Evaluating the Revegetation Success of Foothills Fescue Grassland

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1.0 Introduction

Indigenous temperate grasslands are the most altered ecosystems on earth (Heindenreich 2009). Restoring the remaining fescue grassland following industrial activity has been, and continues to be a priority for research activities in Southern Alberta (Southwest Alberta Sustainable Community Initiative -Development and Consultation Roadmap March 2008; the Hard Grass Advocate, 2010; Foothills Restoration Forum, 2006). Foothills Fescue Prairie (Rough Fescue – Idaho Fescue – Parry Oat grass plant community) is an ecosystem type with a high biodiversity of plants (Provincial Museum of Alberta 1996), including rare and uncommon species. This area is also home to several endangered wildlife species, including ferruginous hawk, short-eared owl, mountain plover, long-billed curlew, upland sandpiper and Sprague's pipit. Loss of native ecosystems can result in in economic impacts threatening health, food production, climate stability and basic need such as clean water (Wilson 2009). Maintaining ecological integrity in the remaining 20% of Foothills Fescue in Alberta is critical to the plant and animal species which are not able to live on cultivated lands.

To minimize disturbances on native prairies, both Alberta Environment and Sustainable Resources Development (ESRD) and the Alberta Energy Regulator (AER) emphasized the avoidance of sensitive prairie ecosystems in industrial development. In conjunction with pre-planning to reduce disturbance, and avoiding rough fescue grassland, restoring areas affected by oil and gas activities to former fescue grassland conditions is important for maintaining wildlife species biodiversity and habitat. For industry to continue to have access to this rare grassland community, it is important that every effort is made at reclaiming fescue grassland to its former ecological functions.

Seeding fescue grassland is often associated with low emergence and poor establishment. Alternative methods for re-vegetating fescue grassland include fescue plugs and the use of native hay. Each method has been partially effective, depending on site access, hay harvest techniques and operational costs.

AITF (Alberta Innovates - Technology Futures) has previously demonstrated that plains rough fescue grassland can be restored to its former ecological function following oil & gas disturbances (Woosaree and James, 2004; Woosaree, 2007). Specifically, the research made use of seeding early colonizing species along with plains rough fescue. Results showed that native seed mixes have the potential for both effective site stabilization and establishing a more "ecologically compatible" plant community on well-site disturbances. The question was proposed as to whether the same technique could be repeated in the foothills fescue community.

The primary objective of this project was to demonstrate the ability to re-establish foothills fescue grassland, once it is disturbed. Additional research questions include:

- Can a seeded community resist invasion of forage species?
- Can management practices be augmented to favour a native community?
- Are there survival/establishment benefits to seeding in the fall compared to the spring?
- Can plugs of native species be successfully planted while dormant?
- Will cultivated oats enable seed mixes to be based more on late seral species?
- Will the use of late seral species accelerate native prairie recovery and expedite a reclamation certificate?
- Will the use of different vegetation layers favour occupancy by sensitive species such as sharp-tailed grouse or other ground nesting birds?

2.0 Methodology

In fall 2011, a new study area was located on a Shell Canada lease, 1.6 km west south west of Del Bonita, AB. This previously cultivated land was approximately 1 ha in size, bordered by fescue grassland to the North and West. The soil is Orthic Black Chernozem on medium textured soils- silty loam/loam (AGRISID, 2014). Previous land use of the study area was the cultivation of field barley.

Seed harvesting by hand from the surrounding area occurred in fall of 2011 and seeds were used to grow plugs of different species for on-site planting (table 2). This experiment consisted of five treatments: spring seeding, spring seeding and plug planting, fall seeding, fall seeding and plug planting, and a wild harvested seed mix.

The study consisted of a completely randomized design with three replicates. The plots were 15 m by 20 m, for a total test area of 4500 m^2 (roughly 0.5 ha) (Fig 1). The spring seeding and planting occurred on June 21, 2012. The plots were selectively sprayed to control for patches of smooth brome grass (*Bromus inermis*) and Canada thistle (*Cirsium arvense*) on August 1st 2012, followed by mowing on September 13, 2012. Fall seeding and planting occurred on October 18, 2012. Leftover seed-mix was seeded at half the rate on the perimeter of the plot to cover bare areas outside of the plot.

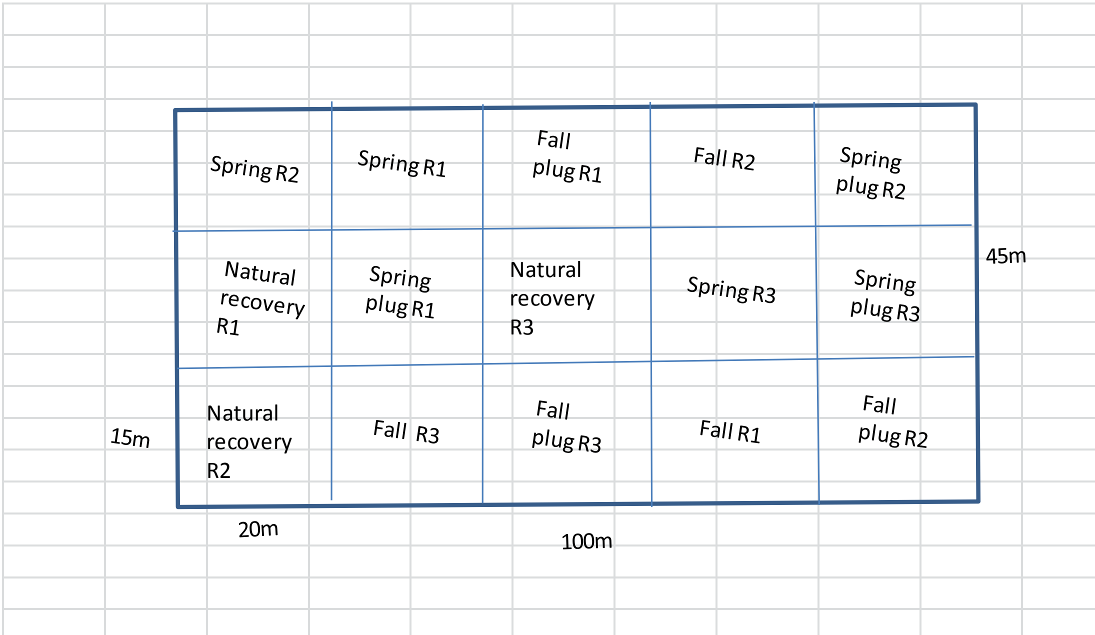

Figure 1 Study design at Del Bonita.

The area was disked in the spring prior to seeding. The Foothills Fescue Rangeland Plant Community Guide was consulted for seed mix design. The resulting seed mix (table 1) consisted of Northern and Western Wheatgrass-Green needle grass plant community (FFA27) with the addition of Parry's oat grass (*Danthonia parryi*) and Idaho fescue (*Festuca idahoensis*) to favour many other late seral foothills fescue plant communities. Wheat grasses and early colonizers were restricted in percentages and emphasis was placed on plant community diversity. Cultivated oats were put in the seed-mix to help the seed flow through the seed drill and to provide wind/water erosion control in the first year of establishment. Third party analysis of seed purity, germination and percent pure seed were completed for all purchased species. The seed mix (Table 1) was seeded at approximately 2000 seeds/m^2 or approximately 8 kg/ha. The seeder was calibrated for half the seeding rate and the plots were cross-seeded.

Collected seed was cleaned, germinated in petri dishes then seeded into Rootrainers® in November of 2011. On May 26, 2012, the plugs were removed from the greenhouse and placed outside to acclimatize. The plugs (Fig 1) were counted and split in half to permit both spring and fall planting. The plugs were planted directly after seeding in a fully randomized block design with equal densities of plugs randomized throughout each block.

Fall seeding and planting was completed on October 18, 2012. Plugs were acclimatized outdoors and were dormant (frozen solid) when planted. The weather was monitored via remote weather station for the right soil temperature of 4 degrees Celsius before seeding so that planted seed would not germinate that season. It was intended for the seed to germinate in the following spring.

Table 1. Seed mix used in the study. The mix was based on Pure Live Seed (PLS).

Species	Common Name	Percent of Mix
Festuca campestris	Foothills rough fescue	40
Hesperostipa curtiseta	Western porcupine grass	8
Pascopyrum smithii	Western wheatgrass	5
Elymus lanceolatus	Northern wheatgrass	5
Koeleria macrantha	June grass	5
Festuca idahoensis	Idaho fescue	6
Danthonia parryi	Parry's oat grass	5
Nassela viridula	Green needle grass	5
Hesperostipa comata	Needle and thread grass	6
Agropyron subsecundum	Awned wheat grass	5
Avena sativa	Cultivated oats	10
	Total	100

Figure 2. Plant plugs incorporated into the plug treatments immediately before spring planting.

Table 2. Plant plugs per plot, included in the spring and fall planting, number per plot

			Plug Counts/Plot	
	Species	**English Name**	**Spring**	**Fall**
Legumes	*Oxytropis viscida*	Viscid locoweed	41	18
	Oxytropis monticola	Late yellow locoweed	13	9
	Astragalus miser	Timber milkvetch	43	35
	Astragalus crassicarpos	Ground plum	39	26
	Thermopsis rhombifolia	Golden/buck bean	1	1
	Astragalus striatus	Ascending purple milkvetch	46	42
Forbs	*Hymenoxys richardsonii*	Colorado rubber plant	22	23
	Heterotheca villosa	Hairy golden aster	20	20
	Gallium boreale	Northern bedstraw	24	17
	Aster falcatus	Creeping white prairie aster	4	8
	Erigeron caespitosa	Tufted fleabane	20	25
	Liatris ligulistylus	Meadow blazing star	20	0
	Artemisia ludoviciana	Prairie sage	6	10
Grasses	*Danthonia Parryi*	Parry's oatgrass	17	0
	Festuca campestris	Foothills rough fescue	292	187
	Helictotrichon hookerii	Hooker's oatgrass	23	11
		Total	631	432

Note. Discrepancies in plant counts are attributed to loss or additional emergence in trays throughout summer.

3.0 Results and Discussion

Plot monitoring and maintenance was conducted on July 9th and 10th, 2014. Community composition and plug survival counts for the fall plantings were collected. The smooth brome (*Bromus inermis*) around the perimeter of the site was observed to still persist after multiple glyphosate applications. A backpack sprayer application of Curtail M© (Clopyralid, MCPA ester) and glyphosate was used to selectively control the spread of were observed on-site. This seems to have spread from a small patch at the entrance gate in 2013 to multiple 6-10 ft. diameter patches in 2014 (Fig 2). To mitigate the spread of downy brome, hand pulling of downy brome plants was accomplished during the site visit.

Figure 3. A downy brome patch (in red box) prior to hand weeding

The natural regeneration plots (Fig 3) were high in both infilling forbs and annual disturbance species; higher rates of infill were observed in bare-ground areas than within treatments with a grass seed mix.

Figure 4. A natural regeneration plot showing good infill of native disturbance species

Figure 4 shows the dominant plant groups observed for each treatment. The grasses were found to have a higher importance value in the spring treatments (both spring seed and spring seed and plug), likely relating to greater seed mix establishment. In contrast, importance values were lower for the fall and natural recovery treatments, correlating with higher bare-ground values for those treatments (Fig 5). Bare-ground leaves niches (or vacuums) available for the ingress and colonization of annual, perennial and noxious weed species. The bare-ground values are expected to decrease over time as litter builds up within the treatment plots and plant competition for space and resources increase.

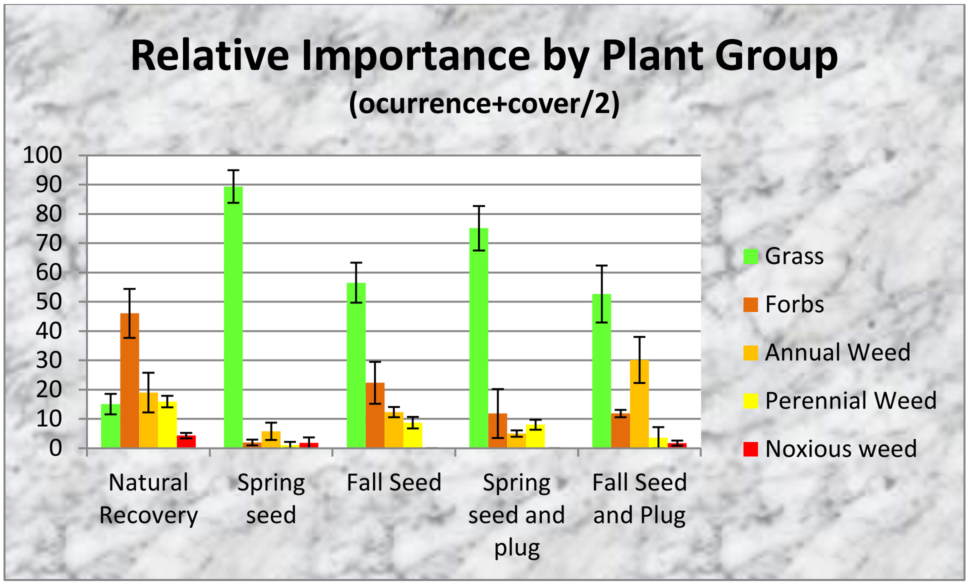

Figure 5. Plant group importance between treatments. Importance is described as the plant group (e.g. grass, forb, etc.) occurrence and associated cover within a plot, divided by 2. Layers of cover can make values over 100%

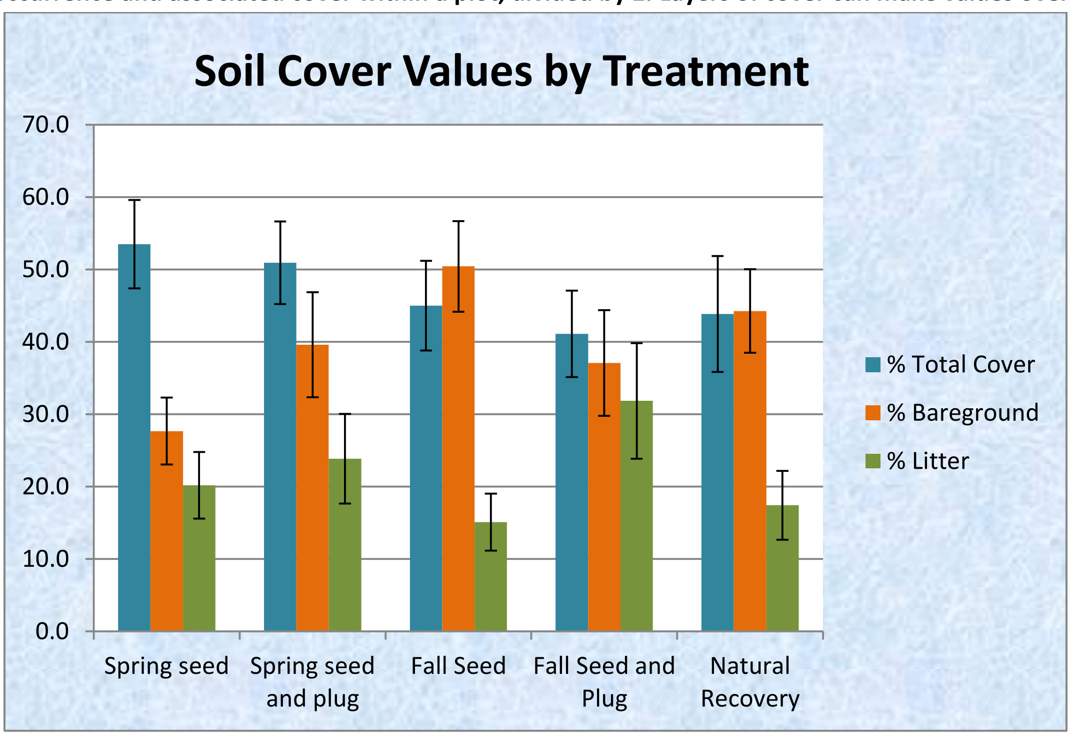

Figure 6. Soil cover values for plants, bare-ground and litter for each treatment.

The analysis of species richness on-site (Fig 6) indicates that the sixteen species planted in the plug treatments significantly adds to plant diversity within plots. Diversity on-site is high in early years as a response to the bare-ground and early disturbance regimes. Over time, as competition and stability increase, diversity is expected to mimic the reference area.

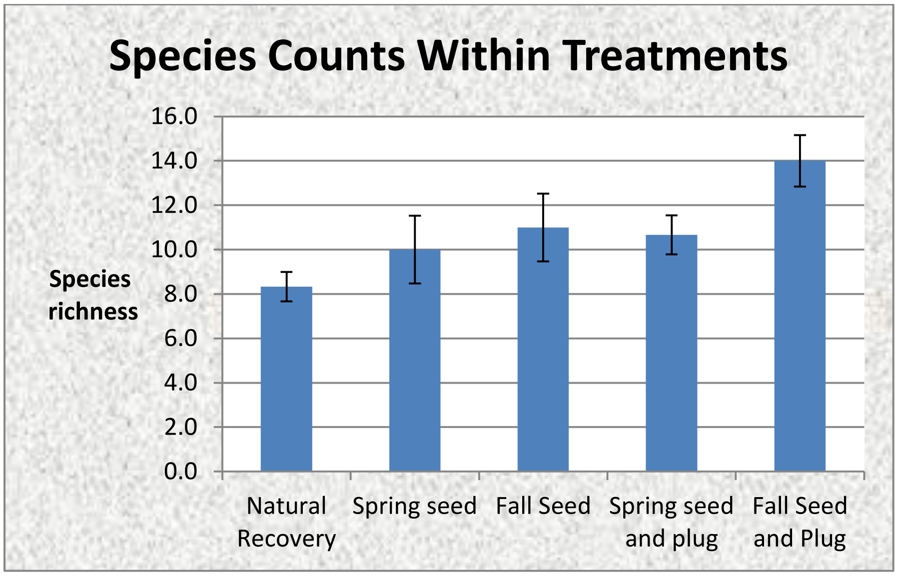

Figure 7. Species richness for each treatment, comparing the number of species found in each treatment (average n=3) to a reference area.

The plug planting treatments showed higher diversity values and higher forb cover rates; the spring planting treatments had higher survival rates than the fall planting treatments. Qualitative observations reported in Woosaree (2013) suggested that plugs require time to grow roots into surrounding soil before winter, as frost heave tends to push plugs out of the ground. Of the sixteen species planted, some did not transplant well at all, and some exceeded expectations. Based on results, other techniques would need to be developed for meadow blazingstar (*Liatris punctata*) and the two milkvetch (*Astragalus species*) (Fig 7).

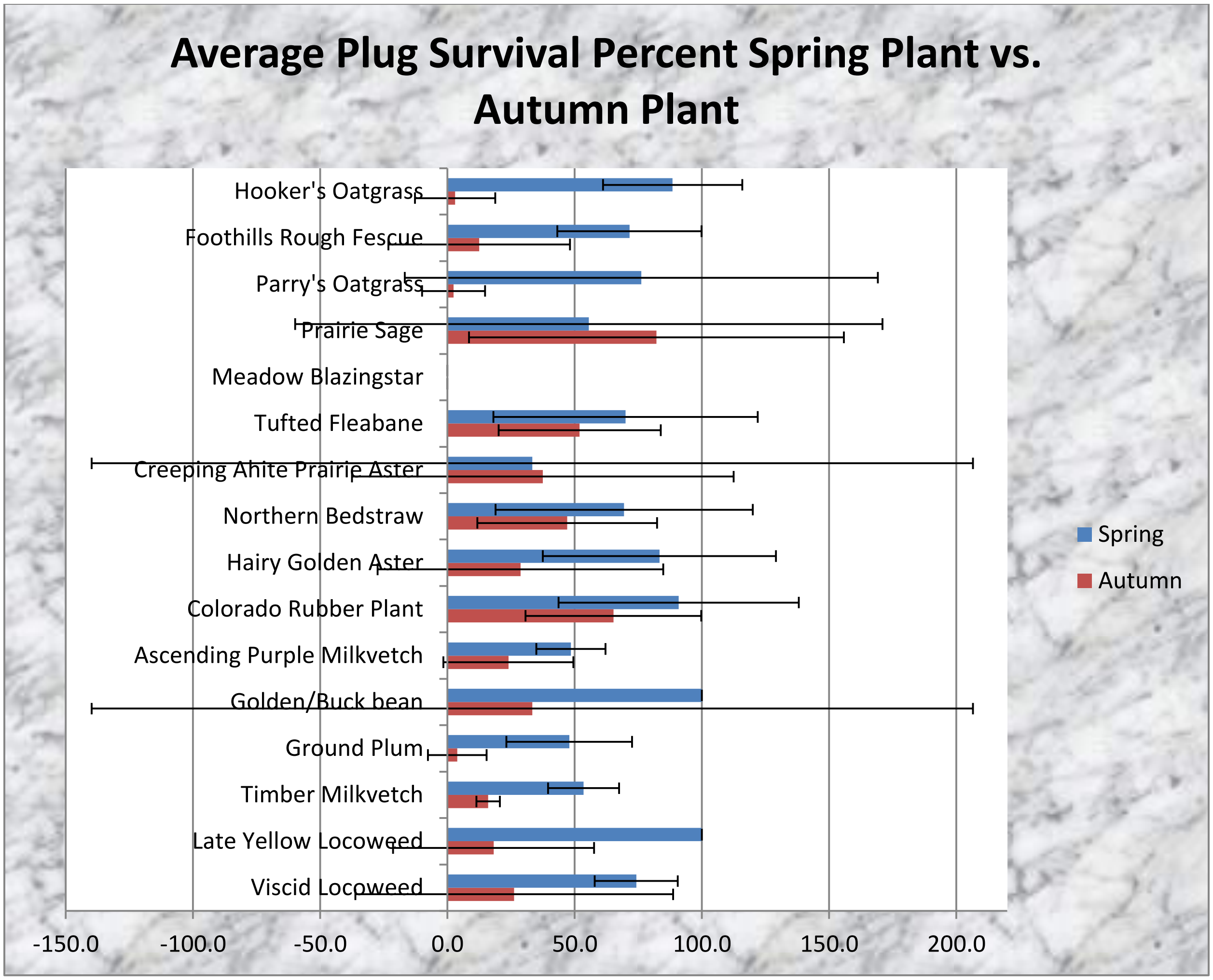

Figure 8. Average percent plug survival rates (n=3) in the spring and fall plug planting treatments. High error due to very low plug amounts e.g. Golden bean; one planted per plot

Comparing communities between restored land and undisturbed reference areas can be a convenient grading system; however, ecological recovery requires a much longer time to develop stable and long-lived plant communities. Table 3 lists species found within the treatments and undisturbed reference areas. The table colours refer to the following different plant groups: green for grass and grass-like species, orange for forbs, beige for perennial weeds, yellow for annual weeds, red for noxious weeds, and blue for mosses and lichens. No shrubs or trees were observed in any of the treatments.

Treatments with seed mixes were observed to be early to mid-seral grass dominant, which is intended for early cover and erosion control. Over time, it is expected that the infill of native forbs will increase, dominant with mid-late seral species (from the seed mix and from the surrounding landscape), and early seral grasses will decrease. Annual weeds are not considered to be undesirables as they are expected to recede as cover values from perennials increase, these annuals are known to additionally provide erosion control. Noxious weeds are a serious risk to community re-vegetation trajectories towards the reference area and need to be controlled to avoid a modified community.

Table 3. Community composition of treatments and a reference area.

Adjacent Reference Area		**Spring Seed**		**Spring Seed and Plugs**	
Name	**Average cover n=4**	**Name**	**Average cover n=12**	Name	**Average cover n=12**
Idaho fescue	38.8	Awned wheat grass	16.3	Awned wheat grass	17.1
Foothills rough fescue	26.3	Western wheat grass	8.8	Slender wheatgrass	9.6
Pasture sagewort	6.5	Green needle grass	5.8	Western wheat grass	3.9
Kentucky bluegrass	6.3	Slender wheatgrass	5.3	Green needle grass	3.3
Fleabane species	6.3	Needle and thread	4.6	Rocky mountain fescue	3.3
Prairie selaginella	4.5	Western porcupine grass	3.8	Western porcupine grass	2.5
Western wheat	3.3	June grass	3.5	Prairie sagewort	2.5
Low goldenrod	3.3	Rocky mountain fescue	2.9	Kentucky bluegrass	2.4
Northern wheat	1.3	Flixweed	0.5	Foothills rough fescue	1.7
Blunt Sedge	0.8	Cheat grass	0.5	June grass	1.3
Sun loving sedge	0.8	Foothills rough fescue	0.4	Tufted fleabane	0.8
Perennial lupine	0.8	Dandelion	0.4	Flixweed	0.5
Golden bean	0.5	Prairie sagewort	0.3	Hairy golden aster	0.4
Prairie crocus	0.5	Stinkweed/pennycress	0.3	Dandelion	0.4
Mealy pixie cup lichen	0.5	Idaho fescue	0.2	Tartary buckwheat	0.3
				Blue flax	0.2
				Viscid locoweed	0.2
				Narrow leaved goosefoot	0.1
				Wheat	0.1

Note.

	grass and grass-like species
	forbs
	perennial weeds

	annual weeds
	noxious weeds
	mosses and lichens

Wild Collected/Natural Recovery

Name	Average cover n=12
Prairie sagewort	23.3
Yellow sweet clover	7.5
Foxtail barley	3.8
Dandelion	3.3
Flixweed	1.7
Slender wheatgrass	1.3
Stinkweed/pennycress	1.0
Tartary buckwheat	0.5
Hairy golden aster	0.4
Kochia	0.4
Undifferentiated seedling	0.2
Canada Thistle	0.2
Cheat grass	0.2
Narrow leaved goosefoot	0.1

Fall Seed

Name	Average cover n=12
Prairie sagewort	12.1
Awned wheat grass	9.8
Slender wheatgrass	4.2
Green needle grass	3.8
Needle and thread	3.3
Flixweed	1.9
Dandelion	1.9
Yellow sweet clover	1.7
Western porcupine grass	1.4
June grass	1.3
Western wheat grass	1.1
Foxtail barley	0.8
Narrow leaved goosefoot	0.4
Stinkweed/pennycress	0.4
Persian darnel	0.3
Rocky mountain fescue	0.3
Tartary buckwheat	0.3
Plains bluegrass	0.2

Fall Seed and Plugs

Name	Average cover n=12
Awned wheat grass	12.9
Green needle grass	4.8
Tartary buckwheat	3.8
Foxtail barley	2.9
Prairie sagewort	2.9
Kochia	2.9
Dandelion	2.1
Western wheat grass	1.8
June grass	1.3
Western porcupine grass	0.8
Prairie sage	0.8
Flixweed	0.8
Persian darnel	0.5
Stinkweed/pennycress	0.4
Needle and thread	0.3
Tufted fleabane	0.2
Cultivated oats	0.2
Slender wheatgrass	0.1
Undifferentiated seedling	0.1
Wheat	0.1
Canada Thistle	0.1
Cheat grass	0.1

Note.

(green)	grass and grass-like species
(orange)	forbs
(pink)	perennial weeds
(yellow)	annual weeds
(red)	noxious weeds
(blue)	mosses and lichens

Figure 9. Visual reference of fall seed (left half) vs spring seed (right half) treatments in 2014, second growing season for fall seeded, third for spring seeded.

Figure 10. An empty plot left for natural regeneration showing good cover and erosion control by infilling native forbs and a re-occurring smooth brome grass patch (red).

Figure 11. A Northern bedstraw plug already flowering on-site. Flowers will produce seed and increase forb frequency and cover across the area.

Figure 12. Early locoweed, a planted plug showing high vigour. This species is expected to set seed this year and add to the soil seed bank

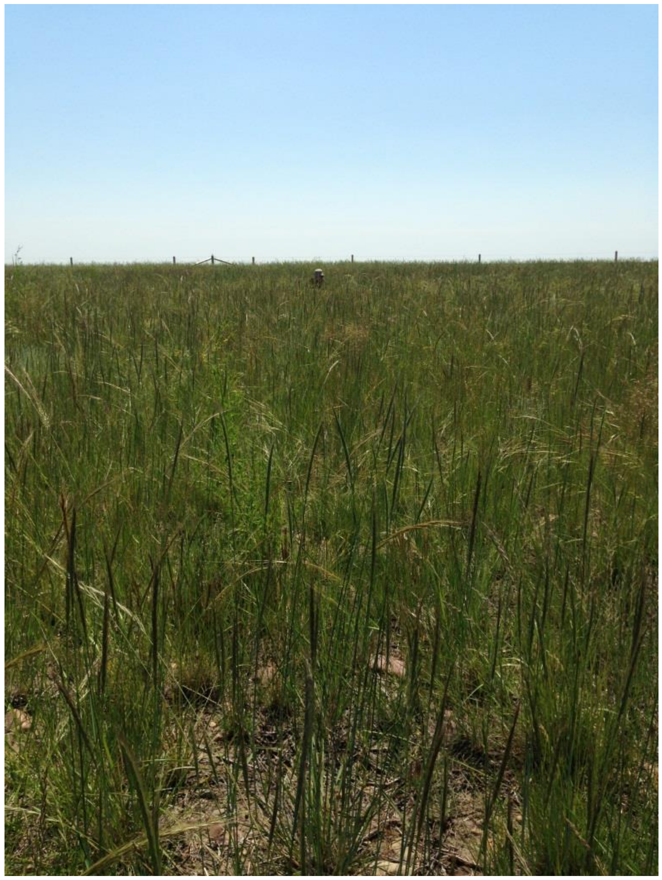

Figure 13. Wheat grasses and needle grasses showing good second year cover, good vigour and seed set in year 2.

4.0 Conclusion

Plug survival rates show that the procedure used in this study does not support the fall planting of plugs. Woosaree (2013) suggests that planting dormant corresponds to a lack of root development into surrounding soil, therefore plants cannot resist frost heave and/or acquire adequate moisture to prevent dessication after being pushed up and exposed. Alternative procedures for fall planting could include the incorporation of sand into the soil medium of the plug so it is not as ridgid and may not be heaved out.

All plugs that did survive are adding to the diversity onsite. Many of these plugs have gone into seed in the second year after planting, adding to the on-site soil seed bank. These plugs are acting as islands initiating community re-seeding known to change plant communities over time. The full benefit of the plug planting will not be realized until farther into succession, when data can provide insite into which species are best used and the associated numbers required to observe advantaged/re-vegetation efficiencies. Forbs are not currently included in seed mixes as the seed has not been developed, traditional harvesting tools and seed cleaning techniques are not ideal for forb seeds. Having forbs onsite also restricts herbicide usage, most noxious weeds are broadleaves and broadcast spraying of a broadleaf selective herbicide would kill the weed but also any other desireable forbs onsite. With forbs in the treatments any broadleaf herbicide will have to be spot sprayed to reduce collateral damage.

The average number of plugs planted in the plug planting plots equaled 5,900 plugs/ha (177 plugs/plot). This is estimated to cost approximately $15,000/ha (roughly $2 per plug and three days labour for one planter). A cost-benefit analysis is required to further understand whether the added cost of the plug development and deployment is worthwhile.

Continued maintenance at the study site is required to ensure that the encroachment of smooth brome (*Bromus inermis*) and Canada thistle (*Cirsium arvense*) do not take over the site and cause the site to become a modified grassland. After multiple sprayings in good conditions, the smooth brome continues to expand, so alternate measures are in order. We suggest a spray followed two weeks later by root removal (shovel disturbance) followed by a second spray after green up. The Canada thistle is currently under control on-site owing to spot applications of glyphosate and Curtail M© . The cheat grass (Bromus tectorum) infestation has been hand weeded twice, and maintenance regimes to mow repeatedly have been put in place, this technique has been successful in the Grasslands National Park in Saskatchewan. Therefore, it is expected that the seeded communities can resist the invasion of forage species with the appropriate mitigation and management practices within the initial years of estalishment.

The seed mix used within the study was a very advanced mix with a good diversity of grasses of differing age classes, seeded at lower percentages. While the data shows better establishment of the spring seeded plots, the warming trend after seeding of the fall plots encouraged germination. Losses from the fall planted seed are likely related to germination then cold weather mortality of seedlings. Even with seed loss, both spring and fall seeding treatments show good plant cover and growth; some of the longer lived species have been witnessed to establish within the treatments, expected to grow in cover values as the site reaches five to ten years after seeding. As a result, there are survival benefits associated with spring seeding and plug planting, including the availability of moisture and the extended time for root establishment over the growth season.

The cultivated oats in the seed mix were successful in providing wind and water erosion control in the first year. Sites required mowing near the end of the first growing season to prevent seed set and germination in the following year. The early cover given by oats enables a higher percent of late seral species in the seed mix. This is postulated to giving a more similiar grassland to reference areas over time. An advancement in seed mixes since this project initiated has been the inclusion of a small percentage of ticklegrass (*Agrostis scabra*) as an early cover species. This would require no mowing, it seeds the first year after planting and is a short lived disturbance perennial.

The natural recovery plots are currently as expected, with forbs and annual broadleaves providing the fastest growth, cover and erosion control. Early, short-lived disturbance grasses have been observed within treatments, and continuous infill from surrounding plots is expected to continue.

Currently sites are meeting the objective of the project- demonstrating the primary re-establishment of foothills fescue grassland. In this trial the late seral species have not yet established onsite, continued monitoring will be necessary to track succession and see if late seral species can begin to dominate the grassland as is intended.

To date, wildlife monitoring has not been incorporated into the follow-up monitoring program. As a result, it is unknown whether the use of different vegetation layers favour the occupancy by sensitive species such as sharp-tailed grouse or just supporting other important ground nesting birds. In the future we may consider setting up a camera to document wildlife usage of the site, which may be a useful indicator of the value of established fescue grassland as a natural capital.

5.0 References

Adam, B.W., R. Ehlert, D. Moisey and R.L. McNeil. 2003. Range Plant Communities and Range Health Assessment Guidelines for the Foothills fescue Natural Subregion. Rangeland Management Branch, Public Lands Division, Alberta Sustainable Resource Development. Lethbridge. Pub. No. T/044 64 pp.

Agroclimatic Information Service.2012. Current and Historical Alberta Weather Station Data Viewer. http://www.agric.gov.ab.ca/acis/alberta-weather-data-viewer.jsp

Alberta Environment, 2011. 2010 Reclamation Criteria for Wellsites and Associated Facilities Application Guidelines. Alberta Environment, Edmonton, Alberta. 52 pp.

Desserud, P.A. 2011. Rough fescue (Festuca hallii) ecology and restoration in Central Alberta. PhD thesis. University of Alberta, Edmonton Alberta. 197 pp.

Foothills Restoration Forum. 2006. Prospectus for a Shared Approach to Research:
Conserving and Restoring Rough Fescue Grasslands.
http://www.foothillsrestorationforum.com/storage/FRF%20Prospectus%20Draft%202%20dk.pdf

Heidenreich B. 2009. What are global temperate grasslands worth? A case for their protection:
An Analysis of Current Research on the Total Economic Value of Indigenous Temperate Grasslands Published by World Temperate Grasslands Conservative Initiative. 21 pp.

Provincial Museum of Alberta. 1996. A Bioinventory of McIntyre Ranch: Extensive Fescue-Dominated Grassland in Southern Alberta. W. B. McGillivray and M. Steinhilber (eds). Natural History Occasional Paper No. 22.

Wilson, S. J. 2009. The Value of BC’s Grasslands: Exploring Ecosystem Values and Incentives for Conservation. Grasslands Conservation Council of British Columbia. 45 pp.

Woosaree, J. 2007. Restoration of rough fescue prairie on a pipeline right-of-way in Bodo Hills. A final report prepared for Penn West Petroleum ltd and Alberta Sustainable Resources Development. 31 pp.

Woosaree, J. and B. James. 2004. Restoring fescue prairie grassland following wellsites disturbances on fescue prairie in east-central Alberta. 16th Int'l Conference, Society for Ecological Restoration, August 24-26, 2004, Victoria, Canada.