Natural recovery was problematic on the Mixedgrass rough fescue site. Exposed topsoil remained relatively bare for the first three years, lacking the flush of colonizing annuals typical of Dry Mixedgrass sites. After 14 years, rough fescue is notably absent from the plant community. Although diverse, the plant community does not reflect the proportional cover of species in the reference plant community or the controls (see Figure B4). This result highlights the additional challenge of re-establishing rough fescue on disturbed topsoil.

There was an increase of undesirable non-native Kentucky bluegrass at the Loamy ecological range site where it was present on the controls. This species is able to capitalize on disturbances and moisture to expand cover when it is present in adjacent undisturbed grasslands.

The timing and duration of livestock grazing can also affect the success of natural recovery, particularly in plains rough fescue plant communities.

Figure B4 - Species Cover on Loamy Mixedgrass Natural Recovery Sites in the Cypress Hills after 14 Years Recovery



B.1.4 Assessing Plant Community Succession on Disturbances

Methods for Analysis of Succession

To assess whether succession towards pre-disturbance native plant communities is occurring, a time series of observations were analysed. The observation data was collected from vegetation transects at each monitoring site one, two, three, five and 14 years post-construction. Sites were grouped by Ecological Range Site (ERS) and compared within these similar climate / physiography / soils units. Loamy and Limy ERS groups were included in the analysis for the Mixedgrass.

Methods included cluster analysis and non-metric multi-dimensional scaling analysis. The resulting groupings of species (communities) were described using indicator species analysis. The plant community was named based on the species that were present most frequently and provided the most cover.

Parameters were developed to identify the various seral stages of communities recovering from disturbance (see Table B2 for definitions of seral stages) and applied to each group resulting from the plant community ordination analysis.

Table B2 - Definitions for Plant Community Seral Stages on Disturbed Topsoils

Seral Stage	Description
Bare ground	< 5% cover of live vegetation.
Pioneer	Site dominated by annual weeds, a cover crop or first year seeded colonizing grasses such as slender wheatgrass.
Early seral	Site dominated by disturbance forbs such as pasture sagewort and other species such as low sedge. Seeded species and colonizing grasses such as spear grasses also establishing.
Mid-seral	Cover of grasses greater than that of disturbance forbs such as the sageworts; decreaser grasses present as a small component of the cover.
Late mid-seral	Cover of grasses greater than that of disturbance forbs such as the sageworts; decreaser grasses occupy about 50% of the cover; infill species present.
Late Seral - native	Cover of long-lived grass species expanding; native species cover from the seed bank established; slower establishing infill species present; decreaser grasses dominant; no more than one structural layer missing.
Late Seral - cultivars	Cover of long-lived grass species expanding; seeded cultivars clearly still dominant; slower establishing species such as fescues present; decreaser grasses dominant; no more than one structural layer missing.
Reference	Community closely resembles the ecological site potential natural community under light disturbance described in the Range Plant Community Guides.
Trending to Modified *	A primarily native plant community where non-native species are increasing over time and occupying > 5% of the total live cover; the succession time scale is as little as 5 and as many as 20 years or more.
Modified	> 70% cover of non-native species.

* Invasive non-native species that are known to replace native species and establish permanent dominance in grassland communities include crested wheatgrass, awnless brome and sheep fescue. There has been a debate about whether Kentucky bluegrass should be included in this category. Our feeling is that Kentucky bluegrass is a somewhat naturalized species that is relatively stable. Cover values are high in wet years but are reduced in dry years and in pastures with improved range health. It does not illustrate the same “fire front” effect on the landscape as the previously listed invasive species.

B.1.5 Express Results – Mixedgrass Plant Community Succession

Reclaiming sites are generally progressing from early to late seral communities with successional pathways and progress variously influenced by soil handling techniques, range health, non-native perennial species and climate. The plant community ordination analysis indicates that positive successional change is occurring on most seeded and unseeded disturbed soils in the long term. Forty percent of all sites where soils were disturbed developed into a late seral plant community after 14 years. Almost none of the monitored sites are equivalent in composition, structure or range health to undisturbed control areas or to reference sites described in the Range Plant Community Guides (Adams et al. 2004, Adams et al. 2005), although many are trending in this direction.

Mixedgrass – Limy Ecological Range Sites

Figure B5 illustrates the progress of revegetation on four seeded sites and one unstripped spoil storage area on Limy range sites in the Cypress Hills. All the seed mixes included at least 31.9% by weight rough fescue (Seed Mix 2). The seed mix for site 23 was Seed Mix 2; the mix for site 54 included 50% of Seed Mix 2 plus 25% needle-and-thread and 25% wild harvested rough fescue. The seed mix for site 57 was 100% wild harvested rough fescue. There is some uncertainty about the treatment at site 56.

The pioneer plant community was only distinguished by the common presence of June grass, with a few other species present and less than 10% green cover.

Rough fescue is establishing in one of the two early seral communities characterized by the prominence of pasture sagewort or knotweed. Seeded grasses, western porcupine grass and other infill colonizers are establishing from the seedbank.

A mid-seral community comprised primarily of species present in Seed Mix 2 developed between the third and 14th year of growth.

An unstripped spoil storage area maintained a late seral state as a plains rough fescue community from the first year after disturbance. The site where disturbed soils on healthy rangeland were seeded to 100% rough fescue transitioned to this state by 14 years post-construction.

Figure B5 - Plant Community Succession on Mixedgrass Limy Ecological Range Sites

Seral Stage	Successional Reclaiming Plant Community (4 seeded sites, 19 observations)	Observation Years Since Topsoil Disturbance
Pioneer	June grass	1, 1, 2
Early Seral	Pasture sagewort - Plains rough fescue - Northern wheatgrass	1, 2, 2, 14
Early Seral	Common knotweed - Pasture sagewort - Western porcupine grass	3, 3, 5, 5
Mid-seral	Green needle grass-Northern wheatgrass-June grass	2, 3, 3, 5, 5, 14, 14
Late Seral	Plains rough fescue-Western wheatgrass-Northern wheatgrass	14

Mixedgrass – Loamy Ecological Range Sites

Six seeded sites and three unseeded sites are included in the cluster analysis for Mixedgrass Loamy soils. Figure B6 illustrates the five plant communities differentiated, their successional status on reclaiming sites and the progression of each site over time.

An early seral community on Loamy sites is characterized by the dominance of the disturbance forb pasture sagewort, the persistence of the colonizing seed mix grass species slender wheatgrass and the low cover of other establishing long-lived native grasses. This plant community persisted for five years on a site subjected to heavy summer grazing on the RoW. It was also found in years two and three on other seeded sites. Rough fescue is present at 3.4% cover with a constancy of 71.4%. Western porcupine grass is colonizing from the seedbank.

Two mid-seral plant communities developed; one dominated by wheatgrasses and desirable decreasers on seeded sites and sites where Kentucky bluegrass is dominant. This invasive exotic grass is present on the undisturbed but should not take over as long as the range stays in healthy condition.

By year 14, four seeded sites are at a late seral stage, characterized by prominence of the slow to establish decreaser species rough fescue. This group includes observations from three sites seeded to Seed Mix 2, one site seeded to pure rough fescue, and one natural recovery site.

The unstripped spoil storage area did not revert to a pioneer community after disturbance but remained as a mid-seral plant community for five years thereafter. Similarly, an unstripped travel lane remained as a late mid-seral plant community for five years after disturbance. These two sites were not monitored in 2010.

Figure B6 - Plant Community Succession on Mixedgrass Loamy Ecological Range Sites

Seral Stage	**Successional Reclaiming Plant Community (6 seeded sites, 20 observations)**	**Observation Years since Topsoil Disturbance**
Early Seral	*Pasture Sagewort - June Grass - Wild Vetch*	1, 2, 2, 2, 3, 3, 5
Mid-seral	*Northern Wheatgrass - Western Wheatgrass – Needle-and-Thread*	3, 5, **14, 14**
	Kentucky Bluegrass - Low Sedge - Pasture Sagewort	5
Late Mid-seral	*Western Porcupine Grass - Northern Wheatgrass - Wild Vetch*	5
Late Seral	*Plains Rough Fescue - Northern Wheatgrass - Pasture Sagewort*	1, 2, 3, **14, 14, 14, 14**

B.1.6 Challenges for Succession on Mixedgrass Sites after Disturbance

Seeded Soils

For seeded sites that remain as early or mid-seral plant communities after 14 years, pasture sagewort (a persistent native disturbance forb) or seeded cultivars (including green needle grass, northern wheatgrass or western wheatgrass) are still dominant, often beyond natural levels.

Unseeded Soils

There was only one unseeded trial site in the Mixedgrass due to concerns about the ability of these sites to revegetate to desirable species and the vulnerability of sites in the Cypress Hills to erosion. This site had very little cover for the first three years and was subject to summer grazing. The bare RoW attracted cattle. Although in the analysis the developing plant community clustered with a late seral community in years two and three, it has shifted into a community dominated by Kentucky bluegrass (an invasive exotic species) in years five and 14.

B.1.7 Succession on Unstripped Spoil Storage Areas and Travel Lanes

Native vegetation at monitoring sites where spoil was stored directly on the grass or where vehicles drove directly on the grass did not revert to a pioneer stage. Native vegetation re-established quickly from underground propagules to provide partial cover consisting of early to mid-seral plant communities. However, many of these sites do not appear to have progressed towards more mature seral stages (see Table B3). Most monitoring sites maintained the same plant species composition and cover over five years. Some sites have maintained the same plant community over the 14 year recovery period.

Table B3 - Seral Stage on Unstripped Mixedgrass Spoil and Travel Lane Sites after 14 Years

Unstripped Construction Areas*	Site #	Successional Stage on Revegetating Undisturbed Soils in 2010 (numbers = years since topsoil disturbance)				
		Pioneer	Early Seral	Mid-seral	Late Mid-seral	Late Seral
Mixedgrass - Limy: Spoil Storage Area	26S					1, 2, 3, 5, 14
Mixedgrass - Loamy: Spoil Storage Area	20S			1, 2, 3, 5		
Mixedgrass - Loamy: Travel Lane	24T				1, 2, 3, 5	

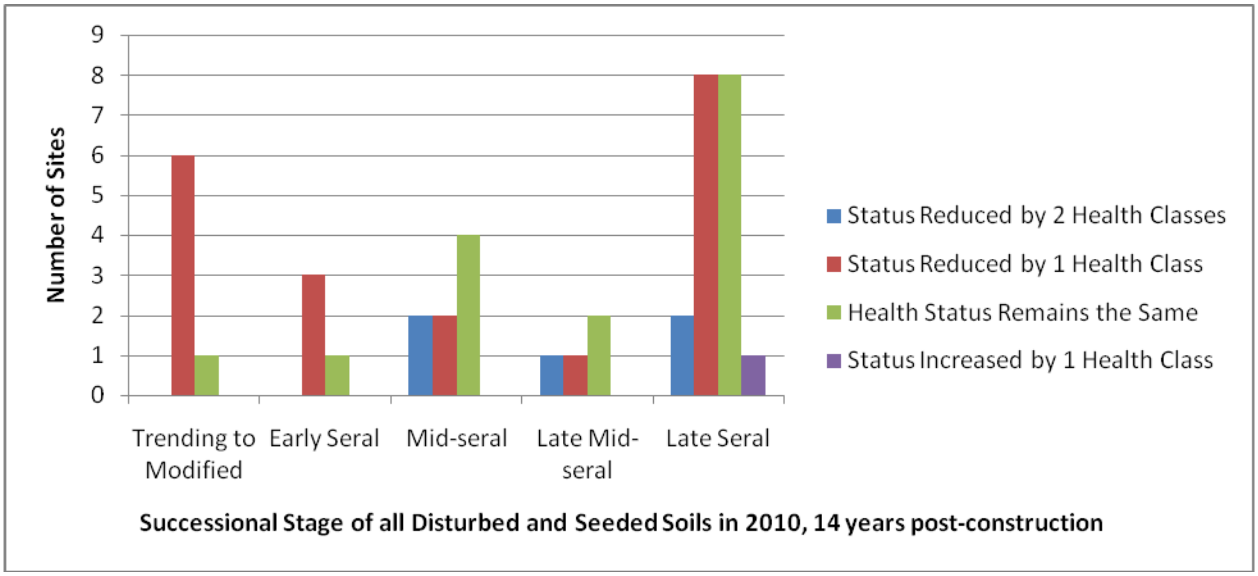
B.1.8 Express Results – Range Health

Range health was measured both on the disturbance and the associated controls in 2010. Health assessments included measures of ecological status (as indicated by plant species composition present on the site), plant community structure, litter, site stability, soil exposure and the presence of noxious weeds (Adams et al. 2009). The health of the range before disturbance affects the ability of a disturbed area to respond and can affect the outcome of restoration. Ultimately, impacts to plant community integrity will impact the provision of ecological services.

Ecological Status

After 14 years, 45% of the sites on disturbed soils have developed into late seral plant communities of varying ecological status (see Figure B7). Some 43% of the 42 measured sites have the same ecological status as the adjacent undisturbed pasture. Another 43% of the sites have reduced ecological status compared to the adjacent rangeland. Ecological status scores dropped by two health classes for 11% of the sites, and increased by one health class at one site. There were no discernible differences in ecological status between seeded and unseeded sites after 14 years.

Figure B7 - Ecological Status and Seral Stage of Reclaiming Sites on Disturbed Soils



Plant Community Structure

Structural layers in healthy native rangelands usually include: low shrubs, tall graminoids and forbs, medium graminoids and forbs, and ground cover (graminoids, forbs, moss and lichen) (Adams et al. 2009). Diversity in the canopy structure provides resilience to fluctuations in grazing pressure and climate events, promotes energy flow and nutrient cycling, and protects the ground surface from erosion (Adams et al. 2009). A consistent observation from all the reclaiming sites on disturbed soils is the continuing lack of a groundcover layer after 14 years. Soil exposure above normal values was still more prevalent on the recovering RoW than on native rangeland, which contributed to reduced health scores. Typically prairie selaginella (Selaginella densa), and to a lesser extent mosses and lichen are the major components of this layer in the Mixedgrass. Litter values were also diminished with increased grazing pressure and lower range health scores.

Invasive Species

Establishment of invasive species from the seedbank or through infill has only been an issue at a few monitoring sites. Crested wheatgrass is establishing on two southern sites in the Mixedgrass where it is present off RoW. The large pastures in the expansive areas of native prairie in the southern portion of the Express Pipeline route are relatively free of introduced species. Further north, where there is increased landscape fragmentation and cultivation, introduced species are more common.

Interacting Variables

Range health was generally better in larger pastures and on Public Land. Smaller pastures and private land, particularly on more northern portions of the RoW, tended to have reduced range health scores. In smaller pastures the disturbed RoW takes up proportionally more land temporarily reducing forage production and disrupting livestock grazing patterns which can put further pressure on both the undisturbed and disturbed portions of the area. Recovery can be delayed if livestock disproportionately select the re-establishing forage species on the RoW over established forage in the balance of the pasture. The droughts experienced during recovery can also exacerbate grazing impacts on the recovering RoW, particularly in smaller pastures.

B.1.9 Express Results – Diversity After Disturbance

An assessment was made of the proportion over time of three growth forms of interest (annual forbs, perennial forbs, and graminoids) on seeded and naturally revegetating soils in the Mixedgrass. The assessment compared the relationship between the diversity of species on a site (represented by Shannon's Diversity Index) and the proportion of a site occupied by each growth form. The biggest changes in proportion occurred on natural recovery sites, where there was a flush of annual forbs immediately after disturbance, their gradual decline over time and the slow steady increase in the diversity of graminoids (grasses and sedges). IN contrast, seeded sites maintained a high cover, low diversity graminoid cover composed of seed mix species in early years.

Over time the diversity of graminoids and the proportion of the naturally reclaiming sites occupied by graminoids increases and are comparable to values on seeded areas and undisturbed controls by 2010.

B.1.10 Express Management Observations and Recommendations

A number of observations and recommendations based on key learning's from Express are presented in Section 11 of the main report. A few are highlighted here.

Restoration Planning

- Sites where long-lived seeded species matched those present naturally on the surrounding rangeland had the best chance of establishing and persisting over time.
- There may be more options for restoration in healthy rangeland. Diminished range health or high grazing intensity can hinder recovery.

Seed Mixes

- Avoid seeding persistent species that are not present naturally on the same ecological range site.
- Non-native sheep fescue is invasive and should not be used for restoration. Sheep fescue may contribute to plant community modification over time.
- It is important to plan for different structural layers when designing a seed mix and include a variety of species with tall, mid and low structural characteristics compatible for the range site and associated plant community. Diverse structure improves range health and builds ecological resilience.
- Persistent cultivars that developed taller structure on the Express RoW are green needle grass, sand grass (sand reed grass), northern wheatgrass and western wheatgrass.

- It is very important to use seed with genetic origin that is compatible with the area of the project. Some cultivars are much taller and more robust than local plants, creating persistent increases in plant community structure on the revegetating disturbance. The common aggressive cultivars on Express were green needle grass, western wheatgrass and northern wheatgrass.
- Slender wheatgrass is a useful short term cover crop, providing erosion control and shade for slower establishing species and disappearing for the most part by year five, leaving space for infill by other species.
- Avoid using non-native species for native prairie restoration unless they are annual cover crops that are guaranteed not to persist more than one year or have the potential to increase in density over time through seed set.

Natural Recovery

- Natural recovery techniques were successful in establishing native plant communities in healthy rangeland in the Mixedgrass Natural Subregion. Cultivars are absent from the reclaiming plant communities, which results in better potential to match off RoW communities in terms of composition and the structural characteristics of local plants. The result is a native plant community rather than a community of native cultivars.
- The timing of topsoil replacement is an important factor in the outcome of natural recovery as a revegetation strategy. Topsoil replacement in the fall or during dormant conditions before the first post-construction growing season is recommended.
- The presence of undesirable non-native species prior to disturbance can negatively affect the outcome of natural recovery as a revegetation strategy. Seeding may be a better option on invaded sites.
- The timing and duration of livestock grazing can also affect the success of natural recovery. Protecting sites from grazing during spring and summer in the first few years can be beneficial.

Communication of Restoration Commitments and Strategies from Construction to Operations

- Remedial repairs and seeding may be required on projects up to 10 years after construction. It is important to communicate restoration goals, commitments and strategies agreed to for construction to the operations team.

Assessing Restoration Progress

- Patience is required to restore native grassland communities. The 14 year post-construction monitoring on Express indicates that succession is still on-going and range health on the disturbances is improving, but lower than the surrounding rangeland.

B.2 Cypress Uplands and Majorville Uplands Case Studies

Summarized from the document: *Long-term Revegetation Success of Industry Reclamation Techniques for Native Mixedgrass Prairie: Cypress Uplands and Majorville Uplands Case Studies* (Lancaster, Neville, and Hickman 2012).

B.2.1 Case Study Project Settings

The purpose of this monitoring project was to provide industry and the government of Alberta regulatory agencies with results and key learnings regarding the long term recovery of native Mixedgrass prairie from industrial disturbance. The project focused on minimal disturbance pipeline construction and documented the long term outcome of three revegetation strategies commonly used in the Mixedgrass Natural Subregion of Alberta, including use of natural recovery, assisted natural recovery (agronomic cover crops) and native seed mixes.

Work that was done on the Husky Majorville Sweet Gas Gathering System, Cypress Pipeline and Merry Flats Sweet Gas Gathering System projects can be considered a best case scenario for restoration of Mixedgrass rangelands; the pastures are large and in generally good range health with relatively few invasive species. The oil and gas developments were led and executed by responsible people who were committed to ensuring their projects met and exceeded guidelines for minimum disturbance.

The three projects are located in two different Ecodistricts in the Mixedgrass Natural Subregion. The Husky Majorville Sweet Gas Gathering System is located in the Majorville Uplands Ecodistrict. Monitoring data was collected four years after construction and seven years after construction in 2011. The Cypress Pipeline and Merry Flats Sweet Gas Gathering System are both located in the Cypress Uplands Ecodistrict. Monitoring in 2011 provided the opportunity to expand data sets collected one, two and three years' post-disturbance with data collected 11 and 12 years post-disturbance.

B.2.2 Minimal Disturbance Construction Techniques for Small Diameter Pipelines

Pipeline construction procedures designed to minimize the disturbance to the native grasslands were strictly adhered to throughout construction of the three projects. Disturbance to the native grasslands was minimized to the extent possible through the following procedures:

- Winter construction;
- Construction only during suitably dry and/or frozen ground conditions. Temporary shut-down in adverse weather conditions;
- Strict adherence to access and traffic control plans;
- Use of polypropylene pipe rather than welded steel pipe wherever possible;
- Reducing the timeframe between topsoil stripping, pipe installation, back fill and topsoil replacement to 48 hours where possible; and
- Two strip gravelling of existing tracks to prevent erosion and to provide stable access.

Construction procedures that differed between the projects are:

- Use of rubber tracked side booms for stringing and pipe installation (Husky);
- Implementation of no-strip trenched pipe installation in native prairie on public lands (Husky);
- Topsoil stripping restricted to approximately one metre over trench line (Cypress & Merry Flats); and
- "Partial sod salvage" over the trench to reduce impact to soils and vegetation (Cypress & Merry Flats).

B.2.3 Revegetation Strategies

Three revegetation strategies were used on the projects:

- An assisted natural recovery strategy, using an agronomic cover crop was implemented on the Alberta portion of the Cypress Pipeline. This strategy is designed to provide cover for the first two years and then die off. The seed mix is composed of two agricultural species: annual flax and fall rye (a biennial). A 1:1 mixture of each species was seeded at half a bushel to the acre for each species.
- Native grass seed mixes, including the dominant indicator species for the surrounding plant communities, were seeded on the Saskatchewan portion of the Cypress Pipeline and the Merry Flats Drilling Program, also located in Saskatchewan. The seed mix was applied at 12 kilograms (kgs) per hectare with a Kinsella Accuroller.
- Natural recovery of bare soils, relying on the soil seed and propagule bank and infill from surrounding grassland was the strategy implemented on the Husky Majorville Project.

B.2.4 Long term Monitoring

The 2011 monitoring was conducted on upland ecological range sites where quantitative data had been collected in previous years for the Cypress, Merry Flats and Majorville projects. Data collected in 2011 was 12 years after construction of the Cypress project, 11 years after construction of the Merry Flats project and seven years after construction of the Majorville project.

A range health assessment was also conducted in 2011 on disturbed soils and adjacent undisturbed reference plots for the Cypress Upland Ecodistrict sites (including Cypress and Merry Flats Project areas) and Majorville Upland Ecodistrict monitoring projects, based on the current manual developed by Alberta Sustainable Resource Development (ASRD) *Rangeland Health Assessment for Grassland, Forest & Tame Pasture Field Workbook (*Adams et al 2009*)*. Range health assessment provides perspective on the ecological function of reclaiming communities. This technique also links current land use to the condition of the reclaiming grassland.

Data was interpreted in the context of new tools developed for classifying rangelands including; Grassland Vegetation Inventory (GVI) mapping of ecological range sites (ASRD and LandWise Inc. 2010) and the "*Mixedgrass Range Plant Community Guide*" (Adams et al. 2004), which links naturally occurring plant communities to ecological range sites. The Cypress Upland monitoring project is situated on shallow to gravel ecological ranges sites and the Majorville Upland project is situated on loamy and limey ecological range sites.

B.2.5 Restoring Site Stability (Vegetation Cover, Litter and Bare Ground)

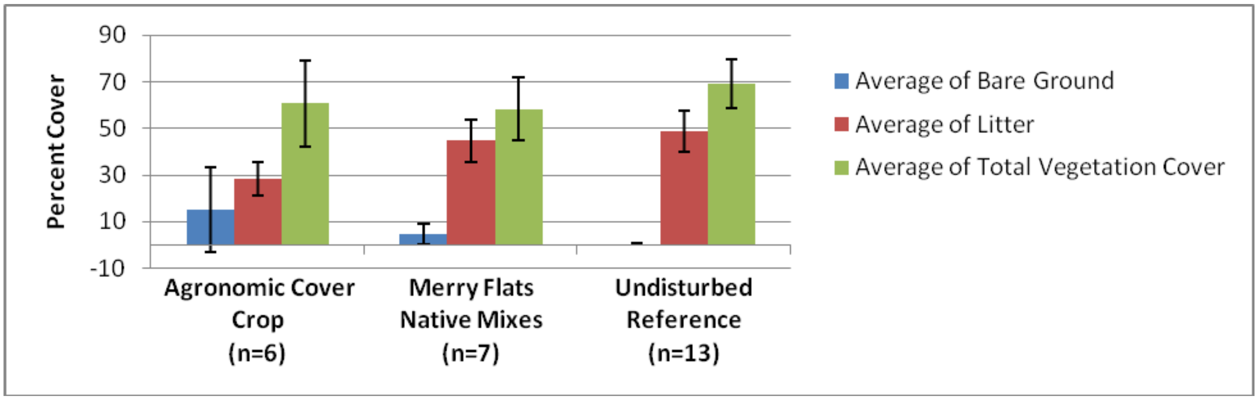
Cypress Uplands: Shallow to Gravel Ecological Range Sites

Indicators of site stability and function were compared for each of the revegetation treatments and compared to undisturbed grassland. The agronomic cover crop produced more live cover in the first two years compared to the native seed mixes. However, after 11 to 12 years, vegetation cover levels are similar between all the treatments and the undisturbed grassland, varying between 54% and 70% cover (see Figure B8).

Litter accumulation reduces soil exposure and helps re-establish nutrient cycling in a disturbance plant community. Litter levels have slowly risen over time for all the revegetation treatments. For each of the monitoring years, litter levels were consistently 5% to 20% higher in the native seed mix treatments than in the assisted natural recovery treatment. However, differences in litter cover are not significant between the revegetation treatments and the undisturbed grassland after 11-12 years.

The agronomic cover crop established early and reduced exposure of bare ground more than the native seed mixes did in the first two years after seeding. However, all three native seed mix treatments resulted in less bare ground in the third year than the assisted natural recovery treatment. Eleven to twelve years after disturbance, exposure of bare ground on the assisted natural recovery treatment and the native seed treatment is still significantly higher than the 0.4% bare ground on the undisturbed grassland. Average soil exposure on the native seed mix sites is 4.6%. The assisted natural recovery sites had on average the most bare ground and the greatest variability between sites, averaging 18.6% substrate exposure (see Figure B8).

Figure B8 - Indicators of Litter, Bare Ground and Vegetation Cover after 11 to 12 Years for Assisted Natural Recovery and Native Seed Mix Revegetation Strategies



Majorville Uplands Natural Recovery: Loamy and Limey Ecological Range Sites

On the natural recovery sites, bare soils exposure has decreased from 50% after four years to 7.6% after seven years recovery but is still greater than the 0.3% bare soil exposure on undisturbed grassland.

Litter accumulation is variable between sites and pastures, with litter being comparable to undisturbed grassland on several sites and less but increasing after four and seven years natural recovery on the majority of sites.

B.2.6 Restoring Range Health

Cypress Uplands: Shallow to Gravel Ecological Range Sites

Range health assessment (Adams et al. 2009) provides a measure of ecosystem function. In the Cypress Uplands study, disturbance plant communities, regardless of which revegetation strategy was used, scored in the "healthy with problems" range after 11 to 12 years of recovery. This indicates considerable progress towards restoration. The three measures that reduced the scores of the disturbance plant communities were the composition of the plant community, missing structural layers and the amount of litter accumulation.

Majorville Uplands Natural Recovery: Loamy and Limey Ecological Range Sites

In the Majorville Uplands study, where natural recovery was the revegetation strategy, range health scores increased for all disturbance communities between four and seven years after construction, indicating that the process of infill is occurring. Exposure of bare ground decreased from 2008 to 2011 and total vegetation cover increased within the sample sites.

Table B4 - Range Health 4 and 7 Years after Disturbance on Majorville Natural Recovery Plots

Range Site and Plot #	4 Years Recovery		7 Years Recovery	
	Undisturbed	Disturbed Soil	Undisturbed	Disturbed Soil
Loamy #13	Healthy	Healthy with problems 66%	Healthy 87%	Healthy 75%
Loamy #14	Healthy with problems 70%	Healthy with problems 53%	Healthy 87%	Healthy 82%
Loamy #20	Healthy 87%	Healthy with problems 50%	Healthy 87%	Healthy with problems 59%
Loamy #18	Healthy with problems 73%	Healthy with problems 51%	Healthy 83%	Healthy with problems 67%
Loamy #21	Healthy with problems 66%	Unhealthy 36%	Healthy 87%	Healthy with problems 68%
Loamy #17	Healthy 87%	Unhealthy 10%	Healthy 76%	Unhealthy 48%
Limey #22	Healthy with problems 58%	Unhealthy 40%	Healthy 87%	Healthy with problems 72%
Sub-irrigated	Healthy 87%	Healthy with problems 61%	Healthy 84%	Healthy with problems 63%

B.2.7 Restoring Plant Communities: Assisted Natural Recovery vs Native Seed Mixes

Cypress Uplands: Shallow to Gravel Ecological Range Sites

There are no traces of the agronomic cover crop species (common flax and fall rye) persisting after 12 years (see Figure B8). The species present are all native and have established naturally from propagules, the seedbank or through infill. The composition of the plant community is very similar to the undisturbed grassland. The cover of rough fescue is still significantly higher on the undisturbed sites at 36% cover versus 14% cover on the disturbance. The early seral grass needle-and-thread and the disturbance forb pasture sagewort are more common on the disturbed site, but in general the cover values reflect what occurs naturally on these rangelands.

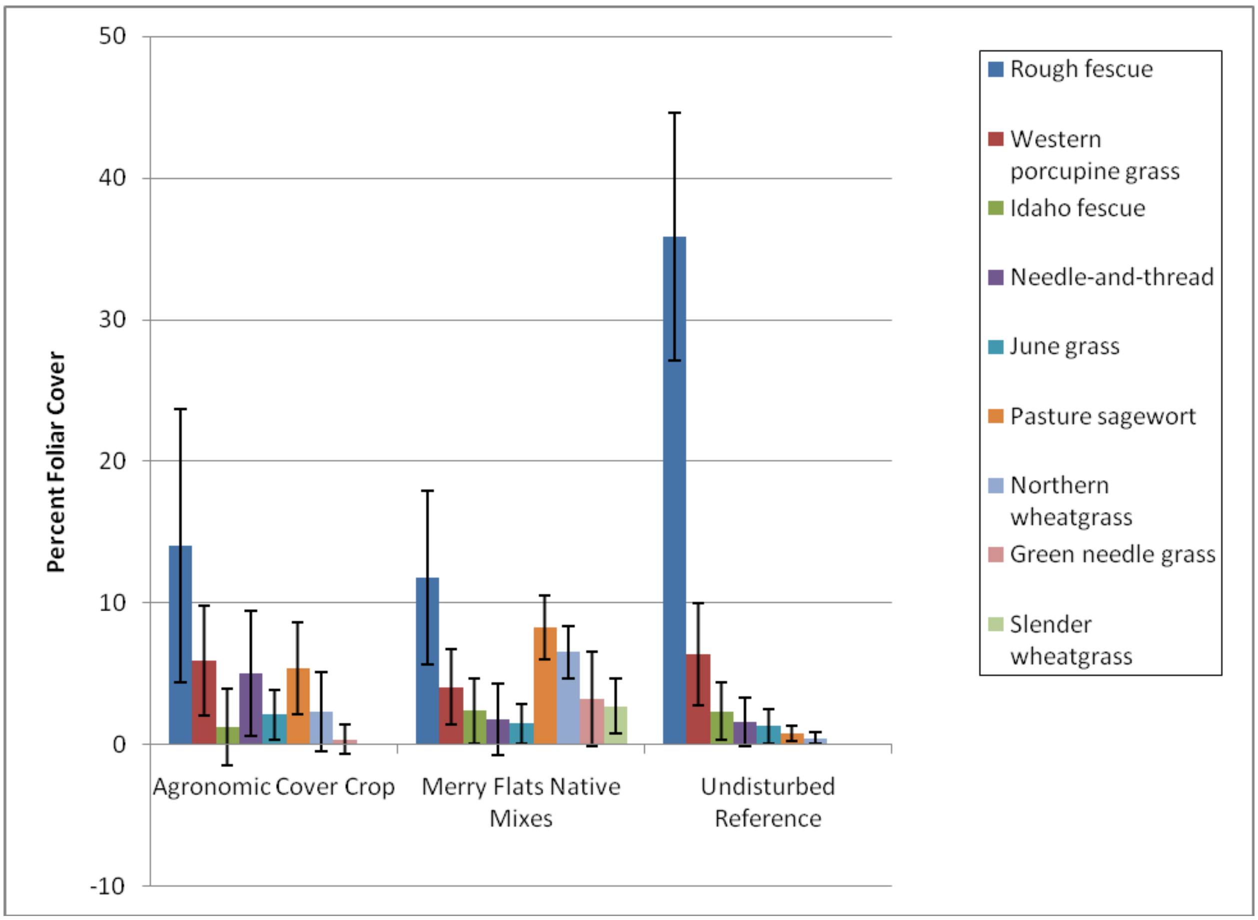
The primary differences between the composition and cover of native seed mix sites versus the undisturbed plant community or the assisted natural recovery sites is the presence of northern wheatgrass, slender wheatgrass and green needle grass cultivars at significantly higher cover than natural cover levels (see Figure B9).

After 11 to 12 years, the cover of rough fescue is still significantly higher on the undisturbed sites than either the assisted natural recovery sites or the native seed mix sites. Both the assisted natural recovery sites and the native seed mix sites did produce rough fescue at similar average cover and similar levels of variability between sites.

Western porcupine grass, an important species in the Mixedgrass, is present at similar cover levels on seeded sites, assisted natural recovery sites and control sites.

Cover of the disturbance forb pasture sagewort is higher on both disturbance treatments compared to the undisturbed grassland.

Figure B9 - Comparison of Average Species Cover after 11 to 12 Years for Assisted Natural Recovery and Native Seed Mix Revegetation Strategies



Forb Infill on Revegetating Disturbances: Neither of the Cypress Upland revegetation strategies included introduction of native forbs to the disturbed soils. Both the assisted natural recovery and the native seed mixes resulted in some natural infill, particularly of pasture sage. A great number of forbs established on the disturbance over 11 to 12 years, about 77% of the number of species observed on undisturbed sites. None of the forbs provide much cover and very few occur with great constancy across the sites within each treatment. The most common species on the disturbances are golden bean, hairy golden aster and common yarrow.

Identifying Successional Disturbance Plant Communities: Plant community ordination identified four plant communities that developed over time on disturbances in healthy *Plains rough fescue –Western porcupine grass – Sedge* communities (MGA1(Adams et al. 2004)) on loamy and shallow to gravel range sites in the Cypress Upland (see Table B5). Key observations are as follows:

- Two early seral communities are identified, primarily in years two and three after seeding; one dominated by native seed mix components (Slender wheatgrass - Northern wheatgrass - Pasture sage); the other by species found naturally as well as in native seed mix 2 (Pasture sage - Northern wheatgrass - Western porcupine grass).
- The one mid-seral community includes observations from both seed mixes and the cover crop treatments and observations span all years.
- The late seral plant community (Plains rough fescue - Pasture sage - Northern wheatgrass) includes observations primarily from 11 and 12 years post-seeding and includes all treatments. Both cover crop and native seed mix strategies are resulting in this community over time.
- Two of the disturbed sites seeded to a cover crop and one site seeded to a native seed mix are clustering with the reference community observations, indicating good recovery over 11 to 12 years.

Over time, 11 and 12 years after disturbance, species relationships in the revegetating Cypress Uplands grasslands are becoming more similar to each other and to the undisturbed sites. A desirable successional trend is occurring for both the cover crop revegetation strategy and the native seed mix strategies (see Table B5).

Table B5 - Succession of Reclaiming Plant Communities

Seral Stage	Plant Community Groups	Cover Crop *	Native Mix 1 *	Native Mix 2 *	Native Mix 3 *	Control *
Early Seral	Pasture sage - Northern wheatgrass - Western porcupine grass	2, 3, 3		2, 3, 3	1, 2, 2	
Early Seral	Slender wheatgrass - Northern wheatgrass - Pasture sage		2, 2, 3, 3, 11	2		
Mid-seral	Western porcupine grass - Plains rough fescue - Low sedge	2, 3, 12	11	2	3	
Late Seral	Plains rough fescue - Pasture sage - Northern wheatgrass	1, 1, 2, 12, 12, 12	11, 11, 11	11, 11		2
Reference	Plains rough fescue - Western porcupine grass - Selaginella	1, 12, 12	11		1	24 obs, all years

*Each number is an observation that references the number of years since seeding at one site.

B.2.8 Restoring Plant Communities: Natural Recovery

Majorville Uplands: Loamy and Limey Ecological Range Sites

In the initial years of natural recovery, western wheatgrass, northern wheatgrass, green needle grass and sedge species play an important role in colonizing bare soils in the Mixedgrass. Pasture and prairie sagewort play an important role in providing initial cover and shade for emerging graminoids, catching snow and conserving moisture. Over time the western and northern wheatgrasses increase in cover, stabilizing the soils with their ability to produce a network of rhizomes within the soil. Green needle grass also increases in cover as it is well adapted to disturbance. As the colonizing species provide initial structure over the soil surface, needle-and-thread grass seed rain from the adjacent undisturbed grassland is trapped within the bare soil spaces. Pasture sagewort continues to play an important role in the forb component of the plant community. Other disturbance related forbs continue to provide infill and the species composition can vary over time depending on available moisture and site conditions in the area surrounding the disturbance.

B.2.9 Data Gaps and Further Research Required

Further research is required to assess revegetation strategies and recovery trends on large disturbed areas such as full strip well sites, or large diameter pipelines in the Mixedgrass.

Research is required to determine long term recovery trends on sites where invasive non-native species such as crested wheatgrass, awnless brome, Kentucky bluegrass and sweet clover are present in the area surrounding the disturbed soils.

Further research is required to determine the most appropriate revegetation strategy (natural recovery, assisted natural recovery or native seed mixes) for disturbances located in areas with unhealthy range health scores and which of the range health indicators are most likely to affect recovery.

B.3 Natural Recovery on Minimal Disturbance Well Sites in the Mixedgrass NSR- 2012 Monitoring

In an effort to collect additional data for Blowout and Sand/Sandy ecological range sites and for underrepresented ecodistricts like the Sweetgrass Uplands, a number of well sites on public lands were selected for monitoring. Older well sites where agronomic species like crested wheatgrass were planted were discarded. The resulting subset are all minimum disturbance well sites of various ages and most are natural recovery sites. Recent wellsites on distinct Blowout or Sand/Sandy ecological range sites were not identified in the field. Data falls into two groups based on the range plant community present on the undisturbed reference area associated with each monitoring site.

B.3.1 Mixedgrass Range Plant Community MGA9 (Sagebrush/Northern wheatgrass - June grass)

The Sagebrush/Northern wheatgrass - June grass (MGA9) range plant community is the reference plant community on Blowout to Loamy range sites in the Cypress Upland and Sweetgrass Upland ecodistricts. Two wellsites constructed using minimum disturbance best practices ten years ago were monitored in the Sweetgrass Upland. Key observations are:

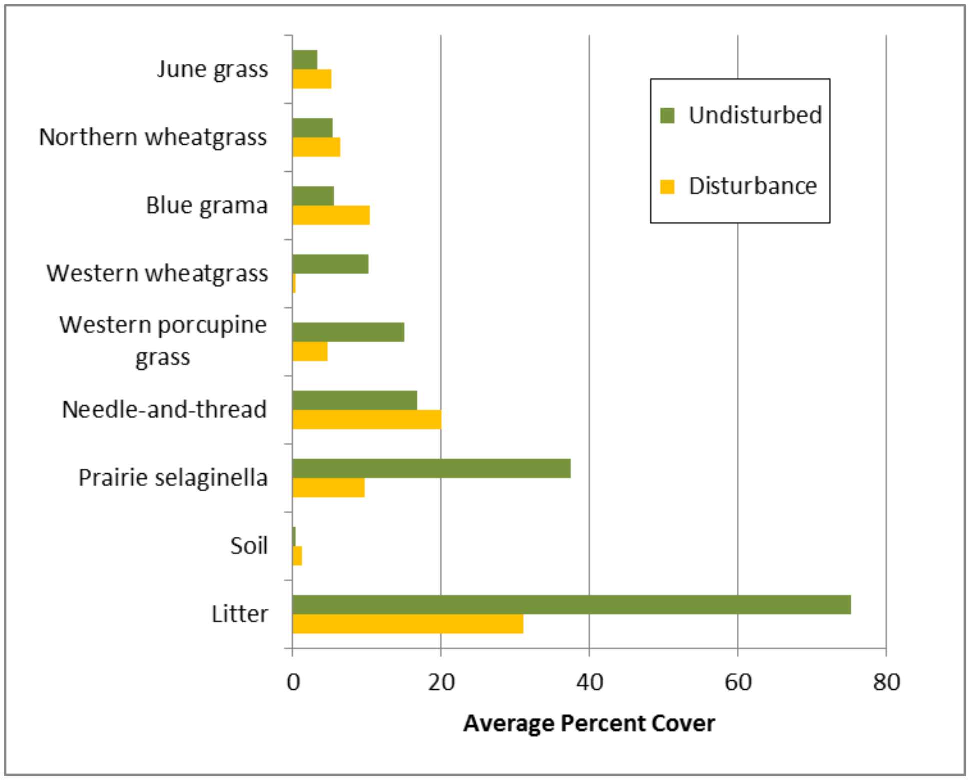
- Cover of tall grasses, forbs and groundcover is reduced but recovering;
- Total numbers of species are approaching off-site numbers;
- The number of native forb species is greater than 50% of number on undisturbed grassland;
- Litter values on undisturbed areas are double those found on the RoW;
- Introduced weeds are goat's beard and common dandelion; and
- Disturbances may be targeted by grazers.

A data summary of each site is presented in Table B6. Figure B10 compares the species composition and cover of dominant species on the disturbed naturally recovering sites and the undisturbed reference areas after ten years.

Table B6–Community and Range Health Score on Blowout Mixedgrass Natural Recovery Sites

Site #	Ecodistrict	Date of Disturb -ance	Range Health	Range Plant Community	# of species	# of Native Forbs	# of Exotic Forbs	# of Invasive Species
T5 Disturbed	Milk River Upland	2005	unhealthy (33)	Agrosmi-Boutgra-Stipcom	12	3	0	0
T5 Native	Milk River Upland		healthy w problems (65)	MGA9	13	5	0	0
T6 Disturbed	Sweetgrass Upland	2002	unhealthy (47)	Boutgra-Stipcom-Stipcur	20	8	1	0
T6 Native	Sweetgrass Upland		healthy (87)	MGA9	22	11	1	0
T7 Disturbed	Sweetgrass Upland	2002	healthy w problems (68)	Stipcom-Agrodas-Koelmac	15	6	1	0
T7 Native	Sweetgrass Upland		healthy w problems (73)	MGA9	22	10	1	0

Figure B10 - Comparison of Average Species Cover after 10 Years Natural Recovery on Two Wellsites (T6 and T7) on Blowout Ecological Range Sites in the Sweetgrass Uplands



B.3.2 Mixedgrass Range Plant Community MGA21 (Wheatgrass - Needle-and-Thread)

The Wheatgrass - Needle-and-Thread (MGA21) range plant community is the reference plant community for loamy range sites in the Majorville, Lethbridge and Vulcan Plains ecodistricts. Three sites that support this reference community and one site that supports the successional MGA22 (Needle-and-Thread - June Grass) were monitored. The construction dates of the natural recovery sites span a number of years so direct comparisons or averaging between data sets are not possible. A data summary of each site is presented in Table B7. Key observations are:

- Sites tend to have comparable numbers or a few more species on disturbance and more native forbs on disturbance than on undisturbed sites;
- Introduced species on disturbance include goat's beard, common dandelion, flixweed and lamb's quarters;
- Invasive species present despite healthy range condition on undisturbed areas include crested wheatgrass, and both crested wheatgrass and Canada thistle on disturbances; and
- Dominant natural recovery species are western wheatgrass, needle-and-thread and blue grama.

Table B7 – Community and Range Health Score on Loamy Mixedgrass Natural Recovery Sites

Site #	Ecodistrict	Date of Disturbance	Range Health	Range Plant Community	# of species	# of Native Forbs	# of Exotic Forbs	# of Invasive Species
T1 Disturbance	Majorville Upland	2007	unhealthy (13)	Artefri-Stipcom	11	4	0	0
T1 Native	Majorville Upland		healthy (84)	MGA22	8	3	0	0
T2 Disturbance	Lethbridge Plain	2004	unhealthy (9)	Agrosmi-Descsop	15	7	3	1
T2 Native	Lethbridge Plain		healthy (87)	MGA21	10	3	1	0
T3 Disturbance	Majorville Upland	2010	unhealthy (25)	Agrosmi	10	3	1	1
T3 Native	Majorville Upland		healthy w problems (68)	MGA21	9	2	0	0
T4 Disturbance	Majorville Upland	1992	healthy w problems (63)	Agrosmi-Boutgra-Stipcom	7	2	0	0
T4 Native	Majorville Upland		healthy (84)	MGA21	11	4	0	0

Appendix C Target Recovering Plant Communities

Introduction

Designing native seed mixes for industrial disturbances not suited to natural recovery or assisted natural recovery in the Mixedgrass Natural Subregion is as much an art as it is a science. The purpose of the native seed mix is to revegetate the disturbance with native grass species that will allow the process of succession to take place and to establish a mid- to late-seral plant community over time.

The Range Plant Community Guide for the Mixedgrass (Adams et al. 2013) provides a detailed discussion of plant community classification methods and the resulting plant community descriptions reported as one page summaries. Each plant community description provides the mean % cover for each species, the range of % cover in which the species occurs and the percent constancy of occurrence for each species within the data set. The current Range Plant Community Guide for the Mixedgrass contains 38 native grassland plant community descriptions, seven modified native plant communities and six native shrubland plant communities. Data collected from the ESRD Range Reference Area Monitoring Program was used to compile the Guide.

Given the diversity of ecological range sites and successional plant community types that can be encountered within a relatively small area on the prairie landscape, it is necessary to establish which ecological range sites have species in common based on the Agricultural Region of Alberta Soil Information Database (AGRASID) soil and landscape correlation and common ecodistrict characteristics. These "clusters" of ecological range sites with common dominant native grass species are referred to as target **recovering plant communities**. They are clearly not mature reference native plant communities but rather composed of the average mean % cover of the dominant native grass species that are drivers in the successional process. The mean % cover of the combined native forb species has been provided as an average value. Mean % cover for native shrub species, exposed soil, moss and lichen component and total vegetation is also provided to illustrate the components of the target recovering plant community at a mid- to late- successional stage. ESRD Range Resource Management Branch provided the data set used to prepare the Mixedgrass Range Plant Community Guide for the preparation of the target recovering plant communities.

The specifics of the target recovering plant communities for each cluster of ecological range sites are presented in this appendix, accompanied by recommendations for seed mix design. The recommended native species will provide the initial vegetative cover to stabilize the disturbed soils and facilitate the recovery of the plant community (including the native forb component) over time. Examples of native seed mixes, based on the target recovering plant community are given as % Pure Live Seed by Weight. The value for each recommended species has been computed through an iterative process that converts the % foliar cover anticipated in the recovering plant community, to the % by weight of pure live seed required for each species in the seed mix. For example, how much northern wheatgrass pure live seed is required in the seed mix to reach a target of 4 % foliar cover in the target recovering plant community?

It is important to note that this is only the first step in seed mix design. Further guidance for calculating seeding rates is provided in Appendix D with the inclusion of "*Seeding Rate Conversion Charts for Using Native species in Reclamation Projects"* (Hammermeister 1998). Examples of Reports of Seed Analysis accompanied by an explanation of how to interpret the reports have been provided by 20/20 Seed Labs Inc. (Appendix D). It is recommended that qualified professionals with experience in native prairie restoration be consulted for native seed mix design.

C.1 Target Recovering Plant Communities for the Cypress Upland Ecodistrict

Two distinct clusters of common native plant communities are encountered in the Cypress Upland Ecodistrict. Climate, soils and slope position appear to be key factors that define each target.

C.1.2 Cypress Upland: Loamy, Shallow to Gravel, Gravel and Thin Breaks Range Sites

The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Cypress Upland Ecodistrict in Table 11 (Adams et al. 2013). The plant communities included in this cluster include: MGA1, MGA2, MGA30, MGA31, MGA7 and MGA8.

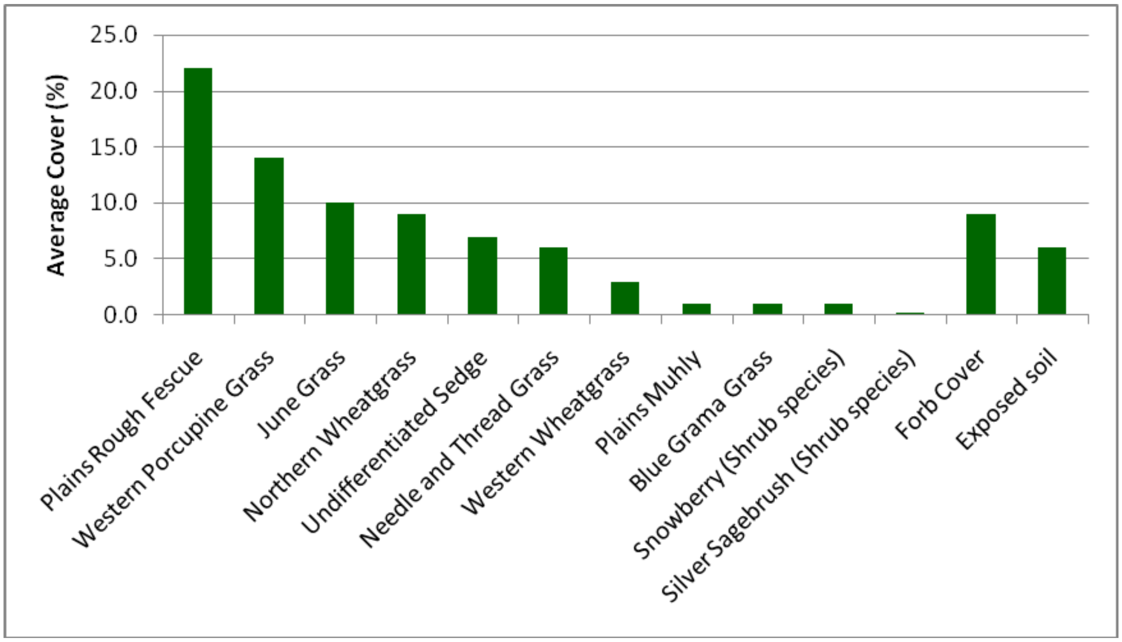
This cluster generally applies to the mid to upper slope positions in the Cypress Upland Ecodistrict. Native grasslands are largely intact under the stewardship of large ranching operations. In this area Plains rough fescue is a key indicator species common to loamy, shallow to gravel, gravel and thin breaks ecological range sites. The cluster includes mid- and late seral stage and reference plant communities found on loamy textured topsoils. Common dominant species include: plains rough fescue, western porcupine grass, June grass and northern wheatgrass. This cluster is illustrated in Table C1 and Figure C1. The values in table percentages have been rounded to the nearest whole number.

Table C1 - Target Recovering Plant Community for Cypress Upland: Loamy, Shallow to Gravel, Gravel and Thin Breaks Range Sites

Species	Common Name	Average % Cover	Absolute Minimum % cover	Absolute Maximum % cover	% Constancy
Festuca hallii	Plains Rough Fescue	22	0	85	71
Stipa curtiseta	Western Porcupine Grass	14	0	74	91
Koeleria macrantha	June Grass	10	0	31	98
Agropyron dasystachyum	Northern Wheatgrass	9	0	29	74
Carex species	Undifferentiated Sedge	7	0	29	97
Stipa comata	Needle-and-Thread Grass	6	0	37	53
Agropyron smithii	Western Wheatgrass	3	0	22	60
Muhlenbergia cuspidata	Plains Muhly	1	0	14	3
Bouteloua gracilis	Blue Grama Grass	1	0	17	43
Symphoricarpos occidentalis	Snowberry (Shrub species)	1	0	9	11
Artemisia cana	Silver Sagebrush (Shrub species)	0.3	0	7	4
Average total vegetation cover		**74**			
Average Forb Cover		**9**			
Average Moss and Lichen cover		**40**			
Average exposed soil		**6**			

Plains rough fescue plant communities are difficult to restore. A slow growing, deeply rooted perennial species, rough fescue is slow to establish. It does not compete well with other species. Observations indicate restoration potential is greater on drier sites such as shallow to gravel or gravel range sites than loamy range sites that are more prone to invasion by non-native plants such as Kentucky bluegrass and awnless brome. Rough fescue seed must be wild harvested and the supply is often limited. Seed set is erratic and often seed is not available.

Figure C1 - Target Recovering Plant Community for Cypress Upland: Loamy, Shallow to Gravel, Gravel and Thin Breaks Range Sites



This information can then be used to design a native seed mix based on the common dominant species in the cluster and the performance of each species in the recovery process. Table C2 provides an example of the common dominant species recommended for inclusion in a native seed mix expressed as the portion required for each species in % Pure Live Seed by weight. An example for this cluster could include:

Table C2 - Recommended Native Species for Cypress Upland on Loamy, Shallow to Gravel, Gravel and Thin Breaks Range Sites

Species	Proportion of Seed Mix % PLS by Weight	
Plains rough fescue	*Festuca hallii*	50%
Western porcupine grass	*Stipa curtiseta*	20%
Awned wheatgrass	*Agropyron trachycaulum var. unilateral*	05%
Northern wheatgrass	*Agropyron dasystachyum*	10%
June Grass	*Koeleria macrantha*	15%

Awned wheatgrass has been added to provide initial cover and is expected to disappear from the stand in approximately 5 years, providing additional space for infill of the seeded species and encroachment from off site. Northern wheatgrass has been selected to stabilize the soils and provide structure in the stand. The proportion of plains rough fescue has been increased based on results of the long term monitoring projects conducted for this project and the proportion of the western porcupine grass has been increased to compensate for the variability in viable wild harvested seed. June grass has been increased to increase germination and emergence survival and to provide initial structure in the stand.

C.1.3 Cypress Upland: Low Elevation Dry Loamy and Blowout Range Sites

The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Cypress Upland Ecodistrict in Table 11 (Adams et al 2013). The plant communities included in this cluster include: MGA4, MGA5, MGA9, and MGC1.

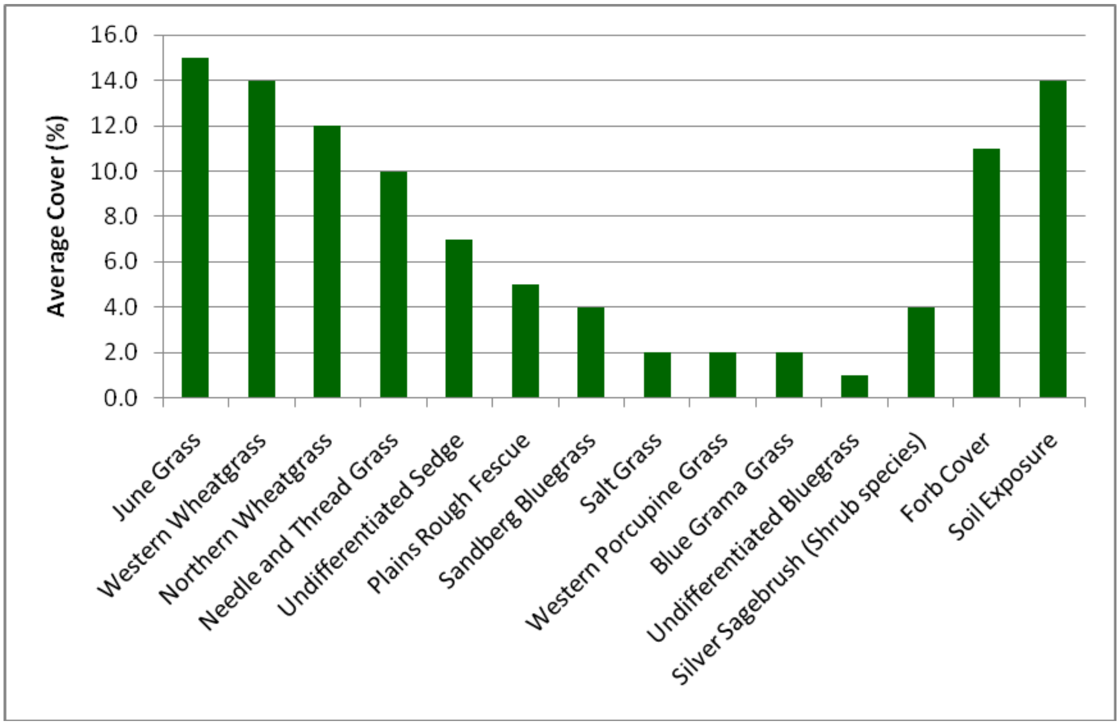
This cluster represents mid- to late seral plant communities found at lower elevations in the Cypress Upland on lower slope, terrace and level landform elements. The lower slopes tend to be more fragmented by cultivation. Drought tolerant species such as June grass, northern and western wheatgrass and needle-and–thread grass are dominant. Plains rough fescue may be present at relatively low cover values. Soil exposure cover values reflect the characteristics of dry loamy to blowout range sites and soils of the Solonetzic Order.

Table C3 - Target Recovering Plant Community for Cypress Upland: Low Elevation Dry Loamy and Blowout Range Sites

Species	**Common Name**	**Average % Cover**	**Absolute Minimum % cover**	**Absolute Maximum % cover**	**% Constancy**
Koeleria macrantha	June Grass	15	8	27	100
Agropyron smithii	Western Wheatgrass	14	5	26	100
Agropyron dasystachyum	Northern Wheatgrass	12	0	37	73
Stipa comata	Needle-and-Thread Grass	10	0	17	45
Carex species	Undifferentiated Sedge	7	0	13	82
Festuca hallii	Plains Rough Fescue	5	0	0	9
Poa sandbergii	Sandberg Bluegrass	4	0	14	73
Distichlis stricta	Salt Grass	2	0	0	9
Stipa curtiseta	Western Porcupine Grass	2	0	12	18
Bouteloua gracilis	Blue Grama Grass	2	0	7	73
Poa species	Undifferentiated Bluegrass	1	0	11	9
Artemisia cana	Silver Sagebrush	4	1	15	73
Average total vegetation cover		**61**			
Average Forb Cover		**12**			
Average Moss and Lichen cover		**55**			
Average exposed soil		**14**			

Plains rough fescue plant communities are difficult to restore. A slow growing, deeply rooted perennial species, rough fescue is slow to establish. It does not compete well with invasive non-native plants. Rough fescue seed must be wild harvested and the supply is often limited. Seed set is erratic and often seed is not available. Moisture may be the limiting factor for restoration of rough fescue plant communities on the lower slopes of the Cypress Upland. The area is prone to periods of drought.

Figure C2 - Target Recovering Plant Community for Cypress Upland: Low Elevation Dry Loamy and Blowout Range Sites



This information can then be used to design a native seed mix based on the common dominant species in the cluster and the performance of each species in the recovery process. Table C4 provides an example of the common dominant species recommended for inclusion in a native seed mix expressed as the portion required for each species in % Pure Live Seed by weight. An example for this cluster could include:

Table C4 – Recommended Native Species for Cypress Upland: Low Elevation Dry Loamy and Blowout Range Sites

Species	Proportion of Seed Mix % PLS by Weight	
June Grass	*Koeleria macrantha*	15%
Western wheatgrass	*Agropyron smithii*	10%
Northern wheatgrass	*Agropyron dasystachyum*	15%
Needle-and-thread grass	*Stipa comata*	25%
Plains rough fescue	*Festuca hallii*	25%
Sandberg bluegrass	*Poa sandbergii*	10%

Western and northern wheatgrass are early colonizers of disturbances and drivers in the successional process on blowout range sites in the Cypress Upland. Seed for these two species is available as native plant cultivars. The recommended % PLS by weight for both western and northern wheatgrass is based on the competitive nature of the native plant cultivars and the relative weight of the seed (number of seeds per gram). Needle-and-thread grass and plains rough fescue are recommended at higher rates to compensate for wild harvested seed. June grass is an important structural component and Sandberg bluegrass is added for its drought tolerance.

C.1.3 Cypress Upland: Saline Lowlands Ecological Range Sites

The Range Plant Community Guide for the Mixedgrass lists MGA6 Salt grass – Sedge – Western Wheatgrass as the late seral to reference plant community for saline lowland range sites in the Cypress Upland Ecodistrict (Adams et al. 2013).

Table C5 - Target Recovering Plant Community for Cypress Upland: Saline Lowland Range Sites

Species	Common Name	Mean	Minimum % cover	Maximum % cover	Constancy
Grasses and sedges					
Carex species	Undifferentiated sedge	25	15	34	100
Distichlis stricta	Salt grass	17	0	14	50
Agropyron smithii	Western wheat grass	7	0	14	50
Poa species	Undifferentiated bluegrass	6	2	10	100
Festuca hallii	Plains rough fescue	6	0	11	50
Puccinellia nuttalliana	Nuttall's Salt-Meadow grass	5	0	10	50
Koeleria macrantha	June grass	3	0	6	50
Muhlenbergia species	Undifferentiated Muhly	3	0	6	50
Spartina gracilis	Alkali cord grass	3	0	5	50
Forbs					
Grindelia squarrosa	Gumweed	1	0	2	50
Gutierrezia sarothrae	Broomweed	2	0	3	50
Antennaria species	Undifferentiated everlastings	1	0	2	50
Average Total Vegetation Cover		**57**	**50**	**64**	
Average Moss and Lichen cover		**26**	**4**	**47**	
Average exposed soil		**19**	**5**	**34**	

This range site and plant community is strongly influenced by discharge of groundwater and accumulation of salts, hence the dominance of salt grass and western wheatgrass. The site may show a cyclic response to variation in total annual precipitation. Vegetation canopy cover will decline and bare soil increase during dry cycles, with a very strong cover of salt grass and western wheatgrass during wet cycles. This community has a significant component of natural bare soil at about 19% (Adams et al. 2013). This range site is also at risk of invasion by non-native plants such as downy brome.

This information can then be used to design a native seed mix based on the common dominant species in the cluster and the performance of each species in the recovery process. Salt grass and western wheatgrass are drivers in the process of succession and adapted to the cyclic moisture conditions.

Table C6 provides an example of the common dominant species recommended for inclusion in a native seed mix expressed as the portion required for each species in % Pure Live Seed by weight. An example for this range site could include:

Table C6 - Recommended Native Species for Cypress Upland: Saline Lowland Range Sites

Species	**Proportion of Seed Mix % PLS by Weight**	
Western wheatgrass	*Agropyron smithii*	30%
Salt Grass	*Distichlis stricta*	25%
Nuttall's Salt-meadow grass	*Puccinellia nuttalliana*	15%
June grass	*Koeleria macrantha*	10%
Sandberg bluegrass	*Poa sandbergii*	20%

Sandberg bluegrass is included as it is drought tolerant and to provide initial cover. Nuttalls salt-meadow grass and June grass will provide diversity by establishing in niche areas within the site.

C.2 Target Recovering Plant Communities for the Sweetgrass and Milk River Upland Ecodistricts

Three distinct clusters of common native plant communities are encountered in the Sweetgrass and Milk River Upland Ecodistricts. Soil texture and slope position appear to be key factors that define each cluster.

C.2.1 Sweetgrass and Milk River Upland Ecodistrict: Overflow Range Sites

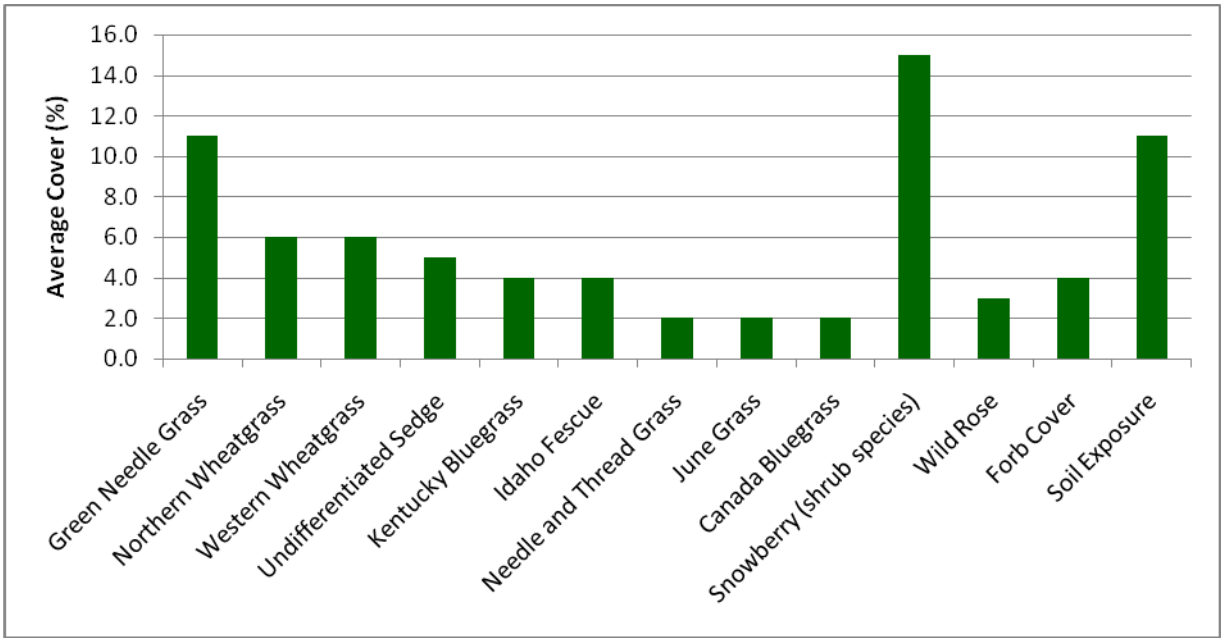
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11 (Adams et al. 2013). The plant communities included in this cluster include: MGB2, MGC7, and MGC2.

Table C7 - Recommended Target Recovering Plant Community for Sweetgrass and Milk River Upland: Overflow Range Sites

Species	Common Name	Average % Cover	Absolute Minimum % cover	Absolute Maximum % cover	% Constancy
Stipa viridula	Green Needle Grass	11	2	22	100
Agropyron dasystachyum	Northern Wheatgrass	6	1	12	100
Agropyron smithii	Western Wheatgrass	6	0	15	64
Carex species	Undifferentiated Sedge	5	0	11	82
Poa pratensis	Kentucky Bluegrass	4.0	4	16	45
Festuca idahoensis	Idaho Fescue	4	0	14	27
Stipa comata	Needle-and-Thread Grass	2	0	8	91
Koeleria macrantha	June Grass	2	0	3	73
Poa compressa	Canada Bluegrass	2	0	7	36
Symphoricarpos occidentalis	Snowberry (shrub species)	15	10	31	100
Rosa woodsii	Wild Rose (Shrub species)	3	1	16	100
Average total vegetation cover		**88**			
Average Forb cover		**4**			
Average Moss and Lichen cover		**2**			
Average exposed soil		**11**			

This cluster represents native plant communities found in areas subject to water spreading and sheet flow. Overflow sites are found in aprons, fans and draws where overland flow enhances site moisture conditions. Green needle grass, northern and western wheat grasses are well adapted to these overflow range sites. Idaho fescue and needle-and-thread grass are also adapted to the fluctuations in moisture from dry to moist and back to dry. The soils and moisture conditions of these range sites increase the risk of invasion by non-native plants when the soils are disturbed.

Figure C3 - Recommended Target Recovering Plant Community for Sweetgrass and Milk River Upland: Overflow Range Sites



Ecologically based invasive plant management will be very important when restoring disturbances in this cluster. Kentucky bluegrass, an invasive non-native plant is present in this cluster at an average mean cover of 4%. However, the plant community description for MGB2 (range 34-42%) illustrates the potential for this species to become dominant resulting in classification as modified plant community.

This information can then be used to design a native seed mix based on the common dominant species in the cluster and the performance of each species in the recovery process. Table C8 provides an example of the common dominant species recommended for inclusion in a native seed mix expressed as the portion required for each species in % Pure Live Seed by weight. An example for this cluster could include:

Table C8 - Recommended Species for Sweetgrass and Milk River Upland: Overflow Range Sites

Species	Proportion of Seed Mix	% PLS by Weight
Green needle grass	*Stipa viridula*	10%
Northern wheatgrass	*Agropyron dasystachyum*	20%
Western wheatgrass	*Agropyron smithii*	10%
Idaho fescue	*Festuca idahoensis*	10%
Needle-and-thread grass	*Stipa comata*	30%
June grass	*Koeleria macrantha*	20%

Green needle grass, northern and western wheatgrass are available as native plant cultivars. The cultivars are aggressive and well adapted to overflow site conditions. They have been included to provide competition to site invasion by Kentucky bluegrass. However it is advisable to keep the percentages relatively low to avoid suppression of the other components of the seed mix. Idaho fescue and needle-and-thread grass are included as they are drought tolerant and well adapted to fluctuations in moisture conditions. June grass is common to these plant communities and adds structure to the stand.

C.2.2 Sweetgrass and Milk River Upland Ecodistricts: Loamy, and Thin Breaks Ecological Range Sites

The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11 (Adams et al. 2013). The plant communities included in this cluster include: MGA10, MGA11, MGA12, MGA13, MGB3, MGA20, MGC3, and MGA32

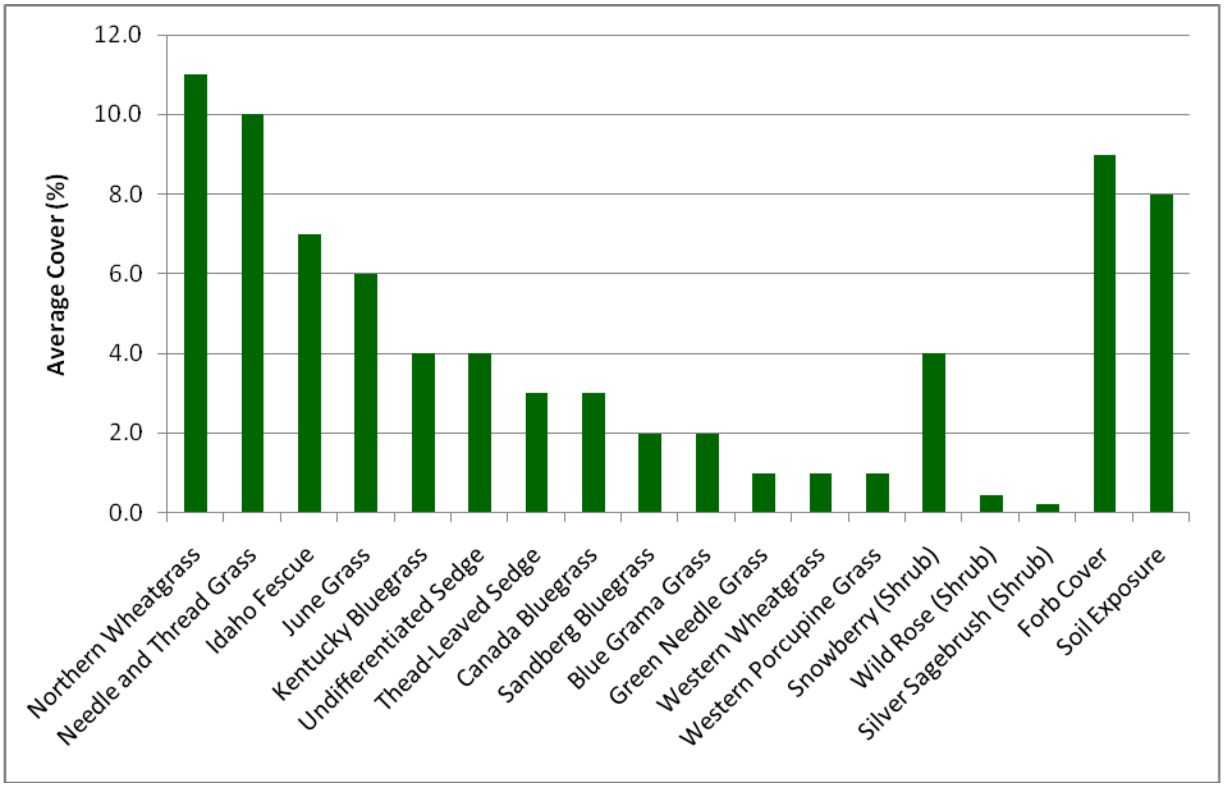
Table C9 - Target Recovering Plant Community for Sweetgrass and Milk River Upland: Loamy and Thin Breaks Range Sites

Species	Common Name	Average Cover	Absolute Minimum % cover	Absolute Maximum % cover	% Constancy
Agropyron dasystachyum	Northern Wheatgrass	11	0	64	99
Stipa comate	Needle-and-Thread Grass	10	0	71	82
Festuca idahoensis	Idaho Fescue	7	0	57	75
Koeleria macrantha	June Grass	6	0	27	97
Poa pratensis	Kentucky Bluegrass	4	0	45	46
Carex species	Undifferentiated Sedge	4	0	17	96
Carex filifolia	Thead-leaved Sedge	3	0	13	21
Poa compressa	Canada Bluegrass	3	0	5	1
Poa sandbergii	Sandberg Bluegrass	2	0	37	22
Bouteloua gracilis	Blue Grama Grass	2	0	20	21
Stipa viridula	Green Needle Grass	1	0	22	44
Agropyron smithii	Western Wheatgrass	1	0	19	2
Stipa curtiseta	Western Porcupine Grass	1	0	23	37
Symphoricarpos occidentalis	Snowberry (Shrub)	4	0	25	58
Rosa woodsii	Wild Rose (Shrub)	0.4	0	9	7
Artemisia cana	Silver Sagebrush (Shrub)	0.2	0	5	6
Average total vegetation cover		**83**			
Average Forb cover		**9**			
Average Moss and Lichen cover		**13**			
Average exposed soil		**8**			

Dominant grass species in this cluster that drive the successional process include: northern wheatgrass, needle-and-thread grass, Idaho fescue and June grass.

Ecologically based invasive plant management will be very important when restoring disturbances in this cluster. Kentucky bluegrass, an invasive non-native plant is present in this cluster at an average mean cover of 4%. However, the plant community description for MGB2 (range 34-42%) illustrates the potential for this species to become dominant resulting in classification as modified plant community.

Figure C4 - Target Recovering Plant Community for Sweetgrass and Milk River Upland: Loamy and Thin Breaks Range Sites



This information can then be used to design a native seed mix based on the common dominant species in the cluster and the performance of each species in the recovery process. Table C10 provides an example of the common dominant species recommended for inclusion in a native seed mix expressed as the portion required for each species in % Pure Live Seed by weight. An example for this cluster could include:

Table C10 – Recommended Species for Sweetgrass and Milk River Upland: Loamy and Thin Breaks Range Sites

Species	Proportion of Seed Mix % PLS by Weight	
Northern wheatgrass	*Agropyron dasystachyum*	20%
Needle-and-thread grass	*Stipa comata*	25%
Idaho fescue	*Festuca idahoensis*	10%
June grass	*Koeleria macrantha*	15%
Sandberg bluegrass	*Poa sandbergii*	20%
Slender wheatgrass	*Agropyron trachycaulum*	10%

Northern and slender wheatgrass are available as native plant cultivars. The slender wheatgrass has been included to act as a nurse crop to provide initial vegetative cover on steep slopes and to provide competition to invasive non-native Kentucky bluegrass. However it is advisable to keep the percentages relatively low to avoid suppression of the other components of the seed mix. Idaho fescue and needle-and-thread grass are included as they are drought tolerant and well adapted to fluctuations in moisture conditions. June grass is common to these plant communities and adds structure to the stand.

C.2.3 Sweetgrass and Milk River Upland Ecodistricts: Clayey and Blowout Ecological Range Sites

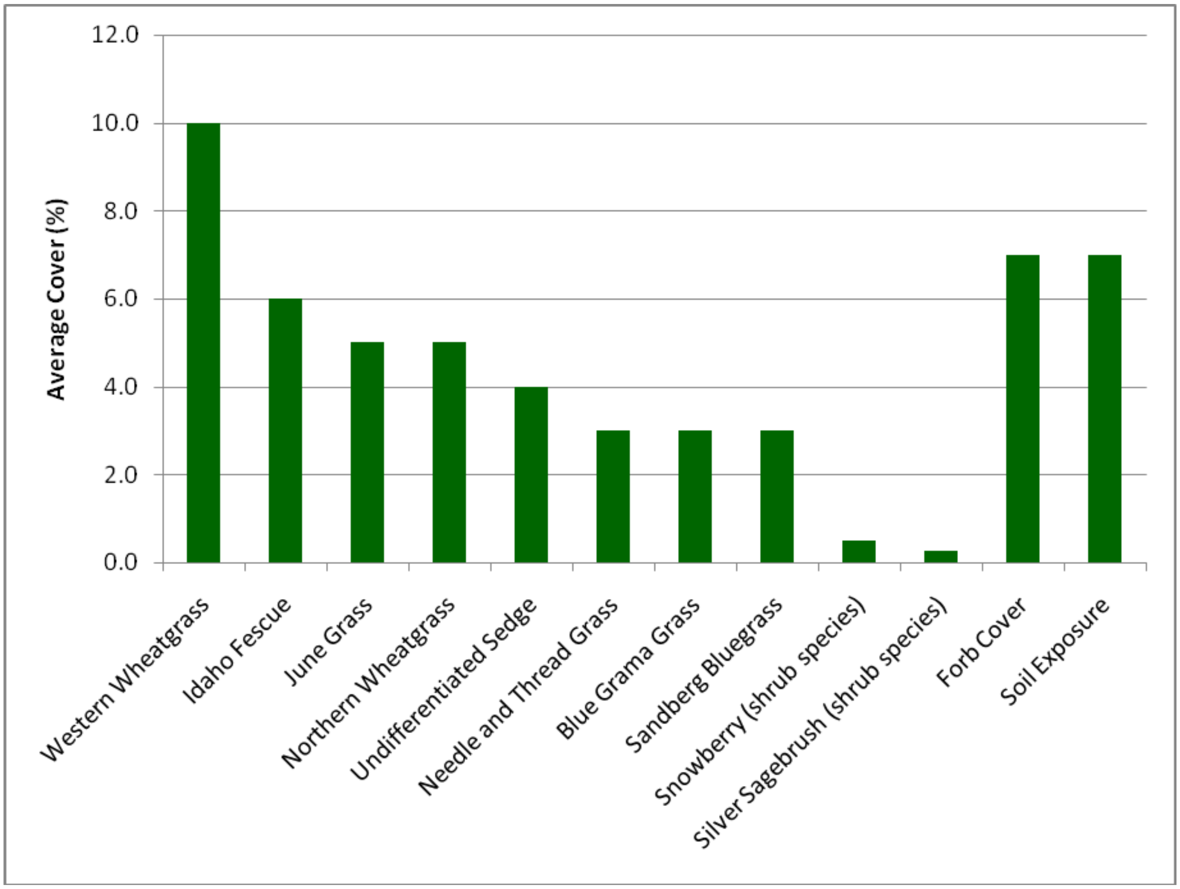
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11 (Adams et al. 2013). The plant communities included in this cluster include: MGA33, MGA34, and MGA35.

Table C11 - Target Recovering Plant Community for Sweetgrass and Milk River Upland: Clayey and Blowout Range Sites

Species	Common Name	Average % Cover	Absolute Minimum % cover	Absolute Maximum % cover	% Constancy
Agropyron smithii	Western Wheatgrass	10.0	0	45	59
Festuca idahoensis	Idaho Fescue	6.0	0	24	59
Koeleria macrantha	June Grass	5.0	0	26	97
Agropyron dasystachyum	Northern Wheatgrass	5.0	0	17	68
Carex species	Undifferentiated Sedge	4.0	0	12	100
Stipa comata	Needle-and-Thread Grass	3.0	0	21	85
Bouteloua gracilis	Blue Grama Grass	3.0	0	30	68
Poa sandbergii	Sandberg Bluegrass	3.0	0	15	32
Symphoricarpos occidentalis	Snowberry (shrub species)	0.5	0	10	18
Artemisia cana	Silver Sagebrush (shrub species)	0.3	0	4	6
Average total vegetation cover		**90.0**			
Average Forb Cover		**7.0**			
Average Moss and Lichen cover		**12.0**			
Average exposed soil		**7.0**			

Northern wheatgrass, western wheatgrass, Idaho fescue and June grass play an important role in the process of succession in this cluster. These species are adapted to the clay based soils of clayey and blowout range sites. Idaho fescue is dominant in the reference plant community MGA33 Idaho Fescue – Northern Wheat Grass. However, northern wheat grass, June grass and western wheatgrass are drivers in the late to mid- seral successional stages. The rhizomatous wheat grasses fracture the clay soils, improving water infiltration. Drought tolerant Sandberg bluegrass is also an important component of the mid-seral successional stage.

Figure C5 - Target Recovering Plant Community for Sweetgrass and Milk River Upland: Clayey and Blowout Range Sites



This information can then be used to design a native seed mix based on the common dominant species in the cluster and the performance of each species in the recovery process. Table C12 provides an example of the common dominant species recommended for inclusion in a native seed mix expressed as the portion required for each species in % Pure Live Seed by weight. An example for this cluster could include:

Table C12 - Recommended Species for Sweetgrass and Milk River Upland: Clayey and Blowout Range Sites

Species	Proportion of Seed Mix % PLS by Weight	
Western wheatgrass	*Agropyron smithii*	10%
Northern wheatgrass	*Agropyron dasystachyum*	10%
Sandberg bluegrass	*Poa sandbergii*	05%
June grass	*Koeleria macrantha*	20%
Idaho fescue	*Festuca idahoensis*	15%
Needle-and-thread grass	*Stipa comata*	25%
Blue grama grass	*Bouteloua gracilis*	15%

C.2.4 Sweetgrass and Milk River Upland Ecodistricts: Sandy Ecological Range Sites

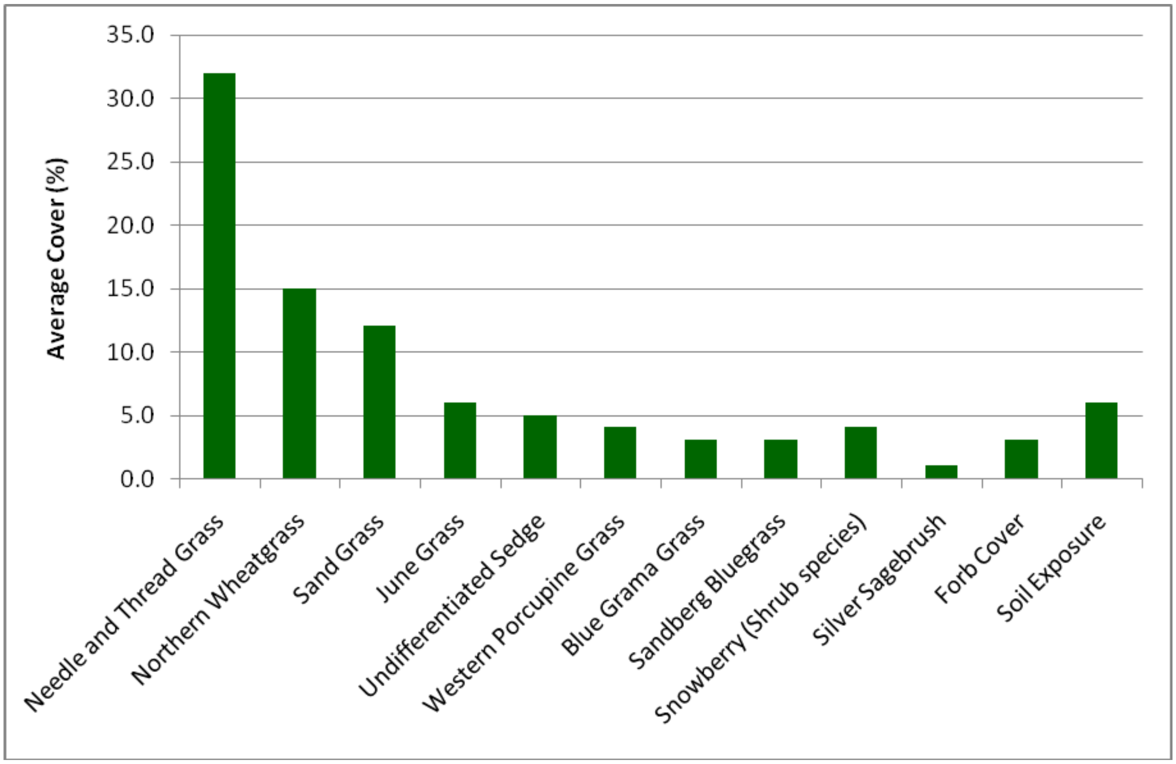
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11 (Adams et al. 2013). The plant communities included in this cluster include: MGA16 and MGB4.

Table C13 - Target Recovering Plant Community for Sweetgrass and Milk River Upland: Sandy Ecological Range Sites

Species	Common Name	Average % Cover	Absolute Minimum % cover	Absolute Maximum % cover	% Constancy
Stipa comata	Needle-and-Thread Grass	32.0	5	58	100
Agropyron Dasystachyum	Northern Wheatgrass	15.0	1	41	100
Calamovilfa longifolia	Sand Grass	12.0	2	42	100
Koeleria macrantha	June Grass	6.0	1	18	100
Carex species	Undifferentiated Sedge	5.0	1	23	100
Stipa curtiseta	Western Porcupine Grass	4.0	0	25	57
Bouteloua gracilis	Blue Grama Grass	3.0	0	10	84
Poa sandbergii	Sandberg Bluegrass	3.0	0	12	78
Symphoricarpos occidentalis	Snowberry (Shrub species)	4.0	0	19	57
Artemisia cana	Silver Sagebrush	1.0	0	5	24
Average total vegetation cover		**74.0**			
Average Forb cover		**3.0**			
Average Moss and Lichen cover		**24.0**			
Average Exposed soil		**6.0**			

Dominant species in this cluster are needle-and-thread grass, northern wheatgrass and sand grass. MGB4 is a modified plant community which is dominated by awnless brome (*Bromusinermis*). If awnless brome is present in the pre-disturbance site assessment then ecologically based invasive plant management will be required.

Figure C6 - Target Recovering Plant Community for Sweetgrass and Milk River Upland: Sandy Ecological Range Sites



This information can then be used to design a native seed mix based on the common dominant species in the cluster and the performance of each species in the recovery process. Table C14 provides an example of the common dominant species recommended for inclusion in a native seed mix expressed as the portion required for each species in % Pure Live Seed by weight. An example for this cluster could include:

Table C14 - Recommended Species for Sweetgrass and Milk River Upland: Sandy Range Sites

Species	Proportion of Seed Mix % PLS by Weight	
Northern wheatgrass	*Agropyron dasystachyum*	10%
Needle-and-thread grass	*Stipa comata*	50%
Sand grass	*Calamovilfa longifolia*	05%
June grass	*Koeleria macrantha*	15%
Sandberg bluegrass	*Poa sandbergii*	10%
Slender wheatgrass	*Agropyron trachycaulum*	10%

C.2.5 Sweetgrass and Milk River Upland Ecodistricts: Saline Lowlands Ecological Range Sites

The Range Plant Community Guide for the Mixedgrass lists MGA19 Salt grass – Western Wheatgrass - Sedge as the late seral to reference plant community for saline lowland range sites in the Milk River Upland Ecodistrict (Adams et al. 2013).

Table C15 - Target Recovering Plant Community for Sweetgrass and Milk River Upland: Saline Lowland Range Sites

Species	Common Name	Mean	Minimum % cover	Maximum % cover	Constancy
Grasses and sedges					
Distichlis stricta	Salt grass	29	12	60	100
Agropyron smithii	Western wheat grass	14	5	23	100
Carex species	Undifferentiated sedge	7	0	21	100
Stipa comata	Needle and thread grass	6	0	19	100
Agropyron dasystachyum	Northern wheat grass	6	0	17	50
Poa pratensis	Kentucky bluegrass	5	0	31	17
Stipa viridula	Green needle grass	4	0	9	50
Deschampsia cespitosa	Tufted hair grass	4	0	17	50
Koeleria macrantha	June grass	3	0	9	100
Forbs					
Artemisia species	Undifferentiated Artemisia	2	0	11	17
Haplopappus lanceolatus	Lance-leaved ironplant	1	0	2	50
Shrubs					
Symphoricarpos occidentalis	Snowberry	3	0	8	50
Total vegetation		**76**	**50**	**96**	
Moss and Lichen cover		**9**	**0**	**47**	
Soil exposure		**15**	**2**	**34**	

This range site and plant community is strongly influenced by discharge of groundwater and accumulation of salts, hence the dominance of salt grass and western wheatgrass. The site may show a cyclic response to variation in total annual precipitation. Vegetation canopy cover will decline and bare soil increase during dry cycles, with a very strong cover of salt grass and western wheatgrass during wet cycles. This community has a significant component of natural bare soil at about 15% (Adams et al. 2013). If Kentucky bluegrass (invasive non-native plant) is identified in the pre-disturbance site assessment, ecologically based invasive plant management will be required.

This information can then be used to design a native seed mix based on the common dominant species in the cluster and the performance of each species in the recovery process. Salt grass and western wheatgrass are drivers in the process of succession and adapted to the cyclic moisture conditions.

Table C16 provides an example of the common dominant species recommended for inclusion in a native seed mix expressed as the portion required for each species in % Pure Live Seed by weight. An example for this range site could include:

Table C16 - Recommended Species for Sweetgrass and Milk River Upland: Saline Lowland Range Sites

Species	Proportion of Seed Mix % PLS by Weight	
Western wheatgrass	*Agropyron smithii*	20%
Salt Grass	*Distichlis stricta*	25%
Northern wheatgrass	*Agropyron dasystachyum*	15%
June grass	*Koeleria macrantha*	15%
Tufted hair grass	*Deschampsia cespitosa*	25%

Western wheat grass and salt grass are included as they are drought tolerant and can tolerate salt laden soils and fluctuations in soil moisture. Northern wheatgrass will provide initial cover and structure. Tufted hair grass and June grass will provide diversity by establishing in niche areas within the site.

C.3 Target Recovering Plant Communities for the Lethbridge and Vulcan Plains Ecodistricts

Two distinct clusters of native plant communities are encountered in the Lethbridge and Vulcan Plains Ecodistricts. Soil texture is the dominant factor determining the plant community. The remaining native grasslands of the Lethbridge and Vulcan Plains Ecodistricts are fragmented by cultivation. Invasion of disturbed soils by non-native invasive plants is a key limiting factor to restoration potential in these ecodistricts.

C.3.1 Lethbridge, Vulcan, Plain Ecodistricts: Loamy Ecological Range Sites

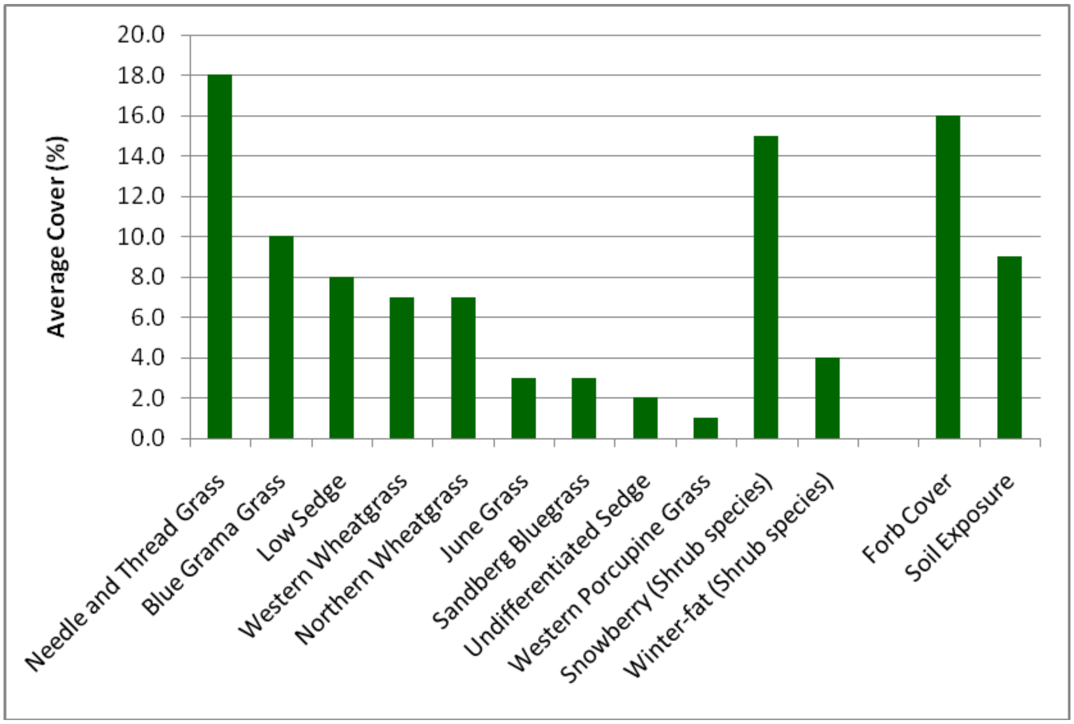
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11 (Adams et al. 2013). The plant communities included in this cluster include: MGA21, MGA22, MGC4, MGC5, MGC6.

Table C17 - Target Recovering Plant Community for Lethbridge, Vulcan Plain: Loamy Range Sites

Species	Common Name	Average % Cover	Absolute Minimum % Cover	Absolute Maximum % Cover	% Constancy
Stipa comata	Needle-and-Thread Grass	18.0	0	96	96
Bouteloua gracilis	Blue Grama Grass	10.0	0	66	64
Carex stenophylla	Low Sedge	8.0	0	45	77
Agropyron smithii	Western Wheatgrass	7.0	0	64	22
Agropyron dasystachyum	Northern Wheatgrass	7.0	0	38	83
Koeleria macrantha	June Grass	3.0	0	34	42
Poa sandbergii	Sandberg Bluegrass	3.0	0	44	25
Carex species	Undifferentiated Sedge	2.0	0	13	21
Stipa curtiseta	Western Porcupine Grass	1.0	0	19	3
Symphoricarpos occidentalis	Snowberry (Shrub species)	15.0	0	63	69
Eurotialanata	Winter-fat (Shrub species)	4.0	0	34	14
Average total vegetation cover		**61.0**			
Average Forb cover		**16.0**			
Average Moss and Lichen cover		**11.0**			
Average Soil Exposure		**9.0**			

Needle-and-thread grass, blue grama grass, northern and western wheatgrass are important drivers in the successional process in this cluster. Snowberry is an important shrub species providing significant cover in open shrublands along the Little Bow drainage. Kentucky bluegrass and Canada bluegrass are both invasive non-native plants found in MGC5. The moist loamy soils of this cluster are particularly sensitive to invasion by non-native plants.

Figure C7 - Target Recovering Plant Community for Lethbridge, Vulcan Plain: Loamy Range Sites



This information can then be used to design a native seed mix based on the common dominant species in the cluster and the performance of each species in the recovery process. Table C18 provides an example of the common dominant species recommended for inclusion in a native seed mix expressed as the portion required for each species in % Pure Live Seed by weight. An example for this cluster could include:

Table C18 - Recommended Species for Lethbridge, Vulcan Plain: Loamy Range Sites

Species	Proportion of Seed Mix % PLS by Weight	
Slender wheat grass	*Agropyron trachycaulum*	10%
Northern wheat grass	*Agropyron dasystachyum*	05%
Western wheatgrass	*Agropyron smithii*	05%
Needle-and-thread grass	*Stipa comata*	40%
Blue grama grass	*Bouteloua gracilis*	25%
June grass	*Koeleria macrantha*	15%

Ecologically based invasive plant management will be required if invasive plants are detected in the pre-disturbance site assessment. The moist loamy soils provide the nutrient and moisture requirements suited to non-native plant invasion of disturbed soils. Slender, northern and western wheat grasses are available as native plant cultivars. They can be quite competitive and should be seeded at low application rates. Slender wheat grass is included to provide initial cover and competition to invasive plants and is expected to disappear from the stand in approximately 5 years. Northern and western wheat grasses are important components but are seeded at low rates to allow space for the development of the needle-and-thread grass and the shrub and forb components.

C.3.2 Lethbridge, Vulcan, Plain Ecodistricts: Sandy and Sands Ecological Range Sites

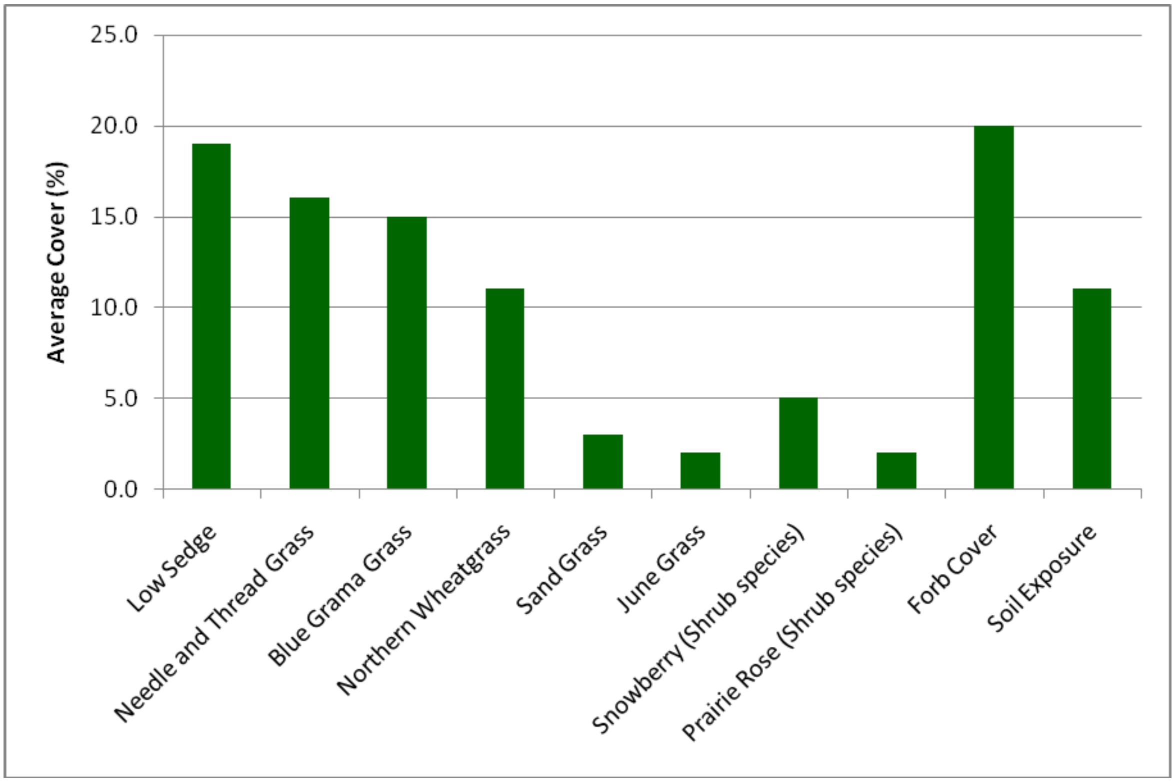
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11 (Adams et al. 2013). The plant communities included in this cluster include: MGA25, MGA24, MGA26, MGA27, MGA28.

Table C19 - Target Recovering Plant Community for Lethbridge, Vulcan Plain: Sandy and Sands Range Sites

Species	Common Name	Average % Cover	Absolute Minimum % Cover	Absolute Maximum % Cover	% Constancy
Carex stenophylla	Low Sedge	19.0	2	52	100
Stipa comata	Needle-and-Thread Grass	16.0	1	69	100
Bouteloua gracilis	Blue Grama Grass	15.0	0	55	90
Agropyron dasystachyum	Northern Wheatgrass	11.0	0	42	98
Calamovilfa longifolia	Sand Grass	3.0	0	21	4
Koeleria macrantha	June Grass	2.0	0	21	65
Symphoricarpos occidentalis	Snowberry (Shrub species)	5.0	0	18	56
Rosa arkansana	Prairie Rose (Shrub species)	2.0	0	12	34
Average total vegetation cover		**62.0**			
Average Forb Cover		**20.0**			
Average Moss and Lichen Cover		**3.0**			
Average Soil Exposure		**11.0**			

Low sedge is a significant species in the process of succession in this cluster. Needle-and-thread grass, blue grama and northern wheatgrass are also prominent. The shrub component is also important with snowberry occurring at an average of 56% constancy. The forb component is also significant at an average of 20%.

Figure C8 - Target Recovering Plant Community for Lethbridge, Vulcan Plain: Sandy and Sands Range Sites



This information can then be used to design a native seed mix based on the common dominant species in the cluster and the performance of each species in the recovery process. Table C20 provides an example of the common dominant species recommended for inclusion in a native seed mix expressed as the portion required for each species in % Pure Live Seed by weight. An example for this cluster could include:

Table C20 - Recommended Species for Lethbridge, Vulcan Plain: Sandy and Sands Range Sites

Species	Proportion of Seed Mix	% PLS by Weight
Needle-and-thread grass	*Stipa comata*	35%
Blue grama grass	*Bouteloua gracilis*	30%
Northern wheatgrass	*Agropyron dasystachyum*	10%
Sandgrass	*Calamovilfa longifolia*	05%
June grass	*Koeleria macrantha*	15%
Slender wheatgrass	*Agropyron trachycaulum*	10%

Slender, northern and western wheat grasses are available as native plant cultivars. They can be quite competitive and should be seeded at low application rates. Slender wheat grass is included to provide initial cover and competition to invasive plants and is expected to disappear from the stand in approximately 5 years. Sandgrass is also available as a cultivar and should be seeded sparingly as it can be very competitive, forming thick mats from long, scaly rhizomes. If non-native invasive plants are detected in the pre-disturbance site assessment, ecologically based invasive plant management will be required.

C.3.3 Lethbridge, Vulcan, Plain Ecodistricts: Saline Lowlands Ecological Range Sites

The Range Plant Community Guide for the Mixedgrass lists MGA29 Salt grass – Foxtail Barley - Western Wheatgrass as the late seral to reference plant community for saline lowland range sites in the Lethbridge, Vulcan Plain Ecodistricts (Adams et al. 2013).

Table C21 - Target Recovering Plant Community for Lethbridge, Vulcan Plain: Saline Lowland Range Sites

Species	Common Name	Mean	Minimum % cover	Maximum % cover	Constancy
Grasses and sedges					
Distichlis stricta	Salt grass	34	10	72	100
Hordeumjubatum	Foxtail barley	11	0	21	90
Poa palustris	Fowl bluegrass	5	0	34	50
Agropyron smithii	Western wheatgrass	5	0	18	70
Bromusinermis	Awnless brome	4	0	28	20
Carex praegracilis	Prairie sedge	3	0	16	30
Carex stenophylla	Low sedge	3	0	12	30
Juncus balticus	Wire rush	2	0	8	50
Poa arida	Plains bluegrass	2	0	14	40
Forbs					
Solidago Canadensis	Canada goldenrod	4	0	26	30
Lepidiumdensiflorum	Common pepper-grass	3	0	15	60
Achilleamillefolium	Common yarrow	2	0	8	60
Average total vegetation cover		**59**	**40**	**81**	
Average Forb Cover		**1**	**0**	**7**	
Average Moss and Lichen Cover		**20**	**0**	**47**	
Average Soil Exposure					

This range site and plant community is strongly influenced by discharge of groundwater and accumulation of salts, hence the dominance of salt grass and western wheatgrass. The site may show a cyclic response to variation in total annual precipitation, vegetation canopy cover will decline and bare soil increase during dry cycles, with a very strong cover of salt grass and western wheatgrass during wet cycles. This community has a significant component of natural bare soil at about 20% (Adams et al. 2013). Foxtail barley can withstand soil disturbance and can dominate the site, limiting infill and species diversity and slowing the process of succession.

This information can then be used to design a native seed mix based on the common dominant species in the cluster and the performance of each species in the recovery process. Salt grass, Fowl bluegrass and western wheatgrass are drivers in the process of succession and adapted to the cyclic moisture conditions.

Table C22 provides an example of the common dominant species recommended for inclusion in a native seed mix expressed as the portion required for each species in % Pure Live Seed by weight. An example for this range site could include:

Table C22 - Recommended Species for Lethbridge, Vulcan Plain: Saline Lowland Range Sites

Species	Proportion of Seed Mix % PLS by Weight	
Western wheatgrass	*Agropyron smithii*	20%
Salt Grass	*Distichlis stricta*	25%
Fowl bluegrass	*Poa palustris*	15%

Western wheat grass, fowl bluegrass and salt grass are included as they are drought tolerant and can tolerate salt laden soils and fluctuations in soil moisture. If Awnless brome is listed in the pre-disturbance site assessment, ecologically based invasive plant management will be required.

C.4 Target Recovering Plant Community for the Majorville Uplands Ecodistrict

The Majorville Upland Ecodistrict is characterized by increased elevation and rolling to hilly upland topography relative to the plains to the west and the east. The combination of elevation, topography and moist loamy soils has produced a unique reference plant community MGA36 Western Porcupine Grass – Northern Wheat Grass (Adams et al. 2013). The indicator species is western porcupine grass. Although portions of this ecodistrict have been fragmented by cultivation, there remain intact blocks of native grassland under the stewardship of large ranches.

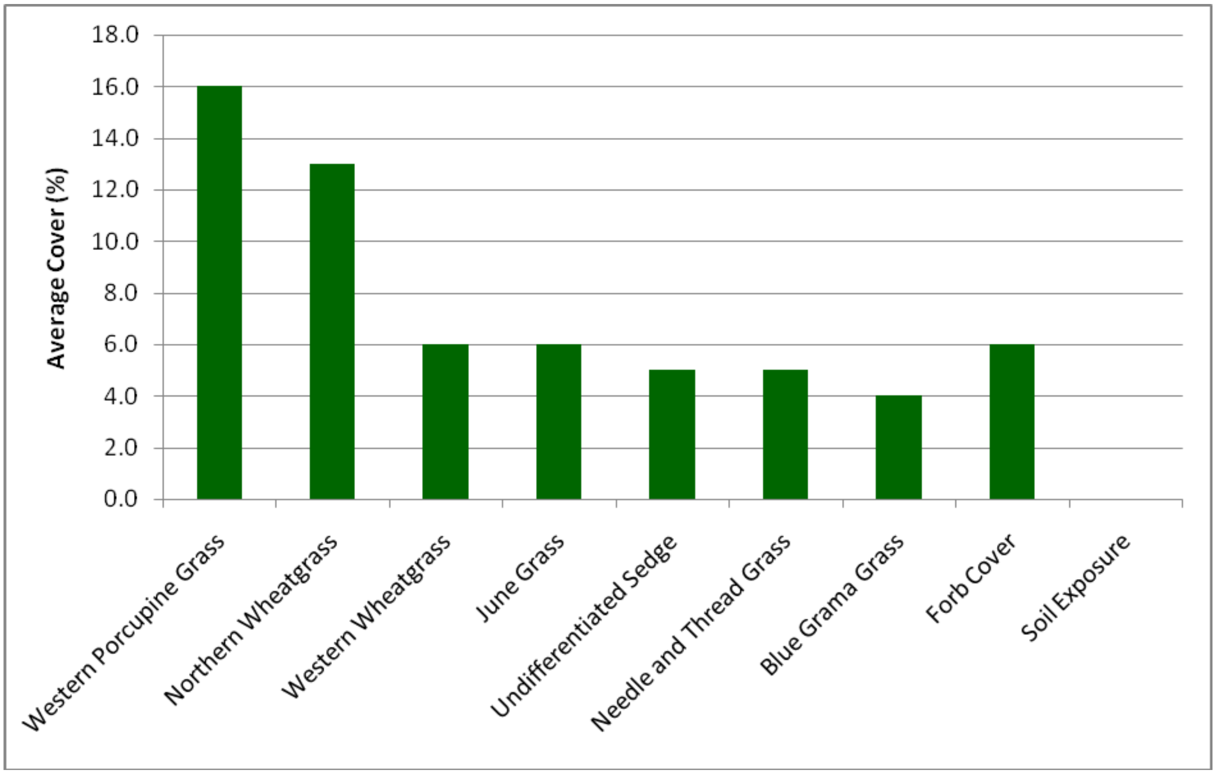
C.4.1 Majorville Upland Ecodistrict: Loamy Ecological Range Sites

Table C23 - Target Recovering Plant Community for Majorville Upland: Loamy Ecological Range Sites

Species	Common Name	Average % Cover	Absolute Minimum % Cover	Absolute Maximum % Cover	% Constancy
Stipa curtiseta	Western Porcupine Grass	16.0	10	26	100
Agropyron dasystachyum	Northern Wheatgrass	13.0	4	20	100
Agropyron smithii	Western Wheatgrass	6.0	1	14	100
Koeleria macrantha	June Grass	6.0	1	12	100
Carex species	Undifferentiated Sedge	5.0	1	6	100
Stipa comata	Needle-and-Thread Grass	5.0	1	9	100
Bouteloua gracilis	Blue Grama Grass	4.0	1	7	100
Average total vegetation cover		**96.0**			
Average Forb Cover		**6.0**			
Average Moss and Lichen Cover		**11.0**			
Average Soil Exposure		**0.0**			

The dominant species for this cluster is western porcupine grass. Northern wheatgrass is also prominent along with western wheatgrass and June grass. Needle-and-thread grass and blue grama grass are present in early to mid- seral successional phases.

Figure C9 - Target Recovering Plant Community for Majorville Upland: Loamy Ecological Range Sites



This information can then be used to design a native seed mix based on the common dominant species in the cluster and the performance of each species in the recovery process. Table C24 provides an example of the common dominant species recommended for inclusion in a native seed mix expressed as the portion required for each species in % Pure Live Seed by weight. An example for this cluster could include:

Table C24 - Recommended Species for Majorville Upland: Loamy Ecological Range Sites

Species	Proportion of Seed Mix % PLS by Weight	
Western porcupine grass	*Stipa curtiseta*	40%
Northern wheatgrass	*Agropyron dasystachyum*	10%
Western wheatgrass	*Agropyron smithii*	05%
June grass	*Koeleria macrantha*	15%
Needle-and-thread grass	*Stipa comata*	20%
Slender wheatgrass	*Agropyron trachycaulum*	10%

Slender, northern and western wheat grasses are available as native plant cultivars. They can be quite competitive and should be seeded at low application rates. Slender wheat grass is included to provide initial cover and competition to invasive plants and is expected to disappear from the stand in approximately 5 years. Western porcupine and needle-and-thread grass are seeded at high rates as they are available from wild harvested seed. If invasive non-native plants have been detected in the pre-disturbance site assessment, ecologically based invasive plant management will be required.

C.5 Final Step

Appendix D provides detailed guidance for the final steps in seed mix design.

Reports of Seed Analysis for each species and the seed lots available are required to make this final computation.

Appendix D Seeding Pathways

For more information on Sourcing Native Plant Material including source lists and availability, please visit:

The Alberta Native Plant Council
http://www.anpc.ab.ca/

and/or

The Native Plant Society of Saskatchewan
http://www.npss.sk.ca/

Seeding Rate Conversion Charts For Using Native Species In Reclamation Projects

Alberta
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Seeding Rate Conversion Charts For Using Native Species In Reclamation Projects

Introduction

Seeding rates for native species planted in reclamation or restoration projects vary. The rate chosen depends on the objectives for the project, the climate and soils in the area and the characteristics of the plant and its seed. This publication will help practitioners to plan seeding rates more accurately.

It's useful to know relative seed weight when deciding what seeding rate to use. The same weight of large heavy seeds does not cover as big an area as small, light seeds. The mortality of small light seed is generally very high.

When ordering seed, it's very important to know the percentage of live or viable seed that can potentially germinate. This is known as pure live seed (PLS) and can be determined by getting a professional seed analysis report. PLS is calculated by multiplying the purity of a seed lot by the germination and dividing by 100.

Many native seeds tend to have high levels of dormancy. When determining germination for a particular seed lot, it is acceptable to combine the percent germination and percent dormant to get an idea of the total viable seed (Ducks Unlimited, 1995).

In Canada, seed is usually purchased on a bulk seed basis, not a PLS basis. In the United States, it is possible to order seed on a PLS basis. Potential buyers in Canada can ask to see seed certificates for specific seed lots and determine the PLS for themselves. More information about seeding native species is available in the following publications: Morgan and Collicutt 1995; Ducks Unlimited 1995; Kerr et al. 1993, Abouguendia, Z. 1995, and Gerling et al. 1996.

Calculating Seeding Rates

Seeding rate planning based on a weight per unit area basis (i.e. kg/ha or lbs/ac) has been found unreliable since seed weight may vary among species. This may produce problems such as unexpected dominance of some species, or, a plant density which may be higher or lower than anticipated. For example, a mix seeded at a rate of 15 kg/ha on a weight basis (i.e. 100% purity) may plant anywhere from 90 to over 10,000 seeds/m^2 depending on which species are in the mix. These problems may have significant influence on plant community development and therefore revegetation success.

An alternative to weight based seeding rate calculation is the pure live seed per unit area calculation (i.e. pure live seeds/m^2 or PLS/m^2) which emphasizes potential plant density. Weight based seeding rates can be converted to PLS/m^2 basis using a reasonably simple formula (Formula 1). The following is an example of a kg/ha to PLS/m^2 conversion for a seed mix consisting of 5 species (Table 1, Columns A and B) seeded at a rate of 15 kg/ha (assuming 100% purity).

Table 1.
Sample calculation for determining total seeding rate in PLS/m^2 from % by weight.

A Species	B Proportion of Seed Mix (% PLS by Weight)	C Seeding Rate (kg/ha of mix)	D Seed Weight (PLS/g)	E Seeding Rate (PLS/m^2, From Formula 1)
Needle and thread grass	35		250	131
Slender wheatgrass	25		350	131
Northern wheatgrass	25		340	128
Green needle grass	10		400	60
Blue grama grass	5		1820	137
Total	100%	15		587 PLS/m^2

Step 1
To calculate the total PLS/m^2 of the seed mix you will first need the proportion of each species in the mix by weight (Table 1, Column B).

Step 2
Determine the seeding rate for the entire mix on a weight basis (i.e. 15 kg/ha as described above) (Table 1, Column C). See Step 7 to convert from kg/ha to lbs/ac.

Step 3
Find the seed weight for each species in the mix using Table 2.

Step 4
Use Formula 1 to calculate PLS/m^2 for each species. Simply plug the values from columns B, C, and D, in Table 1 into Formula 1.

Step 5
To determine the total seeding rate on a PLS/m^2 basis, add together the PLS/m^2 calculated for each species. At a seeding rate of 15 kg/ha, a total of 587 PLS/m^2 were planted (Column E).

Step 6
Check Table 3 to see if this is a reasonable seeding rate for the existing conditions.

Step 7
Use the metric-imperial conversions in Formula 3 to convert PLS/m^2 calculated from kg/ha basis to lbs/ac basis. To calculate PLS/m^2 for 15 lbs/ac instead of 15 kg/ha, simply multiply the calculated PLS/m^2 by 0.89.

Example for slender wheatgrass: 131 PLS/m^2 x 0.891 = 117 PLS SWG/m^2 from a lbs/ac basis, or, the total seeding rate would be 587 PLS/m^2 x 0.891 = 523 PLS/m^2.

Table 2.
Common names, Latin names, and seed weight of selected species.

Common Name	Latin Name	Seed Weight (PLS/g)
American sweet vetch	*Hedysarum alpinum*	200
American vetch	*Vicea americana*	60
awned slender wheatgrass	*Agropyron trachycaulum var.*	260
awned wheatgrass	*Agropyron subsecundum*	350
big bluestem	*Andropogon gerardii*	290
blue grama grass	*Bouteloua gracilis*	1820
bluebunch wheatgrass	*Agropyron spicatum*	310
bluejoint	*Calamgrostis canadensis*	5000
Canada wild rye	*Elymus canadensis*	200
early bluegrass	*Poa cusickii*	2000
fowl bluegrass	*Poa palustris*	2000
fringed brome	*Bromus ciliatus*	306
green needle grass	*Stipa viridula*	400
hairy wild rye	*Elymus innovatus*	392
Idaho fescue	*Festuca idahoensis*	990
Indian grass	*Sorghastrum nutans*	300
Indian rice grass	*Oryzopsis hymenoides*	310
June grass	*Koeleria macrantha*	5100
little bluestem	*Andropogon scoparius*	310
mountain brome	*Bromus carinatus/marginatus*	190
needle and thread	*Stipa comata*	250
nodding brome	*Bromus anomalus*	255
northern awnless brome	*Bromus pumpellianus*	280
northern rough fescue	*Festuca altaica*	654
northern sweet vetch	*Hedysarum boreale*	70
Nutall's alkali grass	*Pucinella nuttalliana*	6140
Parry oat grass	*Danthonia parryi*	222
plains rough fescue	*Festuca hallii*	445
prairie cord grass	*Spartina pectinata*	140
purple prairie clover	*Petalostemon purpureum*	312
Rocky Mountain fescue	*Festuca saximontana*	1498
rough fescue	*Festuca campestris*	550
salt grass	*Distichlis stricta*	1150
sand dropseed	*Sporobulus cryptandrus*	11670
sand grass	*Calamovilfa longifolia*	600
slender wheatgrass	*Agropyron trachycaulum*	350
switch grass	*Panicum virgatum*	635
tufted hair grass	*Deschampsia cespitosa*	5510
northern wheatgrass	*Agropyron dasystachyum*	340
western porcupine grass	*Stipa curtiseta/spartea*	200
western wheatgrass	*Agropyron smithii*	240

Note: seed weights for each species may vary. Calculations in subsequent tables are based on these seed weights.

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Table 3.

General seeding rate guidelines.

Rate (PLS/m2)	Suitable Conditions
150	very low erosion risk, high desire for native plant colonization, surrounded by native plant community, low risk of exotic species invasion, long term plant community recovery is acceptable, excellent seed bed, drill seeded
225	low erosion risk, high desire for native plant colonization, surrounded by native plant community, low risk of exotic species invasion, long term plant community recovery is acceptable, good seed bed, drill seeded
300	stable soil, low to moderate erosion risk, drill seeded, slow cover establishment acceptable, encourage encroachment of surrounding species, aggressive and/or rhizomatous species in mix, medium time frame for plant community recovery
400	moderate erosion risk, moderate rate of cover establishment, weed competition anticipated, short time frame for plant community recovery needed, poor conditions during seeding
500+	broadcast/hydroseeding, or, unstable soil, susceptible to erosion, rapid cover establishment required, slowly establishing species, discourage encroachment of surrounding species, heavy weed competition

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Formula 1.

Converting seeding rate of a species from % weight basis to PLS/m^2.

To calculate the number of pure live seeds (PLS) per square meter for one species at a time, use the following formula.

This is the percent by weight of species "A" in the seed mix. (i.e. 25% not 0.25) It assumes that the weight percentage is on a pure live seed basis. Most seed mixes should be expressed in this manner.

This is the planned/desired seeding rate on a weight basis for the whole seed mix (e.g. 10 kg/ha).

This is an estimate of the weight of the seed.

$$PLS/m^2 = \frac{\%spp_{wt} \times kg/ha \times PLS/g}{1{,}000}$$

Conversion factor which adjusts for the % value by dividing by 100 and converting the kg/ha to g/m^2.

Sample calculation for slender wheatgrass based on the examples provided in the explanation above:

$$PLS_{SWG}/m^2 = \frac{25\% \times 15\ kg/ha \times 350\ PLS/g}{1{,}000} = 131\ PLS_{SWG}/m^2$$

Formula 2.

Converting seeding rate of a species from PLS/m^2 to % weight basis (i.e. reverse of Formula 1).

$$\%spp_{wt} = \frac{PLS/m^2 \times 1{,}000}{kg\ mix/ha \times PLS/g}$$

Formula 3.

Metric to Imperial conversions:

kg/ha = 1.12 x lbs/acre
lbs/acre = 0.891 x kgs/ha

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Table 4.
Amount of a species seeded (PLS/m^2) at different total seeding rates (PLS/m^2) and proportions of species in the mix (%).

Composition of Species in Mix	Total Seeding Rate of Mix (PLS/m^2)			
(%)	150	225	300	400
5	8	11	15	20
10	15	23	30	40
15	23	34	45	60
20	30	45	60	80
25	38	56	75	100
30	45	68	90	120
40	60	90	120	160
50	75	113	150	200
75	113	169	225	300
100	150	225	300	400

Table 5.
Amount of species seeded (kg/ha) at different total seeding rates (kg/ha) and seeding percentages (% wt).

Composition of Species in Mix	Total Seeding Rate of Mix (PLS/m^2)				
(%)	5	10	15	20	25
5	0.25	0.50	0.75	1.00	1.25
10	0.50	1.00	1.50	2.00	2.50
15	0.75	1.50	2.25	3.00	3.75
20	1.00	2.00	3.00	4.00	5.00
25	1.25	2.50	3.75	5.00	6.25
30	1.50	3.00	4.50	6.00	7.50
40	2.00	4.00	6.00	8.00	10.00
50	2.50	5.00	7.50	10.00	12.50
75	3.75	7.50	11.25	15.00	18.75
100	5.00	10.00	15.00	20.00	25.00

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Table 6.
Conversion factors to determine kilograms of bulk seed needed to obtain 1 kilogram of pure live seed. (Note: Purity is the % of pure living seed on a weight basis. Use the 100% germination rate if seed dormancy is not of concern.)

Purity	Germination (%)										
(%)	100	95	90	85	80	75	70	65	60	55	50
100	1.00	1.05	1.10	1.20	1.25	1.35	1.45	1.55	1.65	1.80	2.00
95	1.05	1.10	1.15	1.25	1.30	1.40	1.50	1.60	1.75	1.90	2.10
90	1.10	1.15	1.25	1.30	1.40	1.50	1.60	1.70	1.85	2.00	2.20
85	1.20	1.25	1.30	1.40	1.45	1.55	1.70	1.80	1.95	2.15	2.35
80	1.25	1.30	1.40	1.45	1.55	1.65	1.80	1.90	2.10	2.25	2.50
75	1.35	1.40	1.50	1.55	1.65	1.80	1.90	2.05	2.20	2.40	2.65
70	1.40	1.50	1.60	1.70	1.80	1.90	2.05	2.20	2.40	2.60	2.85
65	1.55	1.60	1.70	1.80	1.90	2.05	2.20	2.35	2.55	2.80	3.10
60	1.65	1.75	1.85	1.95	2.10	2.20	2.40	2.55	2.80	3.00	3.35
55	1.80	1.90	2.00	2.15	2.25	2.40	2.60	2.80	3.05	3.30	3.65
50	2.00	1.10	2.20	2.35	2.50	2.65	2.85	3.10	3.35	3.65	4.00

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Table 7.
Converting seeding rate (kg/ha) to PLS/m². (Based on seed weights shown in Table 2)

Common Name	Seeding Rate (kg/ha)										
	0.25	0.50	0.75	1	2	3	5	10	15	20	25
American sweet vetch	5	10	15	20	40	60	100	200	300	400	500
American vetch	2	3	5	6	12	18	30	60	90	120	150
awned slender	7	13	20	26	52	78	130	260	390	520	650
awned wheatgrass	9	18	26	35	70	105	175	350	525	700	875
big bluestem	7	15	22	29	58	87	145	290	435	580	725
blue grama grass	46	91	137	182	364	546	910	1820	2730	3640	4550
bluebunch wheatgrass	8	16	23	31	62	93	155	310	465	620	775
Canada wild rye	5	10	15	20	40	60	100	200	300	400	500
fringed brome	8	15	23	31	61	92	153	306	459	612	765
green needle grass	10	20	30	40	80	120	200	400	600	800	1000
hairy wild rye	10	20	29	39	78	118	196	392	588	784	980
Idaho fescue	25	50	74	99	198	297	495	990	1485	1980	2475
Indian grass	8	15	23	30	60	90	150	300	450	600	750
Indian rice grass	8	16	23	31	62	93	155	310	465	620	775
June grass	128	255	383	510	1020	1530	2550	5100	7650	10200	12750
little bluestem	8	16	23	31	62	93	155	310	465	620	775
mountain brome	5	10	14	19	38	57	95	190	285	380	475
needle and thread	6	13	19	25	50	75	125	250	375	500	625
nodding brome	6	13	19	26	51	77	128	255	383	510	638
northern awnless	7	14	21	28	56	84	140	280	420	560	700
northern rough fescue	16	33	49	65	131	196	327	654	981	1308	1635
northern sweet vetch	2	4	5	7	14	21	35	70	105	140	175
northern wheatgrass	9	17	26	34	68	102	170	340	510	680	850
Nutall's alkali grass	154	307	461	614	1228	1842	3070	6140	9210	12280	15350
Parry oat grass	6	11	17	22	44	67	111	222	333	444	555
plains rough fescue	11	22	33	45	89	134	223	445	668	890	1113
prairie cord grass	4	7	11	14	28	42	70	140	210	280	350
purple prairie clover	8	16	23	31	62	94	156	312	468	624	780
rocky mountain fescue	37	75	112	150	300	449	749	1498	2247	2996	3745
rough fescue	14	28	41	55	110	165	275	550	825	1100	1375
salt grass	29	58	86	115	230	345	575	1150	1725	2300	2875
sand dropseed	292	584	875	1167	2334	3501	5835	11670	17505	23340	29175
sand grass	15	30	45	60	120	180	300	600	900	1200	1500
slender wheatgrass	9	18	26	35	70	105	175	350	525	700	875
switch grass	16	32	48	64	127	191	318	635	953	1270	1588
tufted hair grass	138	276	413	551	1102	1653	2755	5510	8265	11020	13775
western porcupine	5	10	15	20	40	60	100	200	300	400	500
western wheatgrass	6	12	18	24	48	72	120	240	360	480	600

*Note: these PLS/m² are converted from kg/ha. For a lb/ac conversion, multiply the PLS/m² by 0.891.

Seeding Rate Conversion Charts For Using Native Species in Reclamation Projects
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Table 8. Converting PLS/m^2 to kg/ha. (Based on seed weights shown in Table 2.)

Common Name	Seeding Rate (PLS/m^2)																	
	15	20	25	30	40	50	60	75	100	125	150	175	200	250	300	350	400	450	500
American sweet vetch	0.75	1.0	1.3	1.5	2.0	2.5	3.0	3.8	5.0	6.3	7.5	8.8	10.0	12.5	15.0	17.5	20.0	22.5	25.0
American vetch	2.5	3.3	4.2	5.0	6.7	8.3	10.0	12.5	16.7	20.8	25.0	29.2	33.3	41.7	50.0	58.3	66.7	75.0	83.3
awned slender	0.58	0.77	1.0	1.2	1.5	1.9	2.3	2.9	3.8	4.8	5.8	6.7	7.7	9.6	11.5	13.5	15.4	17.3	19.2
awned wheatgrass	0.43	0.57	0.71	0.86	1.1	1.4	1.7	2.1	2.9	3.6	4.3	5.0	5.7	7.1	8.6	10.0	11.4	12.9	14.3
big bluestem	0.52	0.69	0.86	1.0	1.4	1.7	2.1	2.6	3.4	4.3	5.2	6.0	6.9	8.6	10.3	12.1	13.8	15.5	17.2
blue grama grass	0.08	0.11	0.14	0.16	0.22	0.27	0.33	0.41	0.55	0.69	0.82	1.0	1.1	1.4	1.6	1.9	2.2	2.5	2.7
bluebunch wheatgrass	0.48	0.65	0.81	1.0	1.3	1.6	1.9	2.4	3.2	4.0	4.8	5.6	6.5	8.1	9.7	11.3	12.9	14.5	16.1
Canada wild rye	0.75	1.0	1.3	1.5	2.0	2.5	3.0	3.8	5.0	6.3	7.5	8.8	10.0	12.5	15.0	17.5	20.0	22.5	25.0
fringed brome	0.49	0.65	0.82	1.0	1.3	1.6	2.0	2.5	3.3	4.1	4.9	5.7	6.5	8.2	9.8	11.4	13.1	14.7	16.3
green needle grass	0.38	0.50	0.63	0.75	1.0	1.3	1.5	1.9	2.5	3.1	3.8	4.4	5.0	6.3	7.5	8.8	10.0	11.3	12.5
hairy wild rye	0.38	0.51	0.64	0.77	1.0	1.3	1.5	1.9	2.6	3.2	3.8	4.5	5.1	6.4	7.7	8.9	10.2	11.5	12.8
Idaho fescue	0.15	0.20	0.25	0.30	0.40	0.51	0.61	0.76	1.0	1.3	1.5	1.8	2.0	2.5	3.0	3.5	4.0	4.5	5.1
Indian grass	0.50	0.67	0.83	1.0	1.3	1.7	2.0	2.5	3.3	4.2	5.0	5.8	6.7	8.3	10.0	11.7	13.3	15.0	16.7
Indian rice grass	0.48	0.65	0.81	1.0	1.3	1.6	1.9	2.4	3.2	4.0	4.8	5.6	6.5	8.1	9.7	11.3	12.9	14.5	16.1
June grass	0.03	0.04	0.05	0.06	0.08	0.10	0.12	0.15	0.20	0.25	0.29	0.34	0.39	0.49	0.59	0.69	0.78	0.88	1.0
little bluestem	0.48	0.65	0.81	1.0	1.3	1.6	1.9	2.4	3.2	4.0	4.8	5.6	6.5	8.1	9.7	11.3	12.9	14.5	16.1
mountain brome	0.79	1.1	1.3	1.6	2.1	2.6	3.2	3.9	5.3	6.6	7.9	9.2	10.5	13.2	15.8	18.4	21.1	23.7	26.3
needle and thread	0.60	0.80	1.0	1.2	1.6	2.0	2.4	3.0	4.0	5.0	6.0	7.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0
nodding brome	0.59	0.78	1.0	1.2	1.6	2.0	2.4	2.9	3.9	4.9	5.9	6.9	7.8	9.8	11.8	13.7	15.7	17.6	19.6
northern awnless brome	0.54	0.71	0.89	1.1	1.4	1.8	2.1	2.7	3.6	4.5	5.4	6.3	7.1	8.9	10.7	12.5	14.3	16.1	17.9
northern rough fescue	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.1	1.5	1.9	2.3	2.7	3.1	3.8	4.6	5.4	6.1	6.9	7.6
northern sweet vetch	2.1	2.9	3.6	4.3	5.7	7.1	8.6	10.7	14.3	17.9	21.4	25.0	28.6	35.7	42.9	50.0	57.1	64.3	71.4
northern wheatgrass	0.44	0.59	0.74	0.88	1.2	1.5	1.8	2.2	2.9	3.7	4.4	5.1	5.9	7.4	8.8	10.3	11.8	13.2	14.7
Nutall's alkali grass	0.02	0.03	0.04	0.05	0.07	0.08	0.10	0.12	0.16	0.20	0.24	0.29	0.33	0.41	0.49	0.57	0.65	0.73	0.81
Parry oat grass	0.68	0.90	1.1	1.4	1.8	2.3	2.7	3.4	4.5	5.6	6.8	7.9	9.0	11.3	13.5	15.8	18.0	20.3	22.5
plains rough fescue	0.34	0.45	0.56	0.67	0.90	1.1	1.3	1.7	2.2	2.8	3.4	3.9	4.5	5.6	6.7	7.9	9.0	10.1	11.2
prairie cord grass	1.1	1.4	1.8	2.1	2.9	3.6	4.3	5.4	7.1	8.9	10.7	12.5	14.3	17.9	21.4	25.0	28.6	32.1	35.7
purple prairie clover	0.48	0.64	0.80	1.0	1.3	1.6	1.9	2.4	3.2	4.0	4.8	5.6	6.4	8.0	9.6	11.2	12.8	14.4	16.0
rocky mountain fescue	0.10	0.13	0.17	0.20	0.27	0.33	0.40	0.50	0.67	0.83	1.0	1.2	1.3	1.7	2.0	2.3	2.7	3.0	3.3
rough fescue	0.27	0.36	0.45	0.55	0.73	0.91	1.1	1.4	1.8	2.3	2.7	3.2	3.6	4.5	5.5	6.4	7.3	8.2	9.1
salt grass	0.13	0.17	0.22	0.26	0.35	0.43	0.52	0.65	0.87	1.1	1.3	1.5	1.7	2.2	2.6	3.0	3.5	3.9	4.3
sand dropseed	0.01	0.02	0.02	0.03	0.03	0.04	0.05	0.06	0.09	0.11	0.13	0.15	0.17	0.21	0.26	0.30	0.34	0.39	0.43
sand grass	0.25	0.33	0.42	0.50	0.67	0.83	1.0	1.3	1.7	2.1	2.5	2.9	3.3	4.2	5.0	5.8	6.7	7.5	8.3
slender wheatgrass	0.43	0.57	0.71	0.86	1.1	1.4	1.7	2.1	2.9	3.6	4.3	5.0	5.7	7.1	8.6	10.0	11.4	12.9	14.3
switch grass	0.24	0.31	0.39	0.47	0.63	0.79	0.94	1.2	1.6	2.0	2.4	2.8	3.1	3.9	4.7	5.5	6.3	7.1	7.9
tufted hair grass	0.03	0.04	0.05	0.05	0.07	0.09	0.11	0.14	0.18	0.23	0.27	0.32	0.36	0.45	0.54	0.64	0.73	0.82	0.91
western porcupine grass	0.75	1.0	1.3	1.5	2.0	2.5	3.0	3.8	5.0	6.3	7.5	8.8	10.0	12.5	15.0	17.5	20.0	22.5	25.0
western wheatgrass	0.63	0.83	1.0	1.3	1.7	2.1	2.5	3.1	4.2	5.2	6.3	7.3	8.3	10.4	12.5	14.6	16.7	18.8	20.8

Seeding Rate Conversion Charts For Using Native Species in Reclamation Projects
Alberta Agriculture, Food and Rural Development 1998

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Appendix

United States Department of Agriculture Planning or Data Sheet for Grass and/or Legume Seeding

Adapted from USDA, NRCS Form ND-CPA-9

		Pure Live Seed Needs								Bulk Seed Needs	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
		Full Seeding									
Species	Strain or Variety	Seeds Per Sq. Ft.	PLS Lbs. Per Acre	Percent Desired in Mixture	Number PLS Per Sq. Ft. (3) x (5)	PLS Lbs/Ac Needed (4) x (5)	Acres to be seeded	Total Lbs PLS Needed (7) x (8)	Percent Purity	Percent Germi-nation	Lbs. Of Bulk Seed Needed (9) ÷ (10x11)

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Interpreting your Report of Seed Analysis:

Important notes:

- Your Report of Seed Analysis is based on the grade table that the crop type is found on.
- The “Date” found in the upper right hand corner of the report is the date that the germination is completed, not the date that the report is issued.
- A “Senior Member” is a proven skilled seed analyst who has undergone 2-4 years of training in an accredited Seed Laboratory and passed examination administered by CFIA. This seal represents a certification of skill and knowledge.

Purity tests

There are two tests that determine the quality of physical purity on a seed report:

1. % Pure Seed – this is component breakdown of classified contaminants (Pure Seed, Weeds, Other Crops, Inert, Ergot), as expressed as a percentage.
   - This test is performed on sample sizes that are based on 2500 seeds.
   - Pure seed for each species follows specific rules for accurate determination. This includes small, shriveled, or otherwise injured seeds, provided they are larger than one half the original size.

2. Purity test – this is an evaluation of any other species or disease body that is present in a seed lot, expressed as numbers or %, calculated to represent per 25 grams of seed.
   - This test is performed on sample sizes that are based on 25,000 seeds.
   - Note that some contaminants are listed in number quantities and others in percentages. For example, in the Northern Wheatgrass sample, the “Total Weed Seeds of All Kinds” equals 80. That means there were 80 species of weeds (all listed in the Noxious and Other Weed Categories and totaled here) present in 25 grams. However, the Other Crops are grouped together and reported as “Less Than” or “More Than” a percentage.
   - When contaminants are expressed as percentages, they must be reported as “Less than” the grade maximum. If the “Total Other Crop Seeds” reads “Less than 1% by weight”, it means that there were less than the maximum allowable % found in the sample. This doesn’t mean that there was actually 1% other crops found. The exact % of other crops (or other contaminants) is found in the % Pure Seed evaluation. These two tests must be interpreted together to have an accurate idea of which contaminants were found and at what rate in any given sample

Pure Living Seed

This is a calculation based on the % pure seed value multiplied by the germination value. This allows for a singular value when comparing seed lots that have high germination but varying % pure seed test results. For example, the two Northern wheatgrass samples provided both have relatively high pure seed % values, but differing germinations. This results in a very different Pure Living Seed calculation.

Germination Test

This test evaluates a seed lot's maximum germination potential. It is based on each individual seed's ability to produce healthy essential structures under optimal conditions.

- **Abnormals** are seedlings that have severe impairment to one or more of their essential structures. This means that the seedling does not have the genetic capability to carry itself to maturity. For example, seedlings with deep hypocotyl lesions that extend into the conducting tissue will not have the ability to become healthy and mature plants. They will be classified as "abnormal".
- **Dead** seeds are incapable of growth. Their embryo tissues are damaged and will not exhibit any growth
- **Fresh** seeds have imbibed water but have not begun the germination process. These seeds are viable but may have a physiological issue that is blocking the germination process, such as dormancy.
- **Hard** seeds are present and evaluated in clovers and other member of the *Fabaceae* family. Hard seed do not imbibe water but may be capable of growth in the future.

Tetrazolium chloride (TZ) Test:

This test is a quick representation of seed viability. It is usually available within 24 hours of the lab receiving the sample and should reflect the seed's germination capability. However, it is particularly useful in species where deep dormancy is often observed, such as in native species. When used in conjuction with the germination test, it can establish a level of dormancy and also the maximum germination potential.

In the example of the Needle and Thread grass, the germination is only 62%. However, there are 33% fresh seeds reported. The TZ is reporting 95% viability. This means that the fresh seeds are dormant, and when added to the "normal" evaluation, the maximum potential of the seed lot is 95%. Not all seed testing companies will give their customers a profile of the dead or fresh seeds. If this was the case in this sample, and a TZ was not performed, the customer would think that the maximum potential of the seed lot was on 62%. However, through a more comprehensive germination profile and the utilization of a TZ test, we have a much more accurate picture of what this seed is capable of.

The Report of Seed Analysis is very complicated and represents many aspects of the Canadian Grading System. The correct interpretation, proper combination of seed tests, along with the knowledge and experience of a certified seed analyst can ensure that confident and informed decisions are made for each individual seed lot.

Carey Matthiessen, 20/20 Seed Labs Inc.
Senior Analyst
Lab Manager

20/20 Seed Labs Inc.

Report Of Seed Analysis

CFIA Accreditation No.1068

This designates Date: Apr 18, 2012

that a sample of Wheatgrass, northern

Lot# 123-4567

Lab No. AB1120401008

was received from:
Scarecrow Enterprises
#201, 509 11 Avenue

Nisku, AB, CA
T9E 7N5

and was tested at:
20/20 Seed Labs Inc.
Suite #201, 509 - 11 Avenue
Nisku, AB, CA T9E 7N5
p 780-955-3435 f 780-955-3428
w http://clients.2020seedlabs.ca/
e reports@2020seedlabs.ca

signed by:
SENIOR MEMBER OF
SEED COMMERCIAL ANALYSTS ASSOCIATION CANADA INC
139
Carey Matthiessen

This sample was analyzed according to Canadian Methods and Procedures (CFIA)* for:

% PURE SEED *

Pure Seed	99.9	Other Crop Seeds	0.0	Weed Seeds	0.0	Inert Matter	0.1
Ergot	0.0	Multiple Seed Units	N/A			Pure Living Seed	90

PURITY *

WEED SEEDS: No. PER 25 GRAMS **TOTAL GRAMS ANALYZED FOR PURITY: 50**

NOXIOUS WEED SEEDS		OTHER WEED SEEDS		OTHER CROP SEEDS	
Prohibited Noxious					
Total Prohibited	0.0				
Primary Noxious					
Total Primary	0.0				
Secondary Noxious					
Total Secondary	0.0				
Primary Plus Secondary	0.0	**Total Weed Seeds of All Kinds**	0.0	**Total Other Crop Seeds**	0%
Brassica spp.	0.0			**Sclerotia Bodies**	n/a
				Sweet Clover	0.0
				Ergot Bodies	0%

Germination *

Germination (%)	90	Hard Seeds (%)	0	Germ. Incl. Hard Seeds (%)	N/A
Abnormals (%)	2	Deads (%)	8	Fresh (%)	0

ACCREDITED REMARKS

Total extended pre-chill days that were used to break dormancy: 3

The responsibility for any seed sold under this Report with respect to Grade or any other specification rests entirely with the seller. Accredited by CFIA to conduct tests in accordance with the laboratory's scope of accreditation and the Canadian Methods and Procedures for Testing Seed.

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20/20 Seed Labs Inc.

Detailed Testing Result Summary

CFIA Accreditation No.1068

This designates

that a sample of Wheatgrass, northern

Lot# 123-4567

Date: Apr 18, 2012

Lab No. AB1120401008

was received from: Scarecrow Enterprises **and was tested at:** 20/20 Seed Labs Inc.

REQUESTED TEST	RESULTS	
Pure Living Seed (1)		
	Pure Living Seed (%)	90

The responsibility for any seed sold under this Report with respect to Grade or any other specification rests entirely with the seller. Accredited by CFIA to conduct tests in accordance with the laboratory's scope of accreditation and the Canadian Methods and Procedures for Testing Seed.

40.01-B Page 2 / 2 Revision: 111129

20/20 Seed Labs Inc.

Report Of Seed Analysis

CFIA Accreditation No.1068

Date: Apr 18, 2012

This designates that a sample of Wheatgrass, northern

Lot# 123-4567

Lab No. AB1120401009

was received from:

Scarecrow Enterprises
#201, 509 11 Avenue

Nisku, AB, CA
T9E 7N5

and was tested at:

20/20 Seed Labs Inc.
Suite #201, 509 - 11 Avenue
Nisku, AB, CA T9E 7N5
p 780-955-3435 f 780-955-3428
w http://clients.2020seedlabs.ca/
e reports@2020seedlabs.ca

signed by:

SENIOR MEMBER OF

SEED COMMERCIAL ANALYSTS ASSOCIATION CANADA INC

139
Carey Matthiessen

This sample was analyzed according to Canadian Methods and Procedures (CFIA)* for:

% PURE SEED *

Pure Seed	88.94	Other Crop Seeds	4.10	Weed Seeds	2.18	Inert Matter	4.79
Ergot	0.10	Multiple Seed Units	N/A			Pure Living Seed	60

PURITY *

WEED SEEDS: No. PER 25 GRAMS **TOTAL GRAMS ANALYZED FOR PURITY: 50**

NOXIOUS WEED SEEDS		OTHER WEED SEEDS		OTHER CROP SEEDS	
Prohibited Noxious		Green needlegrass	21.5	Slender wheatgrass	
Total Prohibited	0.0	Narrow-leaved hawk's beard	11.0	Alfalfa	
Primary Noxious		Downy brome	37.5	Smooth bromegrass	
Cleavers bedstraw	0.5	Japanese brome	6.5		
Canada thistle	0.5				
Total Primary	1.0				
Secondary Noxious					
Night-flowering catchfly	2.5				
Total Secondary	2.5				
Primary Plus Secondary	3.5	**Total Weed Seeds of All Kinds**	80.0	**Total Other Crop Seeds**	More than 3% by weight
Brassica spp.	0.0			**Sclerotia Bodies**	n/a
				Sweet Clover	0.0
				Ergot Bodies	Less than 1% by weight

Germination *

Germination (%)	67	Hard Seeds (%)	0	Germ. Incl. Hard Seeds (%)	N/A
Abnormals (%)	15	Deads (%)	18	Fresh (%)	0

ACCREDITED REMARKS

Total extended pre-chill days that were used to break dormancy: 3

The responsibility for any seed sold under this Report with respect to Grade or any other specification rests entirely with the seller. Accredited by CFIA to conduct tests in accordance with the laboratory's scope of accreditation and the Canadian Methods and Procedures for Testing Seed.

40.01-B Page 1 / 2 Revision: 111129

20/20 Seed Labs Inc.

Detailed Testing Result Summary

CFIA Accreditation No.1068

This designates

that a sample of Wheatgrass, northern

Lot# 123-4567

Date: Apr 18, 2012

Lab No. AB1120401009

was received from: Scarecrow Enterprises **and was tested at:** 20/20 Seed Labs Inc.

REQUESTED TEST	RESULTS	
Pure Living Seed (1)		
	Pure Living Seed (%)	60

The responsibility for any seed sold under this Report with respect to Grade or any other specification rests entirely with the seller.
Accredited by CFIA to conduct tests in accordance with the laboratory's scope of accreditation and the Canadian Methods and Procedures for Testing Seed.

40.01-B Revision: 111129

20/20 Seed Labs Inc.

Report Of Seed Analysis

CFIA Accreditation No.1068

This designates Date: Apr 18, 2012

that a sample of Needle And Thread

Lot# 345-6789

Lab No. AB1120401050

was received from:

Scarecrow Enterprises
#201, 509 11 Avenue

Nisku, AB, CA
T9E 7N5

and was tested at:

20/20 Seed Labs Inc.
Suite #201, 509 - 11 Avenue
Nisku, AB, CA T9E 7N5
p 780-955-3435 f 780-955-3428
w http://clients.2020seedlabs.ca/
e reports@2020seedlabs.ca

signed by:

SENIOR MEMBER OF

COMMERCIAL SEED ANALYSTS ASSOCIATION CANADA INC

139
Carey Matthiessen

This sample was analyzed according to Canadian Methods and Procedures (CFIA)* for:

% PURE SEED *

Pure Seed	94.3	Other Crop Seeds	Trace	Weed Seeds	0.2	Inert Matter	5.5
Ergot	0.0	Multiple Seed Units	N/A			Pure Living Seed	

PURITY *

WEED SEEDS: No. PER 25 GRAMS **TOTAL GRAMS ANALYZED FOR PURITY: 150**

NOXIOUS WEED SEEDS		OTHER WEED SEEDS		OTHER CROP SEEDS	
Prohibited Noxious		Green foxtail	0.8	Creeping red fescue	
Total Prohibited	0.0	Wild barley	0.3	Slender wheatgrass	
Primary Noxious		Downy brome	1.8		
Total Primary	0.0				
Secondary Noxious					
Total Secondary	0.0				
Primary Plus Secondary	0.0	**Total Weed Seeds of All Kinds**	2.9	**Total Other Crop Seeds**	Less than 2% by weight
Brassica spp.	0.0			**Sclerotia Bodies**	n/a
				Sweet Clover	0.0
				Ergot Bodies	0%

Germination *

Germination (%)	62	Hard Seeds (%)	0	Germ. Incl. Hard Seeds (%)	N/A
Abnormals (%)	3	Deads (%)	2	Fresh (%)	33

Method: AOSA Germination Method: P 15-25°C, 14 day prechill 5°C

ACCREDITED REMARKS

Total extended pre-chill days that were used to break dormancy: 7

The responsibility for any seed sold under this Report with respect to Grade or any other specification rests entirely with the seller.
Accredited by CFIA to conduct tests in accordance with the laboratory's scope of accreditation and the Canadian Methods and Procedures for Testing Seed.

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20/20 Seed Labs Inc.

Detailed Testing Result Summary

CFIA Accreditation No.1068

Date: Apr 18, 2012

Lab No. AB1120401050

This designates

that a sample of Needle And Thread

Lot# 345-6789

was received from: Scarecrow Enterprises **and was tested at:** 20/20 Seed Labs Inc.

REQUESTED TEST	RESULTS	
Tetrazolium chloride (1)		
	Viable Seeds (%)	95.0

The responsibility for any seed sold under this Report with respect to Grade or any other specification rests entirely with the seller.
Accredited by CFIA to conduct tests in accordance with the laboratory's scope of accreditation and the Canadian Methods and Procedures for

Appendix E Mixedgrass Rancher and Industry Workshop Summaries

E.1 Mixedgrass Recovery Strategies Rancher's Workshop December 4th, 2012 Summary

Expectations of Recovery

Recovery is defined as reaching an equivalent capability in forage production plus adequate *functional* litter cover. Forage production should be from species similar to surrounding area and if seeded include diversity of species to accommodate slope etc. Recovery area needs to be able to tolerate grazing as soon as possible.

Reducing the amount of exposed soil as soon as possible is important to prevent soil loss through erosion or invasion by weeds and/or non-native agronomic species.

The two preferred practices for successful recovery are minimal disturbance and no-strip. Less soil disturbed will maximize soil benefits and is better for recovery. If stripping is necessary, strip only to trench width and seed in the spring.

Indicators used by ranchers to gauge recovery success are visual assessments to determine speed of recovery, looking for species diversity and return of landforms; lack of weeds and rocks surfaced during industrial activity.

Ranchers understand that climate and the timing of activity need to be taken into account to determine the time frame for the process of recovery. In general, hope for five years and expect seven.

Non-Native Species Invasion

Common species of concern are smooth brome, downey brome, japonese brome, sweet clover, thistle, toad flax, leafy spurge, absinthe and crested wheat grass.

Experience with non-native species invasion suggests that:

- Development timing and land use can increase non-native invasion.
- Some of the newer species, crested wheat grass for example, are more aggressive than they used to be.
- Most invasions result from poor access management, imported feed, and proximity to cultivation.
- Along with spraying invasive species, management plans involving grazing and seeding to provide competition should be implemented.

Grazing Management

For the most part, it is better not to use fencing unless for a short time period to allow plants to germinate and develop a root system (large disturbance) or for cattle safety. Very important for industry to understand that should fencing be required, it will also need to be removed when appropriate.

Communication with land managers is paramount. Techniques such as timing of development activity, fencing and grazing rotation can be utilized to facilitate reclamation. Communication between industry and ranchers can result in innovative techniques that benefit both parties. For example, wild hay cut and baled from an area adjacent to the disturbance used as feed for cattle on the disturbed area.

Industrial activity and the associated noise such as compressor stations do impact cattle distribution.

Industry must recognize the importance of water resources to the ranching industry.

Additional Recommendations

Best management practices should be site specific to increase recovery success. Pre-site assessment, land manager communication and ensuring that reclamation and management plans are executed as agreed regardless of lease ownership are of primary importance.

Education of newer companies that inherit lease rights is important. Management issues are compounded when LOC is purchased by another company; often continuity of construction and reclamation plans is lost.

The timing of development activity involves planning with land manager. Drilling is best in winter months to minimize impact on grazing, invasion of non-native species and increases speed and success of recovery. Pipeline activities are best before frost.

Some of the pipeline trenches do sink/settle after time. Some companies have the philosophy of leaving the trenched area flush with the area either side of trench once their installation is complete. At least one of the energy companies leaves a crown, 4" to 5", over the disturbed trench area once installation is complete. Suggestion that the crowning works better in establishing a terrain which is close to original; this crowning does settle after time. Sink areas are a concern when working cattle off horseback.

Ranchers are very concerned about the Enhanced Approval Process (EAP) and the possible lack of checks and balances to ensure that Best Management Practices will be incorporated into industrial developments.

In addition, there is concern that the EAP reduces or eliminates vital communication with landowners and land managers.

E.2 Mixedgrass Recovery Strategies Industry Workshop December 10th, 2012 Summary

The workshop included presentations on the "Recovery Strategies for Industrial Development" project, followed by a roundtable discussion which focused on questions designed to capture the knowledge the participants have gained from their experience working in native prairie restoration. The following is a compilation of the participant's responses to the "Focused Round Table Discussion Questions".

Best Practices for Recovery in Mixedgrass Prairie

Pre-disturbance site assessment, planning and communication between industry, contractors and land managers are paramount. Choosing the best method for recovery success depends on site specifics including: shape and size of disturbance, how long the seedbank has been disturbed or removed, the range health and land use of the area adjacent to the disturbance, and the available seed source and plant propagules in surrounding grassland.

Natural Recovery

Works best in drier range sites and on narrow or smaller disturbances. The more edge to surface area ratio provided allows for increased native encroachment (i.e. better for smaller diameter pipeline disturbances than full disturbance well sites or large diameter pipelines). As a long term successional process, natural recovery will ultimately yield target native species. Significant challenges with larger disturbances are: proximity to cultivation and other sources of invasive non-native species, weeds controlled under the Alberta Weed Control Act, and insufficient establishment of target native species to provide competition for invasive non-native species.

Assisted Natural Recovery

Cover Crop

Suitable for wellsites or larger diameter pipeline disturbances where wind and/or water erosion present challenges. Site specific factors need to be considered in choosing a cover crop, such as the presence or absence of grazing, timing and density of grazing and the presence of invasive species such as crested wheatgrass. The presence of crested wheatgrass in or adjacent to the disturbance presents an additional challenge when using a cover crop. Control measures to reduce the crested wheatgrass need to be implemented before it sets seed. Control measures and seeding of the cover crop need to be carefully planned. Participants indicated some success with cover crops chosen to deter cattle grazing such as fall rye, canola and flax.

Wild Harvested Hay

Additional budget and possible additional easement needs to be included during planning process. Experience has shown that the procedure requires a harvesting area in the ratio of 3:1(required area to harvest for area of disturbance). Due to the additional time required, cost and variable availability of materials (land use or timing of activity and seed set), the procedure is most appropriate for very small disturbances with erosion concerns. Purchase of native seed is a more cost effective recovery option, but monitoring and research indicate positive results from wild harvested hay. Participants suggested that guidelines should be developed for the procedure, including guidelines to reduce the possible introduction of weeds and invasive non-native species. Wild harvested hay can be crimped, mulched or lightly harrowed with additional straw to add organic matter and to increase soil stability. It is important to use weed free straw, especially if rough fescue is evident in the control. Alfalfa pellets have also been used as an additional mulch with good results, but at much higher cost.

Seeding with Native Seed Mixes

Appropriate for larger disturbances. To date this strategy has been used to obtain reclamation certification for wellsites within a 5 year period and for large diameter pipelines. Common restoration challenges include the aggressive nature of some native plant cultivars, seeding rates and over seeding, invasive non-native species invasion, the management of livestock grazing and the lack of clear monitoring guidelines and restoration goals. The process of native plant community succession and the timeline for recovery needs to be clearly understood.

There are many challenges related to the market availability of native seed. The biggest problem is anticipating industry needs. Communication and planning in the early stages of project development would facilitate improved supply management. Seed supply companies need a longer term plan to adequately respond to industry needs. This would be an important step towards revitalizing the native seed industry. Growers need time to accommodate the production of native seed. Sustainable markets are required. Ideally, native plant cultivars produced from the DU Ecovar program or source identified seed produced from the Alberta Innovates (formerly ARC) native seed production program are best. However production requires demand and unfortunately, sufficient supply on short term demand is not feasible. To meet requirements, industry often has to use what is commercially available and as close as possible to surrounding native community. Improved communication is required. Industry may not be aware of improvements that have been made within the native seed industry or new seed sources that have become available due to industry needs, monitoring and research.

Plug Planting

Recovery strategy appropriate for difficult environments, such as steep slopes, to restore sage brush habitat in overflow areas, or to incorporate species of grasses and sedges that take a long time to establish such as rough fescue. It is also useful for very small areas requiring infill vegetation. Research and monitoring projects are gradually increasing the understanding and viability of this method. Challenges include: cost effectiveness, competition from invasive non-native species, grazing management and weed control.

Invasive Non-Native Species Management

Allowing annual weeds to establish on the site can benefit sites long term. The weeds catch snow and limit the damage caused by cattle and wind erosion. Once the desired vegetation begins to establish, the weeds decrease. Regardless of recovery strategy, larger disturbances are more likely to struggle with invasive species.

What are the species of concern from your experience in mixedgrass?

Alsike clover, Canada thistle, creeping red fescue, crested wheatgrass, dandelion, downy brome, foxtail barley, goatsbeard, Japanese Chess, Japonese brome, Kentucky bluegrass, leafy spurge, mayweed, Russian wild rye, smooth brome, sweet clover, wild barley, wormwood absinthe, and yellow toad flax.

What management measures have you used and what has been the success?

Periodic range health assessments are an excellent monitoring tool. If there are issues (declining score in the rating of the assessment questions) then specific management strategies can be implemented to deal with the issue. Invasive species management is very important. Sometimes invasive species are left unchecked in areas for a long time which dramatically increases the mitigation required and the cost of treatment. Some of the more successful treatments for invasive species invasion involve using a site specific combination of the following:

- Mow or rake litter build up first, haul away grass thatch (simulated grazing). Grass clippings/trash need to be removed to open up bare ground for grass seedlings to emerge. Pick up litter with round baler so moisture and seed (or chemical spray) can get down to the soil.
- Remove as many plants as possible by hand digging/picking, burning, roto-spiking, mowing or spraying.
- "Simplicity" or other recommended herbicides have been found to be effective. Multiple applications will be required to reduce seed source. May need to apply up to three times per year for two years.
- Grazing, possibly remove fences and put salt block in area to be 'cleared' to lure cattle.
- Best to seed site on third year to create some competition.

What are the stumbling blocks preventing improved restoration potential?

Expectations of the timeframe for recovery

Need to educate project management (engineers, geologists and accountants). Currently they don't provide sufficient budget for monitoring and follow up (fence removal for example). They need to understand the restoration process and expectations for recovery so they can address budget and other constraints during the planning process. All parties need to understand that prolonged drought or other adverse weather conditions tend to prolong the timeframe of recovery.

Pre-Disturbance Assessment will help everyone understand potential challenges that may increase timeframe or expectations of recovery. For example, the surrounding area has a low range health score, the proposed site has a sensitive species such as rough fescue, and is located in a moist/loamy range site.

Full restoration is generally not a reasonable expectation within a short timeframe. Determining that the site is on the correct trajectory towards recovery is more appropriate. Overall, proponents hope for 5 years but accept that achieving reclamation certification in less than 10 is more realistic. A better understanding of plant community succession, such as the importance of early colonizers (annual weeds) in providing protection for slow-growing perennial grasses, e.g. rough fescue, would provide a better understanding of trajectory and the stages of recovery. Some bare ground should be acceptable for several years following disturbance. Eventually, e.g. in 3 -5 years, bare ground will allow infill of perennial species. Often so-called weedy species are sprayed, and sites are re-seeded. This may promote the establishment of aggressive wheatgrass colonizers and reduce the potential for native species infill.

Lack of suitable species for seed mixes

Lack of source identified, locally available (within the Natural Subregion) seed is an issue. Often industry decisions are based on economic factors which can result in the application of cultivars developed and grown in other areas (United States, Manitoba) or non-native seeds. Advance planning and communication between seed providers and industry would improve availability of required native seed. Need to promote the understanding of the timeframe required to produce seed. Seed companies need to have a plan in place to supply demand, which needs to be in 2, 4 and 6 year cycles. It takes two years to establish a field and the second year of production is usually the best.

Suggestions:

- Reducing the amount of wheat grass in the seed mixtures will be beneficial.
- Finding ergot free to satisfy ESRD (<1% not good enough on seed certificate).
- To fulfill DSA requirements on post 2010 disturbances, it may be challenging to find custom seed mixes (customized based on controls).

- Seed mixes usually include only graminoids. Forbs are an important part of any ecosystem and are rarely available, if at all. Cultivars of easily-grown species, e.g. wheatgrasses, usually dominate seed mixes, preventing establishment of competition-susceptible native perennials.
- Partnerships or cooperatives would do a lot to stimulate the native plant industry. For example companies planning large projects could work with native seed growers and seed supply companies to agree to confirm purchase even if project is delayed.

Grazing management

Ranchers can greatly assist in facilitating reclamation establishment by working with industry and contractors. For example, grazing at appropriate times can be used to lower litter levels or control invasive species. Managing cattle with fencing, water sources and salt when grazing is not appropriate can facilitate initial vegetation establishment on large disturbances.

Communication and cooperation between ranchers and industry will assist the assessment and implementation of site specific grazing management that will benefit both parties in the long term.

Lack of follow up after initial reclamation treatment

If follow up monitoring is used, good decisions can be made that aid in site recovery, such as early re-seeding or fence removal. For industry, the commitment to evaluation and periodic monitoring pays dividends by ensuring a positive successional plant community trajectory and site certification. Reclaimed sites that are not monitored or managed will quickly deteriorate resulting in costly measures required to mitigate problems. Monitoring assessments determine the issues affecting plant community succession and determine whether remedial action is required. Sites should be visited multiple times throughout the growing season, but time and budget are constraints. Ultimately, follow up should be done 1, 2, 5, 7, and 12 years after initial reclamation treatment.

Inspections are rarely done on certified sites unless a complaint is received. It was suggested that a mechanism be included to require monitoring for a specified time period after reclamation certification is obtained.

There is currently more due diligence demonstrated in monitoring of larger scale projects than smaller ones.

Knowledge Gaps and Potential Research Questions

- What role does soil compaction play in the recovery of unstripped minimal disturbance sites? Sites where soil compaction has taken place should be monitored and research questions defined. Research should be funded and given priority. The Mixedgrass NSR is prone to Chinooks and poses increased risk for rutting and compaction of soils during winter construction and development activities. Mixedgrass loamy soils are more at risk than soils in the Dry Mixedgrass.
- More monitoring and research is required to define appropriate seeding rates for sites that require seeding.
- The best methods to manage downy brome including herbicidal products, alternatives to chemical treatment and the timing of chemical application or alternative treatments.
- Effects of soil disturbance on mycrorhizal populations and whether inoculating disturbance will improve restoration potential.
- Does uneven distribution of replaced topsoils on a disturbance promote more species diversity?
- If grazing is used as a tool to promote restoration how can the stocking rate, timing and duration for grazing be determined on a site and issue specific basis?
- Effect of soil disturbance on soil microbes?

- Methods to stimulate seed production in healthy areas surrounding disturbance?
- Regarding wild harvested hay, guidelines to ensure recovery of harvested areas, percentage filling in, and potential for centrally located designated areas to supply native hay. Further study on the success of the technique is required.
- Role of early colonizers in perennial establishment.
- Research is required regarding the role of forbs in plant community succession. Suggestion to include more information on the use of forbs in plantings, perhaps as a follow up to seeding?
- Further research and monitoring regarding the importance of the two-lift stripping procedure to native plant community restoration.
- The planting of wild harvested native grasses without processing first. An example would be *Calamagrostis canadensis*. It is a very light seed and is very difficult to clean.
- Effectiveness of using nursery propagated native plant material, (rooted seedlings) to start hard to establish species (e.g., shrubs, forbs) or, to establish native species on difficult sites (steep terrain, exposed areas, xeric sites).
- Awns play an important role in establishing seed naturally. Processing to remove the awn can damage up to 50% of the seed, increasing the cost. We need to understand the function of the awn. Consider methods of applying seed mulch? Example, *Stipa Comata*, problem with awn, seeds fluffy, how to apply rather than clean it, seed mulch?

Mixedgrass Research / Monitoring Projects Underway

Peggy Desserud: Research on applying wild hay on large (1 ha or greater) disturbances. One 1 ha wellsite in the Sweetgrass Uplands (TWP 1, R 7), wild hay applied July 2012, and one 1.5 wellsite west of Gem in the Majorville area (TWP 25, R 16) wild hay to be applied in 2013. Sites will be monitored for 3 – 4 years. Results will be published.

- Two 1 ha wellsites in the Sweetgrass Uplands (TWP 1, R 8) seeded with native seed mixes in 2011 will be monitored in 2013.

Eric van Gaalen: Several sites (across dry mixed and mixed): hand-raking litter/debris from surrounding undisturbed areas on lease and manually spreading/raking in across disturbed area – sometimes combined with hand seeding. Fairly efficient for small (10mx10m) disturbance and seems effective at propogating adjacent biota, nutrients, reducing wind/water erosion. Monitoring to continue.

- One wild hay site in mixedgrass / dry mixed grass transition north of the Sweetgrass Hills. Mowed/chopped/spread/lightly crimped mid-summer 2012. Required harvest area was approximately three times greater than disturbed area. Monitoring to continue. This has potential to a preferred option over native seed mixes although it takes substantially more time to harvest/spread hay than to seed the site with drill seeder.
- Two sites (one mixed on dry mixed): net free aspen matting to reduce erosion (water/wind): sites in progress, still optimistic about value.
- Planning to use mini-rotospik (mounted on front end of skid steer) for micro-contour improvement on access road for at least one site. Used with great success on a solonetzic dry mixedgrass access trail following intensive remediation job. The mini-roto spik appeared to not damage perennial roots but shifted litter, selaginella, a small amount of soil from high areas to ruts. Within two years, the access was hard to find due to recovery.

Comments on the Map/Target Plant Communities for Mixedgrass

- Cluster 9, Saline Lowlands. Avoidance must be considered. If avoidance is not possible, special mitigation will be required.
- The dominant reference plant community in the Majorville Upland is MGA36 Western Porcupine Grass – Northern Wheat Grass. It should be removed from Cluster 7 and highlighted as its own cluster.
- Sites in the Milk River and Sweetgrass Uplands should be seeded early in April for optimal success. Kentucky bluegrass and Canada bluegrass are common invasive species in this area. Although a component of the cluster they should not be seeded and may require additional management to prevent invasion of disturbed sites.
- Silver sage brush has been seen to recover on blowout and overflow range sites.

It is important to understand the moisture continuum of the ecodistricts of the Mixedgrass NSR. Driest: Lethbridge Plain, Blackfoot Plain, Majorville Upland. Moderate: Cypress Slope, Standard Plain, Vulcan Plain. Moist: Cypress Hills, Milk River Upland, Sweetgrass Upland. Restoration success increases as moisture decreases.

Appendix F Species Names – Common and Scientific

F.1 Species Names Ordered by Common Name

Common Name	Scientific Name	*Synonym*
absinthe wormwood	*Artemisia absinthium*	
alkali cord grass	*Spartina gracilis*	
alsike clover	*Trifolium hybridum*	
awnless brome	*Bromus inermis*	
blue grama	*Bouteloua gracilis*	
bluebunch fescue	*Festuca idahoensis*	
Bluegrass species	*Poa sp.*	
broad-leaved toad-flax	*Linaria dalmatica*	
broomweed	*Gutierrezia sarothrae*	
buckbrush	*Symphoricarpos occidentalis*	
Canada bluegrass	*Poa compressa*	
Canada goldenrod	*Solidago canadensis*	
common dandelion	*Taraxacum officinale*	
common goat's-beard	*Tragopogon dubius*	
common knotweed	*Polygonum arenastrum*	
common pepper-grass	*Lepidium densiflorum*	
common wild rose	*Rosa woodsii*	
common yarrow	*Achillea millefolium*	
creeping thistle	*Cirsium arvense*	
crested wheat grass	*Agropyron pectiniforme*	*Agropyron cristatum ssp. pectinatum*
downy chess	*Bromus tectorum*	
everlasting species	*Antennaria sp.*	
field mouse-ear chickweed	*Cerastium arvense*	
fowl bluegrass	*Poa palustris*	
foxtail barley	*Hordeum jubatum*	
Goosefoot species	*Chenopodium sp.*	
graceful sedge	*Carex praegracilis*	
green needle grass	*Stipa viridula*	*Nassella viridula*
gumweed	*Grindelia squarrosa*	
Indian rice grass	*Oryzopsis hymenoides*	*Achnatherum hymenoides*
intermediate oat grass	*Danthonia intermedia*	
Japanese chess	*Bromus japonicus*	
June grass	*Koeleria macrantha*	
Kentucky bluegrass	*Poa pratensis*	

Common Name	Scientific Name	*Synonym*
lamb's-quarters	*Chenopodium album*	
lance-leaved ironplant	*Haplopappus lanceolatus*	*Pyrrocoma lanceolata*
leafy spurge	*Euphorbia esula*	
low sedge	*Carex stenophylla*	*Carex duriuscula*
mountain rough fescue	*Festuca campestris*	
needle-and-thread	*Stipa comata*	*Hesperostipa comata*
northern wheat grass	*Agropyron dasystachyum*	*Elymus lanceolatus*
Nuttall's salt-meadow grass	*Puccinellia nuttalliana*	
pasture sagewort	*Artemisia frigida*	
pineappleweed	*Matricaria matricarioides*	*Matricaria discoidea*
plains bluegrass	*Poa arida*	
plains muhly	*Muhlenbergia cuspidata*	
plains rough fescue	*Festuca hallii*	
prairie rose	*Rosa arkansana*	
prairie sagewort	*Artemisia ludoviciana*	
prairie selaginella	*Selaginella densa*	
quack grass	*Agropyron repens*	*Elytrigea repens var. repens*
Russian wild rye	*Elymus junceus*	*Psathyrostachys juncea*
Russian-thistle	*Salsola kali*	
salt grass	*Distichlis stricta*	
sand grass	*Calamovilfa longifolia*	
Sandberg bluegrass	*Poa sandbergii*	
sedge species	*Carex sp.*	
sheep fescue	*Festuca ovina*	
silver sagebrush	*Artemisia cana*	
slender wheatgrass	*Agropyron trachycaulum*	*Stipa viridula*
streambank wheatgrass	*Agropyron riparium*	*Elymus lanceolatus ssp. riparius*
summer-cypress	*Kochia scoparia*	*Bassia scoparia*
sun-loving sedge	*Carex pensylvanica*	
thread-leaved sedge	*Carex filifolia*	
timothy	*Phleum pratense*	
toadflax	*Linaria vulgaris*	
tufted hair grass	*Deschampsia cespitosa*	
western wheat grass	*Agropyron smithii*	*Pascopyrum smithii*
white sagebrush	*Artemesia ludoviciana var. gnaphalodes*	*Artemesia ludoviciana ssp. ludoviciana*
white sweet-clover	*Melilotus albus*	
wild vetch	*Vicia americana*	
winter-fat	*Eurotia lanata*	*Krascheninnikovia lanata*
wire rush	*Juncus balticus*	
yellow sweet-clover	*Melilotus officinalis*	

F.2 Species Names Ordered by Scientific Name

Scientific Name	*Synonym*	Common Name
Achillea millefolium		common yarrow
Agropyron dasystachyum	*Elymus lanceolatus*	northern wheat grass
Agropyron pectiniforme	*Agropyron cristatum ssp. pectinatum*	crested wheat grass
Agropyron repens	*Elytrigea repens var. repens*	quack grass
Agropyron riparium	*Elymus lanceolatus ssp. riparius*	streambank wheatgrass
Agropyron smithii	*Pascopyrum smithii*	western wheat grass
Agropyron trachycaulum	*Stipa viridula*	slender wheatgrass
Antennaria sp.		everlasting species
Artemisia absinthium		absinthe wormwood
Artemisia cana		silver sagebrush
Artemisia frigida		pasture sagewort
Artemisia ludoviciana		prairie sagewort
Artemesia ludoviciana var. gnaphalodes	*Artemesia ludoviciana ssp. ludoviciana*	white sagebrush
Bouteloua gracilis		blue grama
Bromus inermis		awnless brome
Bromus japonicus		Japanese chess
Bromus tectorum		downy chess
Calamovilfa longifolia		sand grass
Carex filifolia		thread-leaved sedge
Carex pensylvanica		sun-loving sedge
Carex praegracilis		graceful sedge
Carex sp.		sedge species
Carex stenophylla	*Carex duriuscula*	low sedge
Cerastium arvense		field mouse-ear chickweed
Chenopodium album		lamb's-quarters
Chenopodium sp.		Goosefoot species
Cirsium arvense		creeping thistle
Danthonia intermedia		intermediate oat grass
Deschampsia cespitosa		tufted hair grass
Distichlis stricta		salt grass
Elymus junceus	*Psathyrostachys juncea*	Russian wild rye
Euphorbia esula		leafy spurge
Eurotia lanata	*Krascheninnikovia lanata*	winter-fat
Festuca campestris		mountain rough fescue
Festuca hallii		plains rough fescue
Festuca idahoensis		bluebunch fescue
Festuca ovina		sheep fescue

Scientific Name	*Synonym*	Common Name
Grindelia squarrosa		gumweed
Gutierrezia sarothrae		broomweed
Haplopappus lanceolatus	*Pyrrocoma lanceolata*	lance-leaved ironplant
Hordeum jubatum		foxtail barley
Juncus balticus		wire rush
Kochia scoparia	*Bassia scoparia*	summer-cypress
Koeleria macrantha		June grass
Lepidium densiflorum		common pepper-grass
Linaria dalmatica		broad-leaved toad-flax
Linaria vulgaris		toadflax
Matricaria matricarioides	*Matricaria discoidea*	pineappleweed
Melilotus albus		white sweet-clover
Melilotus officinalis		yellow sweet-clover
Muhlenbergia cuspidata		plains muhly
Oryzopsis hymenoides	*Achnatherum hymenoides*	Indian rice grass
Phleum pratense		timothy
Poa arida		plains bluegrass
Poa compressa		Canada bluegrass
Poa palustris		fowl bluegrass
Poa pratensis		Kentucky bluegrass
Poa sandbergii		Sandberg bluegrass
Poa sp.		Bluegrass species
Polygonum arenastrum		common knotweed
Puccinellia nuttalliana		Nuttall's salt-meadow grass
Rosa arkansana		prairie rose
Rosa woodsii		common wild rose
Salsola kali		Russian-thistle
Selaginella densa		prairie selaginella
Solidago canadensis		Canada goldenrod
Spartina gracilis		alkali cord grass
Stipa comata	*Hesperostipa comata*	needle-and-thread
Stipa viridula	*Nassella viridula*	green needle grass
Symphoricarpos occidentalis		buckbrush
Taraxacum officinale		common dandelion
Tragopogon dubius		common goat's-beard
Trifolium hybridum		alsike clover
Vicia americana		wild vetch