Long-term Revegetation Success of Industry Reclamation Techniques for Native Grassland:

Foothills Fescue Foothills Parkland and Montane Natural Subregions

April 2015

Phase 1
Literature Review and Case Studies
2014

Prepared by:
J. Lancaster, R. Adams, B. Adams and P. Desserud

Cover Photos

Pekisko Rangelands, Courtesy of Jane Lancaster, Kestrel Research Inc.

Rough Fescue, Courtesy of Donna Watt, CorPirate Services

Executive Summary Photos

Foothills Fescue, Courtesy of Donna Watt, CorPirate Services

Example Monitoring Frame, Courtesy of Jane Lancaster, Kestrel Research Inc.

Long-term Revegetation Success of Industry Reclamation Techniques for Native Grassland:

Foothills Fescue, Foothills Parkland and Montane Natural Subregions:

Phase 1 – Literature Review and Case Studies - 2014

Date: April 9th, 2015

Prepared for:

Land and Forest Policy Branch, Alberta Environment and Sustainable Resource Development

Prepared by:

J. Lancaster, R. Adams, B. Adams and P. Desserud

Sponsorship

Alberta Environment and Sustainable Resource Development (ESRD)
Alberta Environmental Monitoring, Evaluation & Reporting Agency (AEMERA)
MFC Resource Partnership

Contributors

CorPirate Services

Citation for this Document:

Lancaster J., R. Adams, B. Adams and P. Desserud. 2016. Long-term Revegetation Success of Industry Reclamation Techniques for Native Grassland: Foothills Fescue, Foothills Parkland and Montane Natural Subregions; Phase 1 - Literature Review and Case Studies – 2014. Prepared for: Land and Forest Policy Branch, Alberta Environment and Sustainable Resource Development.

Acknowledgements

The authors would like to acknowledge a funding partnership for this research project from; Alberta Environment and Sustainable Resource Development (ESRD) through the Alberta Environmental Monitoring, Evaluation & Reporting Agency (AEMERA) and MFC Resource Partnership. In kind support was provided by staff from the Range Resource Management Branch, Public Lands Division, Alberta Environment and Sustainable Resource Development.

Executive Summary

The purpose of this research project is to provide industry and the government of Alberta regulatory agencies with results and key learnings regarding the long-term recovery of native grasslands from industrial disturbance. Over the past decade considerable attention has been directed to the profound difficulty of restoring disturbed rough fescue grasslands.

The Phase 1 - 2014 monitoring project focuses on topsoil disturbances and matted wellsites and documents the long-term outcome of revegetation strategies used in the Foothills Fescue, Foothills Parkland and Montane Natural Subregions of Alberta. The development of recovery strategies for the foothills fescue grasslands of southwestern Alberta will proceed somewhat differently than previous recovery strategies. The three prior strategies involved evaluation of reclamation outcomes in a single natural Subregion (Dry Mixedgrass, Mixedgrass and Northern Fescue) each year. Given the profound challenges in achieving plant community restoration in the mesic grasslands of the southwest, this strategy will examine reclamation and restoration outcomes in three natural subregions (Foothills Fescue, Foothills Parkland and Montane) that have quite similar rough fescue dominated plant communities, albeit with varying climatic conditions and associated forest and shrub communities. In recent years, these NSRs have experienced relatively lesser amounts of oil and gas exploration and development and so more effort is required to research and located appropriate project sites to evaluate reclamation outcomes.

Three major categories of wellsites were evaluated in 2014 defined by time of construction and abandonment. Sites developed prior to 1963, representing sites developed prior to Alberta's first reclamation legislation and regulations, were sampled opportunistically to see if natural recovery might be observed as in drier grassland natural subregions. Wellsites in this category were predominantly modified over time to non-native agronomic grass species like awnless brome *(Bromus inermis)*, Kentucky bluegrass *(Poa pratensis)* and timothy *(Phleum pratense)*. The general conclusion for natural recovery in the absence of any knowledge about associated soil handling practices is that this strategy has not resulted in much recovery of the native character of these plant communities. The picture is further complicated as most of these sites are located in lower slope/valley bottom locations with cumulative impacts from other land use pressures.

The second category considered wellsites developed from 1963 to 2000 which reflected early reclamation regulation and practices. Site established pre-1980 resembled the pre-1963 sites and succession was primarily to non-native species with limited infilling of natives or recovery to the offsite character of the plant community. On the post-1980 sites, succession was sharply influenced by cultivars that had been considered as acceptable substitutions of native species for the times they were seeded (Sheep fescue *(Festuca ovina)* and Cicer milk vetch *(Astragalus cicer*).

A case study (1999 – 2002) with good documentation of early minimal disturbance construction practices and use of primarily native seed mixes produced interesting results. Excluding wellsites from grazing resulted with a greater variety of grass species re-establishing on the disturbance in the first year. However, more weeds established and in the long-term diversity declined. Non-native timothy, which was present in the seed bank, is a prolific seed producer and establishes readily on disturbance, developing dense tall stands that shade out other seedlings. The resulting plant communities are unhealthy and isolated from resource utilization. Isolating seeded disturbances from grazing for more than two years post-seeding has detrimental consequences over the long-term and will likely result in failure to establish a healthy native plant community. Grazing pioneer species like non-native timothy is an important tool to reduce its biomass.

Using seed for decreaser species like rough fescue and Parry's oat grass *(Danthonia parryi)* is not effective in re-seeding grasslands that are "trending-to-modified" due to the presence of invasive non-native grass species like timothy, Kentucky bluegrass and awnless brome. Treatment to remove these species from the seed bank must occur first if seeding desirable decreaser species is to have potential for establishment.

The third category considered post-2000 wellsites which applied more advanced practices including matting, plug seeding and seeding of wild-harvested plant material. On these sites, there were some hopeful expressions of native species infilling. Recruitment was evident including a very strong re-establishment of rough fescue on the Lewis wellsite where the surface topsoil had not been stripped.

Use of matting to conserve topsoil and native plants can be effective in reducing disturbance and conserving plant propagules and litter. However, timely removal of the matting is required prior to the growing season. The delayed removal of mats into the growing season can cause buried plants to die or be severely affected. On matted sites that are fenced from grazing, a dense litter layer may persist, suppressing growth of rooted perennials and infill. These sites may be stable, but groundcover and shorter structural layers may be absent, reducing plant community health. On the matted site studied, the number of native perennial forbs was also still reduced after 11 years compared to the surrounding grassland.

The 2015 field season will expand the sampling of reclaimed project sites in the Foothills Fescue and Montane natural subregions.

Table of Contents

List of Figures

List of Tables

Abbreviations

ACIMS	Alberta Conservation Information Management System
AGRASID	Agricultural Region of Alberta Soil Information Database
cm	centimetre
ERS	Ecological Range Site
ESRD	Alberta Environment and Sustainable Resource Development
GPS	global positioning system
GVI	Grassland Vegetation Inventory
ha	hectare
kg	kilogram
km	kilometre
m	metre
NSR	Natural Subregion
PLS	pure live seed
PNC	Potential Natural Community
RoW	right-of-way
RPC	Reference Plant Community
RRMP	Range Resource Management Program
SCA	Soil Correlation Area
ESIS	Ecological Site Information System
AEMERA	Alberta Environmental Monitoring, Evaluation & Reporting Agency
FF	Foothills Fescue Natural Subregion
FP	Foothills Parkland Natural Subregion
Montane	Montane Natural Subregion

1 INTRODUCTION

Industrial development on native grasslands is increasing across the prairies. Healthy range plant communities perform important ecological functions including; net primary productivity, maintenance of soil/site stability, capture and beneficial release of water, nutrient and energy cycling and plant species functional diversity (Adams et al. 2013). Unless we can restore functioning and self-sustaining native plant communities that are resilient to invasive species, we stand to lose our native grasslands. It is clear that our past and some current reclamation practices are not achieving this goal. The goal of this research project is to gather data to understand the long-term effects of past and current reclamation strategies with a view to promoting industry stewardship by improving restoration potential for native plant communities.

This study is part of a multi-year, multi-stakeholder initiative to revisit industry revegetation strategies for native prairie in the Grassland Natural Region. Updating the guidelines is a two-step process based on collecting existing learnings, conducting field studies to gather new insight and then using this information to develop practical recovery strategies. The first document from this initiative; *"Recovery Strategies for Industrial Development in Native Prairie: The Dry Mixedgrass Natural Subregion of Alberta – 1st Approximation"* (Neville et al. 2013) was published February 2013. Data collection for the Mixedgrass occurred in 2011 and the resulting document, *"Recovery Strategies for Industrial Development in Native Prairie: The Mixedgrass Natural Subregion of Alberta – 1st Approximation"* (Neville et al. 2014) was published in March 2014.

This report summarizes ***Phase 1 field data collection*** from several sources to assess whether past and present reclamation strategies are achieving restoration of native grasslands in the Foothills Fescue, Foothills Parkland and Montane Natural Subregions (NSR) (Figure 1-1). It also includes a literature review of reclamation approaches and management relevant to the Foothills Fescue (FF), Foothills Parkland (FP) and Montane Natural Subregions.

The purpose of this study is to:

- Assess whether current reclamation methods are achieving the desired long-term goal of restoring native prairie (successes and areas to improve);
- Provide the long-term data to develop best management practices and appropriate revegetation strategies for industrial disturbances on native prairie in the Foothills Fescue, Foothills Parkland and Montane NSRs;
- Link long-term monitoring data to current tools for reclamation planning, including GVI, AGRASID, the Range Plant Community Guides and the Rangeland Health Assessment handbook;
- Use the information collected to develop and update recovery strategies to support the intent of the 2010 Reclamation Criteria for Grasslands and to provide guidance for the oil and gas industry, reclamation practitioners, contractors, landowners and Government of Alberta regulatory authorities.

Figure 1-1 Natural Subregions of Southwestern Alberta

2 RESTORATION CHALLENGES

2.1 Climate, Soils and Physiography

2.1.1 Foothills Fescue Natural Subregion

The Foothills Fescue NSR occupies the area between the lower elevation, warmer, drier Mixedgrass NSR to the east, the lower elevation Northern Fescue NSR to the northeast and and the higher elevation Foothills Parkland and Montane NSRs to the west. Elevations range from 800m in the north to over 1500m in the Porcupine Hills (Natural Regions Committee 2006). The boundaries correspond closely to Soil Correlation Areas (SCAs) 5 in the south (Del Bonita through Cardston to the Pekisko area), and with SCA6 in the north (Stavely north to Crossfield and Trochu) (Figure 2-1) (Brierley et. al 2001). The Foothills Fescue NSR is subdivided into four Ecodistricts (Figure 2-2) based on elevation and latitude. The extent of remaining native grassland is illustrated in Figure 2-2 and is estimated to be less than 17% of the area of this NSR.

The climate in the Foothills Fescue NSR is characterized by short summers with warm days and cool nights, and long cold winters, moderated frequently by chinook winds. Precipitation in the form of snow is common in late winter and early spring (Adams et al. 2005). Yearly precipitation ranges 397 mm to 589 mm (Adams et al. 2005). Mean daily temperatures range from 4.3ºC in the south at Del Bonita, 5.4ºC in the Chinook wind affected west at Cardston and 3.5ºC at Trochu in the north. Soils are predominantly Orthic Black Chernozems. Rego Black Chernozems occur on gravel and shallow to gravel deposits from glacio-fluvial outwash from mountain and foothills valleys.

Figure 2-1 Foothills Fescue NSR in Relation to Soil Correlation Areas 5 and 6

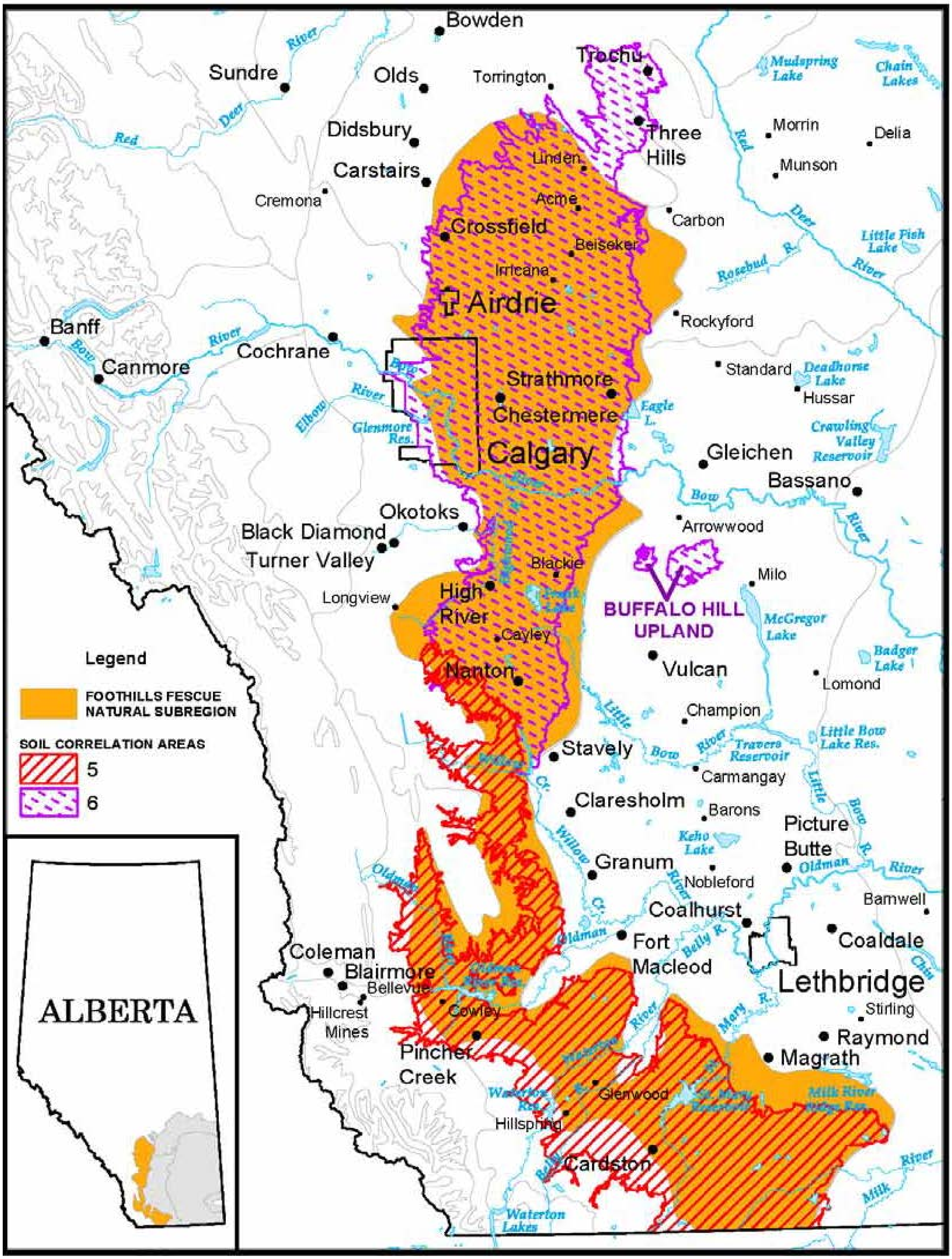
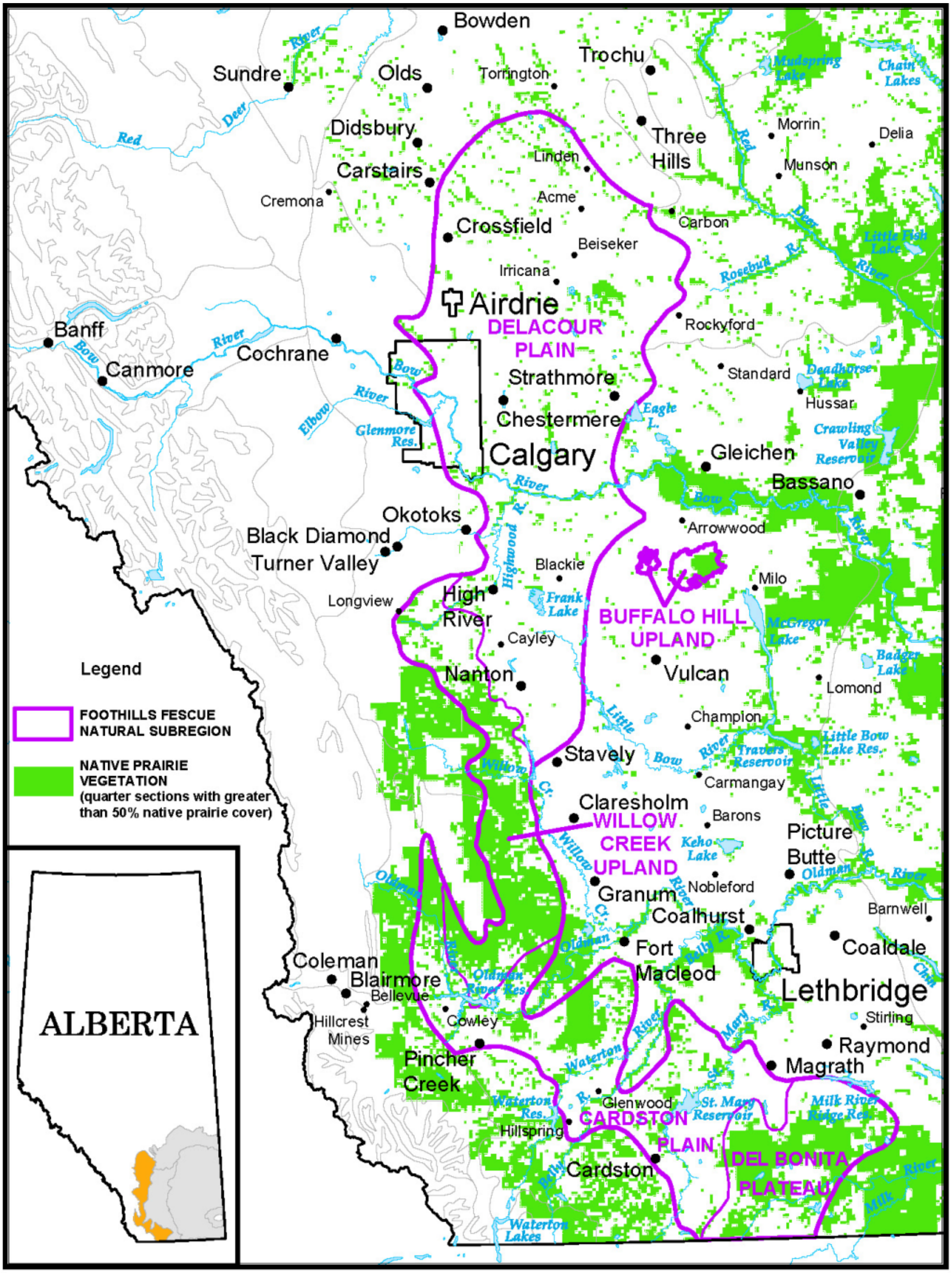


Figure 2-2 Ecodistricts and Remaining Native Prairie in the Foothills Fescue NSR



2.1.2 Foothills Parkland Natural Subregion

The Foothills Parkland NSR represents a transition zone between grassland environments to the east and boreal and montane forests to the west and north (Natural Regions Committee 2006). Forming the most southerly portion of the Parkland Natural Region, it is found on the western edge of the Foothills, running from just north of Calgary to the Porcupine Hills, with another pocket located near the Alberta-Montana border (Figures 2-3 and 2-4).

The Foothills Parkland Natural Subregion has the highest precipitation, warmest winters, and shortest, coolest growing season of any of the parkland Natural Subregions. Proximity to the mountains and a greater incidence of Chinooks is responsible for these characteristics (Natural Regions Committee 2006). Mean annual precipitation in the Foothills Parkland Natural Subregion ranges from 454 to 807 mm. Precipitation decreases significantly to the north, and mean daily temperature decreases slightly to the north. Southern areas receive a higher percentage of precipitation as snow (Landwise 2003).

This is the highest parkland Natural Subregion, and elevations range from 1025 m north of Calgary to about 1400 m in the Porcupine Hills. Rolling to hilly landscapes are typical. Grasslands similar to those in the Foothills Fescue Natural Subregion occur on dry sites, and aspen stands like those in the Montane Natural Subregion occur on moister, cooler northerly aspects and in seepage areas.

Soil parent materials include nonmarine sandstones, mudstones and shales which underlie moderately fine, weakly calcareous till that is often less than 2 m thick on steeper slopes. Ice-contact glaciolacustrine sediments occur across about 20 percent of the Natural Subregion, mainly in lower valley positions. The Foothills Parkland is characterized by deep Orthic Black Chernozems with surface humus horizons at least 15 cm thick, associated with Foothills rough fescue *(Festuca campestris)* dominated plant communities and open deciduous or coniferous forest stands. Forested areas are supported by Orthic Dark Gray chernozemic soils. Seepage areas on lower slope positions and depressions support willow shrublands. Orthic Gleysols occur in the wettest, most poorly drained areas which typically support willow cover (Natural Regions Committee 2006). The Foothills Parkland NSR is described in the Agricultural Regions of Alberta Soils Information Database (AGRASID) as located in Soil correlation Area 8 (Figure 2-3) (Brierley et al. 2001).

Vegetation ranges from dry south and west facing slopes vegetated by Foothills rough fescue-Idaho fescue communities on rapidly drained soils to Foothills rough fescue-Parry's oat grass on somewhat moister southerly slopes. Characteristic sites on moist, moderately well drained northerly slopes, seepage zones or low areas support aspen forests. Balsam poplar *(Populus balsamifera)* also occurs on moister sites, and white spruce *(Picea glauca)* or Douglas fir *(Pseudotsuga menziesii)* are occasional (DeMaere et al. 2012). In the northern unit of the Foothills Parkland Natural Subregion, moist willow groves dominated by beaked willow *(Salix bebbiana)* and with a significant tall herb component are a distinguishing feature (Natural Regions Committee 2006).

Figure 2-3 Foothills Fescue NSR in Relation to Soil Correlation Area 8

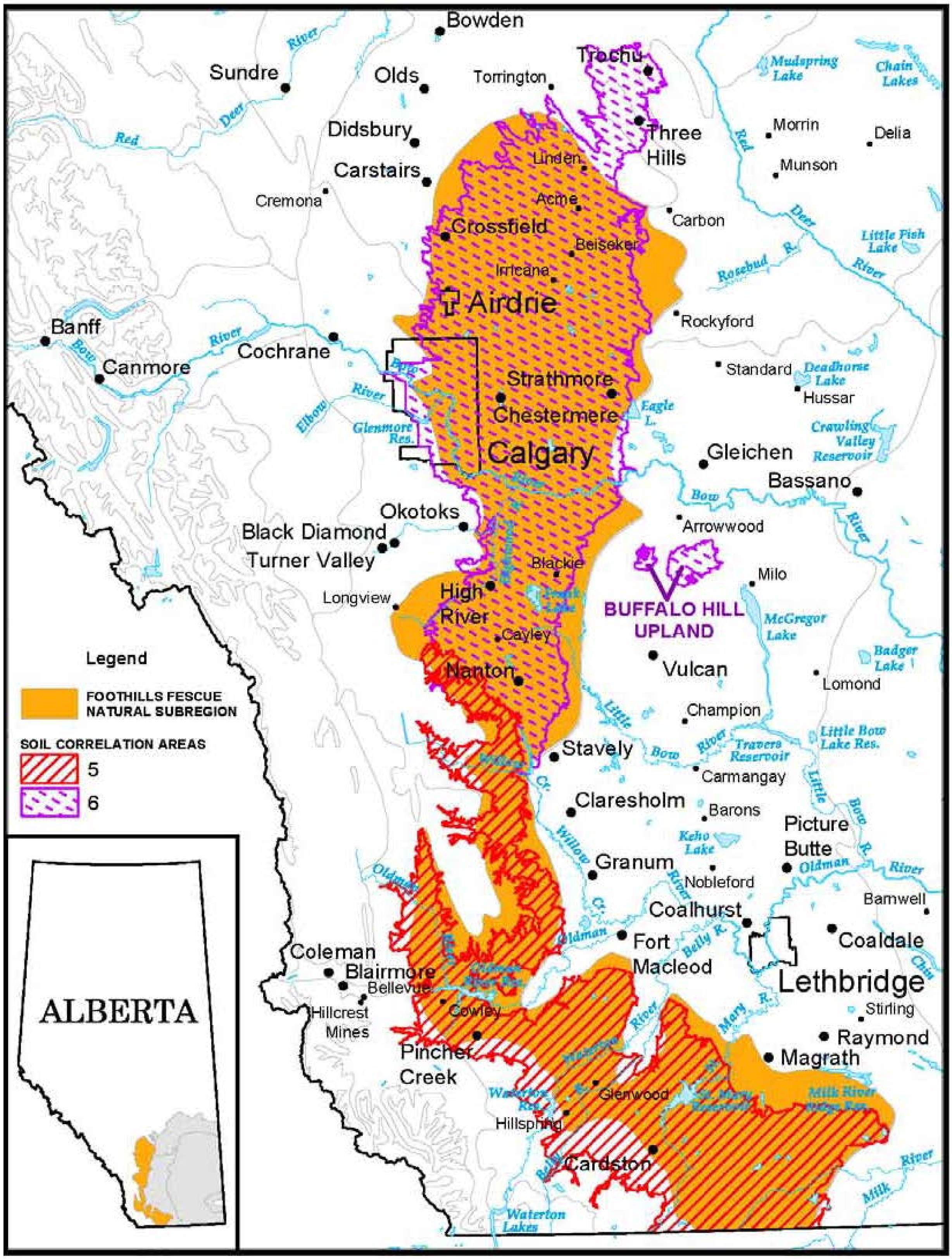
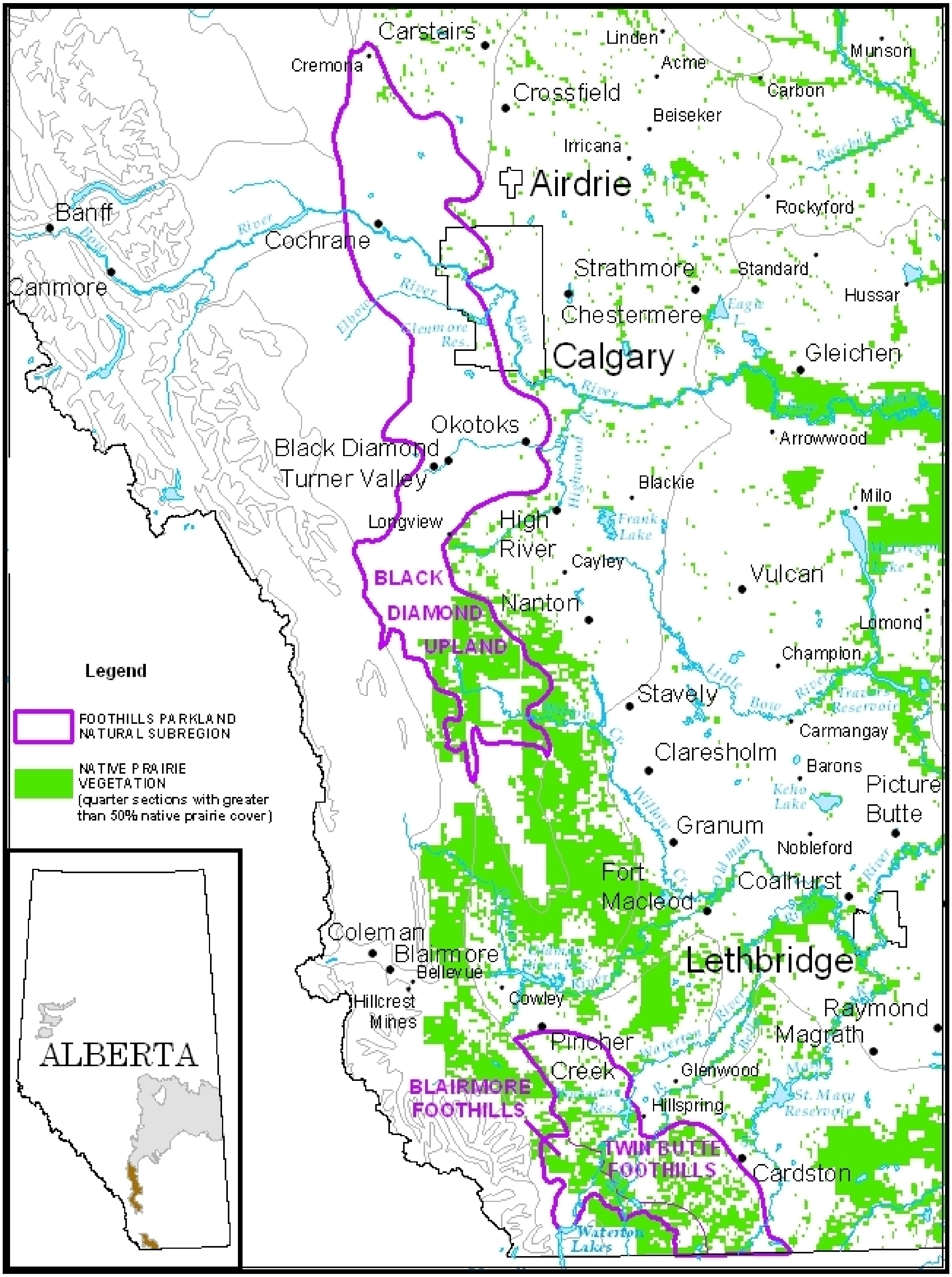


Figure 2-4 Ecodistricts and Remaining Native Prairie in the Foothills Parkland NSR



2.1.3 Montane Natural Subregion

In terms of elevation, the Montane Natural Subregion occurs below the Subalpine NSR in the mountains and above the Foothills Fescue and Foothills Parkland NSRs in southern Alberta. It occurs along lower slopes and valley bottoms in the front ranges, along the base of the Porcupine Hills and at higher elevations in the Cypress Hills. Chinooks are frequent along the Front Ranges, and winters are warm with much greater winter snowfall than the Foothills Fescue NSR and lower amounts than the adjoining Subalpine and Alpine Natural Subregions. The Montane has the warmest winter temperatures of any forested region in Alberta because of chinook activity and reduced influence of Arctic air (Strong and Leggat 1992). Yearly precipitation ranges 308 mm to 1279 mm with two precipitation peaks occurring in May-June and again in August-September (Strong and Leggat 1992). Summer monthly temperatures average about 12ºC and are 2ºC warmer than the Subalpine and 2ºC colder than the Foothills Fescue Natural Subregions.

Terrain is complex, soils are variable and vegetation cover also reflects this diversity of slopes, aspects, substrates and moisture regimes (Natural Regions Committee 2006). The Montane is distinguished from the other subregions by the presence of Douglas fir, limber pine (*Pinus flexilis*) and lodgepole pine (*Pinus contorta*). Dominant upland soils associated with forest cover are well drained, medium to fine textured Luvisolic and Brunisolic types. Grasslands associated with the Montane NSR are similar to those found in the Foothills Fescue and Foothills Parklands NSRs. Particularly well-defined vegetation patterns such as the grassland/forest mosaics of the Whaleback Ridge and the Porcupine Hills reflect the often abrupt nature of topographically controlled moisture and temperature gradients. Grasslands are common on moderately dry south- and west-facing aspects and include Foothills rough fescue, Idaho fescue and Parry’s oat grass on well to moderately well drained Chernozemic soils.

2.2 Cumulative Effects Management and Fragmentation

Cumulative effects are the combined effects of past, present and reasonably foreseeable future land use activities on the environment. Surface disturbance in grasslands can be grouped in a number of measurable categories that help in the understanding and management of cumulative impacts of land use practices to Alberta’s native grasslands. These include:

1) **Permanent conversion to non-native cover types:** Over the past century, extensive tracts of Foothills Fescue, Foothills Parkland and Montane grasslands have been permanently converted to non-native cover types primarily for agricultural cropping, transportation and energy infrastructure, and urban and country residential development. Incremental losses through these processes continue.

2) **Reclamation success and plant community integrity:** Relative to each unique ecological site, intact native grasslands possess a rich diversity of native grasses, forbs and shrubs that produce a characteristic plant community structure, facilitating optimal use of moisture, nutrients and available sunlight. To the extent possible, reclamation practices aim to restore the native plant community so that ecological health and function, and the related ecological services are maintained. In the Alberta Grassland Natural Region, recovery of native plant communities can be more readily achieved in drier prairie environments while mesic foothill environments are much more challenging, primarily due to the greater competitiveness of agronomic grasses and weeds in the moister growing environment. Ecological health, function and associated ecological services will be diminished when plant communities are modified by non-native species.

3) **Anthropogenic edge density and fragmentation:** The progressive additions of linear developments like roads, pipelines and transmission rights-of-way in a unit of native grassland can be expressed as anthropogenic edge density and measured in km/square kilometer of linear feature. Research shows that grassland intactness declines as anthropogenic edge increases. Left unmanaged it results in the progressive fragmentation of native grasslands, reducing their health and function.

4) **Shadow effect and invasive species:** Anthropogenic edge results in disturbed grassland and also an interface into undisturbed grassland for invasive species. The seed stock of invasives may spread from the reclaimed linear feature or be transported by the associated traffic along the access feature. The rate at which invasives move off the linear feature can be measured and expressed as meters/year.

5) **Reduced habitat effectiveness:** Habitat loss, alteration and fragmentation can result in reduced quality of wildlife habitat due to increased mortality, reduced reproductive success, displacement to other habitat and loss of habitat connectivity.

6) **Reduced ecological services:** Reduced watershed protection, carbon storage and soil moisture retention.

Minimum disturbance practices are an essential tool in the management of cumulative effects in native grasslands.

Oil and gas development in the Foothills Fescue, Foothills Parkland, and Montane NSRs began in the early 1900s. Over the past century, oil and gas wells have been developed throughout this time period but at a relative low rate and density. Some recent projects have been developed since the 1990s which focus on reduced impact to native grassland plant communities. The construction practices of the day and the infrastructure required to drill and produce petroleum products in the region resulted in a mosaic of surface disturbances associated with wellsites, access roads, flow lines and sales lines. As well, large diameter pipeline corridors for oil, bitumen and natural gas occur within the NSRs. Transmission lines, highways and rural road infrastructure contribute to native grassland fragmentation.

2.3 Invasive Non-native Plants

Cultivation and industrial development in the Foothills Fescue, Foothills Parkland and Montane NSRs can increase the risk of non-native plant invasion into native plant communities when surface soils are disturbed. Livestock grazing practices that reduce the vigour and cover of desirable native forage plants can also create an environment for the invasion of non-native plants. This includes Prohibited Noxious and Noxious weeds regulated under the Alberta Weed Control Act (Government of Alberta 2010). The nutrient rich loamy soils that dominate many remnant native grasslands provide an ideal growing matrix for aggressive non-native plants once the native vegetation is removed and the soils exposed. Forage crops, perennial hay land and tame pastures scattered throughout the landscape provide an abundant seed source of invasive agronomic species such as awnless brome, timothy, Kentucky bluegrass and sweet clover (*Melilotus officinalis* and *Melilotus alba*). These agronomic species are known to invade exposed soils and encroach into adjacent native plant communities in the Foothills Fescue, Foothills Parkland and Montane NSRs.

The introduction of these invasive agronomic species to the foothills environment has taken place over many decades. First Nations peoples were the first to observe the movement of species like Kentucky bluegrass, which they referred to as “white man’s foot grass”, with the influx of European immigrants in the 1800s as it followed westward migrations. Further introductions accompanied valleybottom farming to produce annual and seeded forage crops.

Today, the remnant native grasslands of the Foothills Fescue, Foothills Parkland and Montane NSRs are a multiple use landscape. Ranching and farming are vital to local economies. Livestock grazing in native grassland is generally limited to summer months at higher elevations, with spring, fall and winter grazing generally confined to low elevation pastures. Agronomic forage is provided during the winter months. General landscape scale observations made during the 2013 field work for this project indicated invasive agronomic plants such as awnless brome or Kentucky bluegrass readily colonizing disturbed soils in moist sites such as riparian areas and water courses or sites such as aspen clones where livestock congregate to seek shelter. Transportation corridors, and stripped and graded wellsites and pipelines built prior to 1993 and seeded to agronomic species provide additional seed source. These pockets and conduits of invasive plants provide a seed source for industrial soil disturbances.

2.4 Regulatory Setting

The regulatory setting for reclamation in Alberta can be categorized into four time periods:

- Pre 1963 – ***Limited policy tools***
- 1963 to 1980 – ***Early reclamation tools***
- 1980 to 2000 – ***Initial minimum disturbance practices***
- 2000 to Present – ***Priority on managing surface disturbance***

Prior to 1963, there was no requirement in Alberta to reclaim industrial disturbances, although some seeding with tame forages did occur. Alberta legislation requiring the reclamation of land disturbed by industrial activities came into effect in 1963 with the enactment of the Surface Reclamation Act. In 1973 the Land Surface Reclamation Act came into effect and provided for planning industrial development to minimize impact (Sinton 2001). Early reclamation practices were developed, the emphasis was placed on soil conservation and seeding with agronomic grasses such as crested wheat grass (*Agropyron cristatum*), and awnless brome to provide reliable vegetative cover to prevent soil erosion.

From 1985 to 1993, reclamation practices focused on improving soil handling procedures, and erosion control. To facilitate precision in soil handling, the area of disturbance required for projects drastically increased. This led to increased disturbance of native plant communities and increased the risk of invasion by aggressive agronomic species invasion.

From 1993 to the present, the importance of the native plant communities’ role in ecological function has been recognized. The focus of reclaiming industrial disturbances has shifted towards reducing the footprint of industrial disturbance and where that is not possible, revegetating disturbed soils with native plant cultivars (Neville et al. 2013).

3 LITERATURE REVIEW OF RECLAMATION PRACTICES IN THE FOOTHILLS FESCUE, FOOTHILLS PARKLAND AND MONTANE NATURAL SUBREGIONS

Foothills Fescue, Foothills Parkland and Montane Natural Subregions are important for the economic, social and biophysical health of southwestern Alberta and the greater Calgary area (Calgary Regional Partnerships 2010). Well-managed fescue grasslands are a valuable resource for livestock production, which is a significant economic factor in southwestern Alberta. They are low maintenance and highly productive, especially during the winter, when tame pasture ranchers must provide hay and fescue grassland ranchers can rely on native forage. Smoliak et al. (1985) describe the fescue grasslands in the southern Alberta foothills as the most productive of Alberta native grasslands.

Watersheds supporting the greater Calgary area and southwestern Alberta are found in the Foothills Fescue, Foothills Parkland and Montane NSRs. Fescue grassland bunch grasses contribute to watersheds through water-trapping capability and soil stabilization, and the large amount of fallen litter adds to carbon sequestration of organic matter (Naeth 1988; Naeth et al. 1991). Nevertheless, oil and gas development, urban expansion and agriculture have resulted in the loss of native grasslands in southern Alberta. For example, of the 1.1 million hectares in the Foothills Fescue NSR, only 250,000 hectares or 16% of native grassland remain (Adams et al. 2005). This literature review examines current and past research into revegetation of disturbances, focusing on the Foothills Fescue, Foothills Parkland and Montane Natural Subregions of Alberta.

3.1 Seeding

3.1.1 Wild-harvested Seed

One of the greatest obstacles to using native species or changing revegetation practices is the limited range and volume of commercially available native seed (Woosaree 2000). Wilson (2002) identified three major constraints to prairie restoration; lack of seed, among-year variability in establishment, and the persistence of introduced, non-native perennial species. Wild harvesting seed presents particular difficulties including uncertainty of the seed maturity dates, variable field conditions, the location of the seed source being not compatible with the reclamation site, the knowledge of the collector, hand-collection methods, and storage methods (Smreciu et al. 2003). Disadvantages of mechanical seed harvesting include collecting unwanted species, difficulty in wet conditions, and possible injury to insect and other small faunal species (Stevenson et al. 1997).

Foothills Rough Fescue

Foothills rough fescue may not produce large volumes of seed every year; however, when it does, rough fescue often has a mast-flowering event. Mast flowering occurs when all occurrences of a species over a large area flower simultaneously. Nevertheless, occasional rough fescue plants flower every year, and may be harvested by hand (Neville, M., personal communication. 2012., Tannas, S., personal communication. 2010). Foothills rough fescue does not easily recover when seeded. Desserud et al. (2010) found little to no rough fescue on pipelines in the Foothills Fescue, Foothills Parkland and Montane NSRs, despite their having been seeded with rough fescue seven to twenty years prior.

Sherritt (2012) had success seeding foothills rough fescue on reclaimed sites in the Foothills Fescue NSR; however, he found it established (after two years) only when seeded as a monoculture, with little competition from other grasses. Tannas (2011) also found good establishment of Foothills rough fescue four years after seeding, including recruitment of seedlings from seed rain. In his experiment, competition from annual weedy species was eliminated by treatment with a broadleaf herbicide (2,4-D) and hand-picking volunteer grassy weeds.

A Foothills rough fescue seeding experiment in a pre-cultivated field in Montana (Foothills Fescue NSR), failed to produce viable rough fescue seedlings (Pokorny and Mangold 2009). The seed mix was rough fescue with native grasses and forbs. Almost none of the native grass seedlings survived the first year, probably due to competition from broadleaf invasive species, e.g. hoary cress *(Cardaria draba)* and Canada thistle *(Cirsium arvense)*. Similarly, Sheley et al. (2006) found Foothills rough fescue did not establish very well in a seeding and herbicide experiment, combined with Idaho fescue *(Festuca idahoenis)* and bluebunch wheat grass *(Pseudoroegneria spicata)*, in Montana (similar to Foothills Fescue NSR).

Idaho Fescue

Idaho fescue established readily in a Foothills Fescue NSR experiment by Sherritt (2012). Tyser et al. (1989) found good establishment of Idaho fescue in a seeding experiment in a Montane area in Glacier national Park in Montana. Sheley and Bates (2008) had success seeding Idaho fescue in an Idaho post-fire restoration (similar to Montane NSR). Sheley et al. (2006) also found good establishment of Idaho fescue in a seeding experiment in Montana (similar to Foothills Fescue NSR).

Rocky Mountain Fescue

Rocky mountain fescue *(Festuca saximontana)* established easily from both seed and plugs in Woosaree and McKenzie's (2015) experiment. However, Desserud (2006) found it dominated a pipeline in the Montane NSR, where it may have been seeded in error instead of Foothills rough fescue.

Oat Grasses

Parry's oat grass failed to germinate in a Foothills Fescue NSR experiment by Sherritt (2012), where it was seeded with Foothills rough fescue, Idaho fescue and June grass *(Koeleria macrantha)*. Sherritt (2012) postulated its hairy lemma may have prevented adequate seed to soil contact when the experimental plots were raked. Intermediate oat grass *(Danthonia intemedia)* successfully established as part of a native seed mix in a northeastern Oregon (similar to Montane NSR) campsite reclamation experiment.

June Grass

June grass established readily in a Foothills Fescue NSR experiment by Sherritt (2012). In his experiment, it also occurred naturally in plots where it was not seeded. Tyser et al (1989) found good establishment of June grass in a seeding experiment in a Montane area in Glacier national Park in Montana.

Wheat Grasses

Slender or awned wheat grass *(Elymus trachycaulus)* often colonizes new disturbances, whether seeded or not. It appeared naturally in Woosaree and McKenzie's (2015) and Sherritt's (2012) Foothills Fescue NSR experiments within two to four years. Nevertheless, it may not persist, even when seeded. Desserud (2006) found no slender wheat grass on pipelines after seven years, despite having been seeded.

Western wheat grass *(Agropyrum smithii)* emerged readily from seed in Woosaree and Mckenzie's (2015) experiment. Western and northern wheat grass *(Elymus lanceolatus)* were abundant on pipelines in the Foothills Fescue and Foothills Parkland NSR, having been seeded, or occurring from natural seed rain (Desserud 2006).

Bluebunch wheat grass readily established in a post-fire restoration project by Sheley and Bates (2008) in Idaho (similar to Montane NSR). In a Montana (similar to Foothills Fescue NSR) seeding experiment, Sheley et al. (2006) found good establishment of Idaho fescue.

Needle Grasses

Needle-and-thread *(Stipa comata)* and western porcupine *(Stipa curtiseta)* grass seed are difficult to harvest due to sharp, hard awns (Barner 2009). Processing is complicated because awns get intertwined, reducing seed flow (Ogle et al. 2006; Bakker 2012). Sherritt (2012) found no western porcupine seedlings in a Foothills fescue NSR experiment, two years after seeding. However, Woosaree and McKenzie (2015) had good emergence of western porcupine grass four years after seeding.

Bluegrasses

Alkali bluegrass *(Poa juncifolia)* emerged naturally in Sherritt's (2012) experiment. Kentucky bluegrass is common in the seedbank of Foothills Fescue and Foothills Parkland soils, emerging readily on disturbances (Desserud 2006; Sherritt 2012; Woosaree and McKenzie 2015). Big bluegrass *(Poa ampla)* readily established in a post-fire restoration project by Sheley and Bates (2008) in Idaho (similar to Montane NSR).

3.1.2 Native Grass Hay

A variant of wild seed harvesting is cutting hay from native grassland to use as a mulch and seed source.

Native hay or mulch has been used as a reclamation seed source in Europe and Great Britain (Kiehl and Wagner 2006; Edwards et al. 2007), northern U.S. (McGinnies 1987), and mixed grass prairie in Canada (Wilson et al. 2004; Desserud and Naeth 2011; Desserud 2013). No research was found regarding the use of native hay or mulch in the Foothills Fescue, Foothills Parkland or Montane NSRs, or similar areas.

In general, the state of native grassland in close proximity to a disturbance is crucial in determining if native hay is a suitable seed source. In a Northern Fescue NSR experiment, seedling emergence from native hay included Kentucky bluegrass, June grass, western porcupine grass and numerous forbs. They concluded native hay is a good seed source for native species in close proximity to a grassland disturbance, if desired species are present (Desserud and Naeth 2011).

Factors which affect the viability of native hay include the variability of native seed production from year to year, e.g. some species do not seed every year; the timing, which will result in the dominance of whichever species have seeded at that time; and methods, such as tackifying, to keep the hay in place (Romo and Lawrence 1990). Another factor is the viability of seed if the hay is stored for future use. Interestingly, Reis and Hofmann (1983) found hay storage of one year did not decrease the amount of seedlings, and actually increased the establishment of some, those which require a period of dormancy. They also recommend cutting hay several times over the summer, storing it and cutting again the following year, to obtain the most diversity of seeds, e.g. different seeding times and years (Reis and Hofmann 1983).

3.1.3 Cultivars and Ecovars™

One solution to poor wild seed availability is the cultivation of commercially viable seed from native seed sources to produce a cultivar, ecovar or ecotype. A **cultivar** is a plant variety which has undergone genetic restriction through selection by plant breeders, and which has been registered by a certifying agency (Ferdinandez et al. 2005). An **ecovar™** is an ecological variety (coined by Ducks Unlimited) of a native plant species selected to produce a population containing maximum genetic variability (Woosaree 2000). Ecovars™ retain much more genetic variety than do cultivars, and theoretically will be more adaptable to environmental changes as a result. The result of a third type of native plant cultivation is termed “ecotype”. An **ecotype** is generally defined as a distinct genotype within a species, resulting from adaptation to local environmental conditions, and that can interbreed with other ecotypes of the same species (Hufford and Mazer 2003).

While cultivation may improve the reliability of seed germination, it often results in a loss of species diversity as a result of genetic shift: the change in the genetic makeup of the line, variety, or hybrid if grown over a long period. Many years of growing seed of native origin at a single location for cultivar production can lead to local adaptations through inadvertent selection and a narrowing of the genome (Burton and Burton 2002). For example, Ferdinandez et al. (2005) found an 8% decrease in genetic diversity in a cultivar of **awned slender wheatgrass** (*Agropyron trachycaulum* subsp. *subsecundus* AC Pintail) after only two generations. The loss of genetic diversity can be partially offset by the annual infusion of wild-harvested seed into the breeding mix (Burton and Burton 2002). Buisson et al. (2006) found that while **California oat grass** *(Danthonia californica)* from non-local seed appeared to germinate more readily than local seed, longer-term survival rate was better with local seed.

Downing (2004) cautioned that native cultivar or ecovar™ suitability in one Natural Subregion does not necessarily imply suitability in another. Nevertheless, despite their production in a Subregion which differs from their original source, the genetic uniqueness of native plant cultivars can be maintained by completely renewing the breeder plots every two generations with newly collected wild seed (Woosaree, personal communication, 2007). Some successful native plant cultivars that have been grown by Alberta Innovates – Technology Futures include those suitable for Foothills Fescue prairie soils, e.g. **Arc Mountain View June grass®, rocky mountain fescue, Canada wild rye** (*Elymus Canadensis)*, **slender wheatgrass, nodding brome** *(Bromus anomalus)* (Alberta Innovates Technology Futures 2013).

3.1.4 Seed Mixes and Seeding Rates

Seed mix plays an important part in native grass revegetation. Emergence success for any seed mix will reflect the combined ability of individual species to emerge under site conditions (soil, climate, and revegetation practices). All else being equal (i.e. site conditions), the major factors affecting emergence will be seed size and seed dormancy (Woosaree and James 2006).

Seeding rates for native grass seed used in the reclamation projects of this review are in the order of 1 to 15 kg/ha (Table 3-1). Sinton et al. (1996) recommend a rate of 8 – 11 kg/ha for drilled seeds, cautioning that rates will vary depending on the size and weight of the seed. Some researchers consider this rate to be too high and may inhibit the invasion of native plants onto disturbed sites (Hammermeister and Naeth 1996). Sheley et al. (2006) suggested lower seeding rates may reduce competition from other species and promote success of species such as Idaho fescue. They also found higher seeding rates benefitted **wheat grasses**, such as **bluebunch wheat grass**.

Table 3-1 Selection of Seeding Rates and Timing of Foothills Rough Fescue
(for Projects in this Literature Review)

Source	Description and Region	kg/ha	Timing	Success?
(Sherritt 2012)	Hand broadcasting in micro-plots, 100% and 30% in a native seed mix, Foothills Fescue NSR	15	Summer	good
(Pokorny and Mangold 2009)	Drill and broadcasting, 15% rough fescue in a native seed mix in Montana	1.1	Fall	poor
(Woosaree and McKenzie 2015)	Drill seeding with native species and cultivated oats, Foothills Fescue NSR	3.2	Spring and Fall	good in Spring, poor in Fall
(Woosaree and McKenzie 2015)	Plugs planted with native species plugs in 15 x 20m plots, Foothills Fescue NSR	187 – 292 plugs/plot	Spring and Fall	good in Spring, poor in Fall
(Tyser et al. 1989)	Hand broadcast with hydro-mulch application and herbicide, Montane NSR (Glacier National Park, Montana), Idaho fescue	1,000 seeds/m2	Fall	Good
(Sheley and Bates 2008)	Broadcast, Montane NSR (southwest Idaho) - Idaho fescue, bluebunch wheat grass, big bluegrass	16.8, 22.4, 28, 33.6	Fall	

Sherritt (2012) tried several seed mixes in a foothills rough fescue experiment in the Foothills Fescue NSR. He seeded **rough fescue** alone and in a mix with 30% **rough fescue** and **other native species**, each at a rate of 15 kg/ha (Table 3-2). He also seeded **rough fescue** at 15 kg/ha and over-seeded with **Dahurian rye** *(Elymus dahuricus)* at 1.1 kg.ha. Within one year, **Foothills rough fescue** successfully established in the fescue-alone treatment, with little establishment in the seed mix where **June grass** and **Idaho fescue** established well. Interestingly, **Dahurian rye** appeared to have appositive effect on **rough fescue**, which may indicate that it is a potential cover crop for foothills rough fescue seeding. In Sherritt's (2012) experiment, **western porcupine grass** and **Hooker's oat grass** *(Helictotrichon hookeri)* failed to establish; however, **Parry's oat grass , June grass** and **Idaho fescue** were all successful.

Sheley et al. (2006) had no success seeding **Foothills rough fescue** in a Montana (similar to Foothills NSR) experiment. They seeded **rough fescue** in equal portions by weight with **Idaho fescue** and **bluebunch wheat grass**, with no-till drill seeding and broadcasting, with and without a cover crop of **common wheat** (*Triticum aestivum*) and herbicides (2,4-D and picloram; Table 3-2). **Idaho fescue** were successful in all treatments.

Woosaree and McKenzie (2015) had poor results with **Foothills rough fescue** in a seed mix study in the southern Foothills Fescue NSR. They seeded a mix of 40% **rough fescue** with **other native species** (Table 3-2); however, spring seeding resulted in less than 1% rough fescue cover and fall seeding had no rough fescue after 3 years. **Slender wheat grass** established well, having over 16% cover despite having been seeded at 5% of the seed mix. **Western wheat grass** also had good establishment, maintaining cover similar to its seed mix value, 8%.

Table 3-2 Seed Mixes Reviewed Showing Percent (%) by Seed Weight

Source	Sherritt	Sherritt	Pokorny	Woosaree	Tyser	Sheley 2008	Sheley 2006
Native grasses							
Foothills rough fescue	30	50	10	40	1		34
Idaho fescue	20		4	5	24	16	33
Bluebunch wheat grass			12		5	17	33
Parry's oat grass	30			5			
Mountain brome					34		
June grass	20			5	7		
Western wheat grass			15	8			
Big bluegrass						17	
Slender wheat grass			11	5			
Western porcupine grass				8			
Prairie sandreed			7				
Green needle grass				5			
Needle-and-thread grass				5			
Northern wheat grass				5			
Sandberg bluegrass			2				
Non-native grasses							
Dahurian rye		50					
Cultivated oats				10			
Forbs					29	16	
Yarrow						17	
Wild blue flax			12			17	
Wild lupine			7				

Tyser et al. (1989) experimented with herbicide and non-herbicide treatments in roadside reclamation in Glacier National Park, Montana, and Montane NSR altitude. Despite the sites being in Foothills rough fescue grassland, their seed mix included very little **rough fescue** (Table 3-2). The dominant species were **Idaho fescue** and **mountain brome** *(Bromus carinatus)*, both of which established well in both treatments – herbicide and non-herbicide treatments.

Hard-coated seeds, e.g. many *Stipa* species, such as **western porcupine grass**, may not germinate in the first year unless scarified. Without seed treatment they should be seeded with non-competitive, early establishers such as **slender wheat grass**, or forbs such as **yarrow** *(Achillea millefolium)* to give them a competitive edge after germination in the second year (Nurnberg 1994). For example, Sherritt (2012) had no germination of **western porcupine grass** two years after seeding; however, Woosaree and McKenzie (2015) had successful **western porcupine** establishment four years after seeding.

Small-seeded species must be seeded at a higher rate than larger-seeded species where a comparable emergence and stand density is desired (Woosaree and James 2006). Where recruitment of resident native species is desired, the density of seeded species appears to be more important than initial plant cover, at least in the first establishment year. Using a lighter seeding rate or a seed mix with lower expected emergence success will likely favour local recruitment. This will also allow for smaller plants such as **June grass** and **Plains rough fescue** *(Festuca hallii)* to find room to grow (Desserud and Naeth 2013). For example, Ewing (2002a) concluded a relatively low seeding rate improved establishment of **Idaho fescue**.

3.1.5 Season of Seeding

The best season in which to seed native grasses depends on the species. Generally cool-season grasses (C3), e.g. most **wheat grasses, Foothills rough fescue, or June grass** benefit from spring or early spring seeding. Sherritt (2012) successfully seeded **Foothills rough fescue** plugs in late June and July. Woosaree and McKenzie (2015) had good establishment of **Foothills rough fescue, Parry's oat grass** and **Hooker's oat grass** when planted in late June and poor recovery when planted in September. Several other researchers had poor **rough fescue** establishment when seeded in the fall (Sheley et al. 2006; Pokorny and Mangold 2009).

Needle grasses, e.g. **western porcupine grass** or **needle-and-thread**, prefer late summer or fall seeding (Pahl and Smreciu 1999). Nurnberg (1994) found hard-coated seeds such as **needle grass** species, may not germinate in the first year unless scarified, which may be the reason for requiring a winter season following seeding. Desserud and Naeth (2013b) concluded **western porcupine grass** required at least two winters before seeds would germinate. **Richardsdon's needle grass** *(Stipa richardsonii)* established better with spring planting had better success than fall planting in a Montane NSR experiment by Page and Bork (2005).

Idaho fescue and **bluebunch wheat grass** appear to establish best with fall seeding (Tyser et al. 1989; Sheley et al. 2006; Sheley and Bates 2008; Woosaree and McKenzie 2015).

3.2 Transplants, Plugs or Sod

Transplant research for grasslands has focused on bunch grasses, with the goal of giving these slow-growing species a head-start in establishment (Table 3-3). Plugs are transplants of plants grown in greenhouse conditions from seed, normally in root trainer containers. Transplanting established seedlings has advantages over direct seeding, especially for slow-growing species such as Foothills rough fescue. Such seedlings are allowed to develop in an environment protected from competition and environmental effects, thus avoiding the most vulnerable growth periods (Tannas 2011).

Foothills Rough Fescue

Tannas (2011) had success with Foothills rough fescue plugs in a wellsite reclamation experiment in southwestern Alberta. Plugs were seeded and grown for three months prior to transplanting. He found Foothills rough fescue plugs had better success than seeding, and also found plugs with larger plant size had the best success (Tannas 2011). Woosaree and McKenzie (2015) had good success with rough fescue plugs when planted in spring (late June), but poor establishment when planted in the fall (September).

Idaho Fescue

Ridenour and Callaway (2003) successfully transplanted Idaho fescue seedlings in a Montana (similar to Foothills Fescue NSR) experiment with spotted knapweed *(Centaurea stoebe)*. In a restoration experiment in Oregon (similar to Foothills Fescue NSR, Huddleston and Young (2004) had success transplanting Idaho fescue plugs. Ewing (2002a) successfully transplanted Idaho fescue seedlings with no mortality in the first year, in a Washington state prairie experiment.

Oat Grasses

Parry's oat grass and Hooker's oat grass plugs were successful when planted in spring, rather than fall, in a Foothills Fescue NSR experiment by Woosaree and McKenzie (2015). In a California coastal prairie experiment, California oat grass transplants had better survival than seedlings produced from seed (Buisson et al. 2006).

Wheat grasses

Page and Bork (2005) successfully planted bluebunch wheat grass plugs in a Montane NSR area in southeastern B.C., finding plugs survived better with fall, rather than spring planting. In a restoration experiment in Oregon, Huddleston and Young (2004) had success transplanting bluebunch wheat grass plugs. They tested the effects of a pre-existing native bunch grass, Lemmon's needle grass *(Achnatherum lemmonii)*, on plug establishment and found bluebunch wheat grass was not affected by distance to the needle grass.

Needle Grasses

Richardson's needle grass plugs were successfully planted in a Montane NSR (southeastern B.C.) experiment by Page and Bork (2005).

Table 3-3 Reclamation Potential of Characteristic Species in the Foothills Fescue, Foothills Parkland and Montane NSRs

Species	Seeding	Plugs	Competition
Foothills rough fescue	needs 3-4 years to establish	yes	very susceptible to native and non-native grasses
Idaho fescue	yes	yes	susceptible to weeds
Rocky mountain fescue	yes	yes	establishes easily, may dominate if over-seeded
Parry's oat grass	yes	yes	may or may not establish
Intermediate oat grass	yes		unknown
June grass	yes	yes	establishes easily, occurs naturally
Bluebunch wheat grass	yes	yes	susceptible to weeds
Slender wheat grass	yes	yes	establishes easily, occurs naturally
Western wheat grass	yes	yes	may outcompete other native grasses
Northern wheat grass	yes		may outcompete other native grasses
Western porcupine grass	yes	yes	requires at least 2 winters to germinate
Bluegrasses	yes		establishes easily, occurs naturally

3.3 Natural Recovery

The earliest examples of natural recovery in Alberta, whereby a disturbed site is reclaimed with no intervention, are the results of cultivated land abandoned and left to recover naturally. Natural recovery could result in an effective, though potentially slow native prairie recovery, with reduced revegetation and invasive species management costs. Conversely, the length of time may delay the issuance of a reclamation certificate and expose the site to erosion and invasive species establishment (Hammermeister and Naeth 1996). A number of factors affect potential success of natural recovery of RoWs from disturbance such as soil type, seed production on the site, range condition, proximity to undesirable vegetation species, length of soil storage, seasonal timing of soil replacement, exposure of the site to wind and pasture management (Lancaster et al. 2012).

In a Foothills Fescue NSR seeding experiment, Sherritt (2012) found several native species naturally emerged in plots where they were not seeded. The most prominent in the second year of recovery were native forbs, e.g. pasture sagewort *(Artemisia frigida)* and dandelion *(Taraxacum officinale)*; and, invasive forbs, e.g. yellow sweet clover *(Melilotus offinalis)*, annual hawkweed *(Crepis tectorum)*, and Canada thistle. Native grasses also established, including June grass, green needle grass *(Stipa viridula)*, alkali bluegrass, Kentucky bluegrass and slender wheat grass. Awnless) brome, an invasive, also appeared (Sherritt 2012). In Woosaree and McKenzie's (2015) Foothills Fescue NSR experiment, natural recovery plots were dominated by prairie sagewort *(Artemisia ludoviciana)* after four years, with foxtail barley *(Hordeum jubatum)*, slender wheat grass, and various forbs also establishing.

In the Foothills Fescue NSR, Desserud (2006) found good Foothills rough fescue establishment on a pipeline left to natural recovery 17 years after construction. On the other hand, despite being in rough fescue grassland, no rough fescue appeared in natural recovery plots in Woosaree and McKenzie's (2015) experiment after four years, nor in Sherritt's (2012) after two years.

3.4 Competition among Native and Invasive Species

Reclamation efforts often must contend with the presence of non-native agronomic grasses, either on the original site, adjacent to it, introduced by grazing cattle, or other human activity including past reclamation practices. Some of these species are well adapted to the thick black or brown soils found in Foothills Fescue, Foothills Parkland and Montane NSRs, such as awnless brome, crested wheat grass, timothy and Kentucky bluegrass. Annual weeds, not noxious or restricted, appear early in disturbance recovery. They may provide soil stability and microsites for perennial grass establishment.

Foothills Rough Fescue

Foothills rough fescue may be particularly susceptible to competition from other native species and weedy species. Sherritt (2012) had success seeding Foothills rough fescue on reclaimed sites in the Foothills Fescue NSR; however, he found it established (after two years) only when seeded as a monoculture, with little competition from other grasses. When seeded with other species, even comparable native species such as June grass or Idaho fescue, little rough fescue emerged. Tannas (2011) also found good establishment of Foothills rough fescue four years after seeding, including recruitment of seedlings from seed rain. In his experiment, competition from annual weedy species was eliminated by treatment with a broadleaf herbicide (2,4-D) and hand-picking volunteer grassy weeds. Nevertheless, when seeded with Kentucky bluegrass, Foothills rough fescue failed to establish (Tannas 2011).

A Foothills rough fescue seeding experiment in a pre-cultivated field in Montana (Foothills Fescue NSR), failed to produce viable rough fescue seedlings (Pokorny and Mangold 2009). Almost none of the native grass seedlings survived the first year, probably due to competition from broadleaf invasive species, e.g. hoary cress and Canada thistle, which could not be eliminated with broadleaf herbicides (2,4-D, metsulfuron-methyl, and glyphosate). In addition, high levels of nutrients, especially nitrogen, from years of fertilizing, likely attracted weedy annuals and may have impeded native grass establishment.

Idaho Fescue

In a restoration experiment in Oregon (similar to Foothills Fescue NSR), Huddleston and Young (2004) tested the effects of a pre-existing native bunch grass, Lemmon's needle grass (*Achnatherum lemmoni*), on plug establishment Idaho fescue fared better when planted 18 cm or more away from the needlegrass. When planted between 6 and 18 cm, it had lower leaf length and biomass, although it also exhibited more tillering.

Ridenour and Callaway (2003) tested the effects of a biocontrol agent, the insect (*Agapeta zoegana, Lepidoptera*), and a native North American fungal pathogen (*Sclerotinia sclerotiorum*) on competition between spotted knapweed and Idaho fescue, in Montana (similar to Foothills Fescue NSR). The fungus successfully killed spotted knapweed with resulting increase in Idaho fescue vigor. The insect, while not eating Idaho fescue, had little effect on spotted knapweed, resulting in lower Idaho fescue development. Nevertheless, Idaho fescue was found to be "highly sensitive" to (±)-catechin, an allelopathic substance exuded from spotted knapweed roots, in a greenhouse experiment (Perry et al. 2005).

Oat Grasses

In a study of the effects of long-term herbicide treatment for leafy spurge *(Euphorbia esula)*, in the Rocky Mountain National Park in Colorado (similar to Montane NSR), Pritikel et al. (2006) found herbicide treatment did not significantly reduce leafy spurge, and did not result in repopulation of Parry's oat grass, co-dominant in un-invaded grassland.

In a California coastal prairie experiment, when neighbours (native and invasive species) of California oat grass transplants were removed within a 25 cm diameter, the transplants succeeded better than those without neighbour removal (Buisson et al. 2006). Wilson and Clark (2001) found California oat grass recovered after 4 years of mowing in a field dominated by invasive tall oat grass (*Arrhenatherum elatius*), in an Oregon upland prairie (110 m elevation). Successive mowing significantly reduced tall oat grass.

June Grass

Invasive species may do more damage than just their presence. In a greenhouse experiment, Jordan et al. (2008) found three invasive plants altered soil properties which negatively affected native species. They assessed soil attribute modifications by awnless brome, crested wheat grass and leafy spurge. They found crested wheat grass soil modifications facilitated awnless brome; whereas, leafy spurge facilitated both invasive grasses. Crested wheat grass had a negative effect on June grass and asters (*Aster spp*.). Awnless brome had negative effects on June grass and wild blue flax *(Linum lewisii)*.

Needle Grasses

Jordan et al. (2008), in a greenhouse experiment, found soil property changes induced by awnless brome, crested wheat grass and leafy spurge had no effect on needle-and-thread grass and green needle grass. In a similar experiment in Wyoming, Mealor and Hild (2007) transplanted needle-and-thread plants from two areas: one invaded by quack grass *(Elymus repens)* and one not-invaded. They examined evolutionary traits of needle-and-thread in response to close proximity to quack grass. Their results showed no difference in needle-and-thread transplants; concluding, needle-and-thread grass is not affected by this invasive species. Needle-and-thread grass was also "highly resistant" to an allelopathic substance produced by spotted knapweed (Perry et al. 2005). Needle-and-thread grass did not recover in areas invaded by leafy spurge, even after long-term herbicide treatment (Pritekel et al. 2006).

Wheatgrasses

Bluebunch wheat grass was found to be "highly sensitive" to an allelopathic substance exuded from spotted knapweed roots, in a greenhouse experiment (Perry et al. 2005).

Kentucky bluegrass

Kentucky bluegrass, originally from Europe and naturalized since the 1700's, frequently emerges on freshly disturbed areas, and may become dominant, especially in grazed areas.

Desserud (2006) found several pipelines in the Foothills Fescue and Foothills Parkland NSRs dominated by Kentucky bluegrass over seven years after construction. Sherritt (2012) noted Kentucky bluegrass readily emerged in many of his rough fescue seeded plots in the Foothills Fescue NSR. In a greenhouse experiment, Tannas (2011) concluded Foothills rough fescue was negatively impacted in tiller growth, root length and biomass by close proximity to Kentucky bluegrass.

3.5 Soil Management Techniques

A diverse vegetation mix is unlikely to develop rapidly unless strategies to initiate diversity are incorporated in the reclamation planning. Such strategies include seedbed preparation through topsoil handling, enhancing the soil chemical and physical properties and improving the nutrient cycle with irrigation or soil amendments.

3.5.1 Handling Topsoil

Much of the literature on handling topsoil deals with the effects on the chemical, physical and microbial properties of the soil, and only a few were found with relation to resulting plant growth. Topsoil handling and storage can affect the potential success of disturbance recovery. Iverson and Wali (1982) found that seed bank density in four-year-old stored topsoil was considerably less than that in adjacent undisturbed prairie in North Dakota. The seeds of some species, e.g. **pasture sagewort** did persist up to four years in stored topsoil; however most others did not.

Mounding and Roughening

Topsoil is commonly spread smoothly on newly reclaimed disturbances; however, mimicking prairie topography, roughening and mounding, thus creating microsites, which might improve native grass establishment (Polster 2014). In a Washington state prairie (similar to Foothills Fescue NSR), Ewing (2002b) found creating mounds (20 cm deep at centre) improved **Idaho fescue** establishment.

Topsoil Stripping

Topsoil stripping was commonly used as a pre-construction practice for pipelines and wellsites prior to the 2000s. Desserud (2006) concluded recovery of rough fescue grassland was poorest on pipelines that had been fully (15 m or more width) stripped; therefore, recommended no topsoil stripping should be done. However, topsoil stripping may be required when restoring old agricultural fields. In an attempt to restore degraded California coastal prairies, seeded with hay crops over many years, Buisson et al. (2006) removed topsoil to eliminate unwanted seed banks and transplanted **California oat grass** with good success.

3.5.2 Irrigation

Because grassland species are adapted to relatively dry conditions, irrigation may not be required to establish native seedlings. However, despite being known as a drought-tolerant species, Tannas (2011) noted **Foothills rough fescue** responded positively to increased water in greenhouse conditions. Tannas (2011) also found rough fescue grassland (Foothills Fescue NSR) responded well to water addition.

3.5.3 Soil Amendments

Soil amendments may also have little effect on some Foothills Fescue NSR grass species. **Idaho fescue** responded poorly to fertilizer, compost and mulch in a Washington state experiment (similar to Foothills fescue NSR) (Ewing 2002a; Hough-Snee et al. 2011). Instead, Idaho fescue thrived in impoverished (organic matter removed) and herbicide-treated soils. Ewing (2002a) postulated that while fertilizer may promote early growth of native grasses, it also attracts weedy species that may outcompete native species. **June grass** ecovar did not respond to phosphorous or nitrogen fertilizers, nor to an arbuscular mycorrhizal fungus (*Penicittium bilaii*) inoculation in a study of Manitoba grasslands (Friesen 2002).

Larney et al. (2005) examined the effect on soil properties of four topsoil replacement depths and five amendment treatments: compost, manure, straw, alfalfa *(Medicago sativa)* and hay, aimed at reclaiming three wellsites in south central Alberta (Foothills Fescue NSR and Northern Fescue NSR). The result was increased organic carbon following the organic amendments. They theorized organic amendments play an important role in improving soil properties related to long-term productivity of reclaimed wellsites, especially where topsoil is scarce or absent (Larney et al. 2005).

Rough fescue grassland (Foothills Fescue NSR) responded to nitrogen addition; however, the effect was not seen until three years after the application, and was manifested mainly by increase in **western snowberry** *(Symphoricarpos occidentalis)* (Tannas 2011).

Intermediate oat grass responded well to several soil treatments including soil scarification, an organic soil amendment (a mix of locally collected organic materials and peat moss and an inoculation of native undisturbed soil), an organic matter and composted sewage sludge treatment and surface application of commercial mulch (Bionet), in a campsite reclamation project in northeastern Oregon (similar to Montane NSR) (Pritekel et al. 2006).

3.5.4 Soil Nutrient Depletion

Nitrogen is a key element in grassland ecosystems, because of its capacity to limit primary and secondary production. Soil amendments, such as straw or sawdust, may reduce nitrogen by increasing micro-organism activity, thus aiding native prairie grasses, tolerant of low-nutrient soils (Desserud and Naeth 2013a). Desserud (2011) noted **June grass** and **western wheat grass** responded well to reduced nitrogen; whereas, **slender wheat grass** showed no preference. Ewing (2002a) removed topsoil to reduce unwanted seed banks, and discovered that **Idaho fescue** seedlings thrived in the nutrient-deficient soil, while weeds prospered and Idaho fescue suffered when mulched and fertilized.

3.5.5 Effects of Grazing

Animal herbivory, in particular cattle and wild ungulates, is a factor in grassland reclamation. Most grassland restoration projects should be protected from grazing, for the first few years until the perennial grasses become well established. Cattle are known to congregate on disturbed sites, probably attracted by the young growth, and may adversely affect the establishment of native grasses (Naeth 1985). In an assessment of grazing in the Montane NSR near Pincher Creek, Kaufmann et al. (2013) concluded cattle selected grazing patches based on topography rather than forage characteristics, preferring areas of reduced slope. Adler et al. (2001) examined the literature on the spatial patterns of grazing. Most studies conclude patch grazing, common in cattle grazing, alters plant communities and successional patterns.

Foothills rough fescue

In an analysis of grazed areas in the Foothills Fescue NSR, Bork et al. (2012) found continued summer grazing, over 20 years, reduced the amount of Foothills rough fescue and increased forbs. Douwes and Willms (2012) found protection from 12 years resulted in a trend towards higher Foothills rough fescue cover. Moisey et al. (2005), in the Foothills Fescue NSR, concluded rough fescue profits from fall grazing, especially in areas with Kentucky bluegrass, which cattle prefer.

The effects of 58 years of elk grazing in Foothills rough fescue grassland was studied in west central Montana (similar to Foothills fescue NSR) by Thrift et al. (2013). They evaluated areas that had been grazed in winter and early spring at two intensities – heavy and light, based on elk usage data and found Foothills rough fescue tolerated light grazing, but not heavy grazing.

Idaho fescue

In an analysis of grazed areas in the Foothills Fescue NSR, Bork et al. (2012) found continued summer grazing had little effect on Idaho fescue. However, Thrift et al. (2013) found Idaho fescue did not tolerate elk grazing at either heavy and light grazing levels, in a west central Montana (similar to Foothills fescue NSR) experiment.

Oat Grasses

Tannas (2001) describes all native oat grasses, Parry's oat grass, California oat grass and intermediate oat grass, as increasers, withstanding moderate to heavy grazing, possibly because they are less palatable than other species. Bork et al. (2012), in an analysis of grazed areas in the Foothills Fescue NSR, found continued summer grazing over 20 years did not affect Parry's oat grass. Douwes and Willms (2012) found 12 years of grazing resulted in dominance by Parry's oat grass. Hayes et al. (2003) found grazing increased abundance of California oat grass in California coastal prairie; whereas, Bartolome et al. (2004) found the opposite trend in a grassland dominated by purple needle grass (*Nassella pulchra*).

Wheatgrasses

Thrift et al. (2013) found bluebunch wheat grass did not tolerate elk grazing at either heavy and light grazing levels, in a west central Montana (similar to Foothills fescue NSR) experiment.

3.5.6 Wind and Water Management

Cover crops of annual species, such as wheat or oats may be used to reduce potential erosion from wind or water. Woosaree and McKenzie (2015) used cultivated oats in a Foothills rough fescue seeding experiment, to improve seed movement in the seed drill, and provide erosion control. They concluded oats provided good protection from erosion. Sherritt (2012) used Dahurian rye in a seeding experiment to test the response of **Foothills rough fescue** to the nurse crop. He found rough fescue responded positively to rye seedlings. Sheley et al. (2006) planted common wheat with Foothills rough fescue, **Idaho fescue** and **bluebunch wheat grass**, finding Idaho fescue was successful with the wheat, if seeded at a low seeding rate (977 seeds/m2). In his experiment, Foothills rough fescue failed to establish (Sheley et al. 2006).

4 2014 MONITORING CASE STUDIES - METHODS

4.1 Data Collection Methods

Monitoring sites were established on existing wellsites and pipelines of various ages in upland Ecological Range Site types. Sites were sought with available information on site history and reclamation treatments where possible (Appendix B). During the first field season of this project efforts were made to survey wellsites of variable age to gain perspective on recovery over an extended time frame. Prior recovery strategy surveys in the Dry Mixedgrass and Mixedgrass NSRs revealed considerable evidence of natural recovery of sites that were disturbed prior to the implementation of reclamation policies and regulations (i.e. 1963). The prevailing understanding of recovery in fescue grasslands going into this study is that there is little evidence to date that disturbed fescue grasslands can be restored. Little information exists other than approximate construction dates for sites prior to 1963. Fragmentary and anecdotal information exists for a number of sites constructed between 1963 and 2000. Detailed treatment information is available for those sites constructed after 2000.

For each assessment (disturbance and control), a 30 metre long transect comprised of ten micro-plots (20 cm x 50 cm Daubenmire frames) was installed to record vegetation species diversity and foliar cover estimates. The controls were an adjacent undisturbed plant community within the same ecological range site to compare vegetation cover, range health and reclamation progress.

Site locations were recorded using hand-held GPS units. Photographs were taken to document each site. A one metre square frame was placed directly over the disturbance and again at the control and photographed from above. A second photo was taken looking along the transect, with the frame in the foreground. A third photograph was an oblique view of the Daubenmire frame.

Vegetation inventories were conducted using micro-plot sampling for species composition and canopy cover. A 20 cm x 50 cm Daubenmire frame was used for grassland communities and a 1 m x 1 m for shrubs. Ten frames were inventoried for each transect. Percentage foliar cover estimates of all vascular vegetation species, clubmoss, moss, lichen, litter and bare ground were recorded.

Data was recorded using standard ESRD – Rangelands MF5 range inventory forms and submitted to ESRD for entry into their Ecological Site Information System (ESIS) vegetation database.

A range health assessment was also conducted on disturbed soils and the undisturbed reference, based on the current manual developed by ASRD and LandWise Inc. (2010). Range health assessment provides perspective on the range capability of reclaiming communities. This technique also links current land use to the condition of the reclaiming grassland.

Data was interpreted in the context of tools developed for classifying rangelands including; Grassland Vegetation Inventory (GVI) mapping of ecological range sites (ASRD and LandWise Inc. 2010), AGRASID and the appropriate Range Plant Community Guide by NSR: Foothills Fescue (Adams et al. 2005), Foothills Parkland (DeMaere et al. 2012), or Montane (Willoughby et al. 2008), which links naturally occurring plant communities to ecological range sites. In the event that a plant community did not correlate to a plant community in the guide, then a name was assigned to the community based on what appeared to be key indicator or dominant species. The plant community name included the word “conditional” as an indicator of no known range plant community to date for the subregion.

4.2 Data Analysis and Interpretation

Data was interpreted for each site by comparing plant species composition and range health on the recovering disturbance versus the undisturbed area established as a comparison. Any information available on construction practices was also considered. There are not enough replicates of treatments, recovery time frames or ecological range sites to group the monitoring results statistically.

4.2.1 Assessment of Successional Stage

Succession is a process defined as the gradual replacement of one plant community by another over time. Seral stages are measures of succession used to describe the state and health of a plant community. More mature seral stages have greater range health and greater ability to perform ecological functions, including; net primary production, maintenance of soil/site stability, capture and beneficial release of water, energy and nutrient cycling and plant species functional diversity (Adams et al. 2013).

Table 4-1 Definitions for Plant Community Seral Stages on Disturbed Topsoil

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.

Assessing the seral stage on disturbance plant community clusters was based on species cover and composition, and an understanding of species persistence (for example annual weeds versus persistent long-lived species versus invasive species). Definitions for plant community seral stages on disturbed topsoil (Table 4-1) have been developed based on long-term reclamation monitoring on the Express Pipeline project (Kestrel Research Inc. and Gramineae Services Ltd. 2011). Invasive non-native species are known to replace native species and establish permanent dominance in grassland communities. Reclaiming grassland sites where invasive non-native species occupy greater than 5% of the total live cover are at risk of succession to non-native modified plant communities.

5 MONITORING RESULTS

Tables of species common and scientific names can be found in Appendix A. Range health scores for each monitoring plot are tabulated in Appendix B. Species cover monitoring data are presented in Appendix C.

5.1 Monitoring Results – Pre 1963 Limited Policy Tools

Detailed vegetation transect summaries for all wellsites are presented in Appendix C.1 with a summary of key species and range health information presented in Table 5-1. The sites summarized in Table 5-1 span the time frame of 1914 to 1962. No construction records were available for these sites and the assumption is that none of these sites received any seeding treatment as they pre-date the requirement for revegetation and re-seeding. Most of the sites were located on uplands to the north of Chain Lakes Reservoir with the exception of the Waldron Ranch location which is located close to the boundary of the drier and warmer Foothills Fescue NSR.

Table 5-1 Wellsites Constructed between 1914 and 1962 in the Foothills Region of Southwestern Alberta

Attribute	Pre 1963 Well Sites							
Name	**Waldron**	**Hughs 1**	**Nelson 1**	**Nelson 2**	**Spruce 2**	**Hughs 2**	**Winter Rge**	**EP**
Construction Year	**1962**	**1914**	**1930s**	**1960**	**1961**	**1961**	**1914**	**1950**
Awnless Brome	2.4	25.5	3.7	7.1	6.7		22.3	70
Kentucky Bluegrass	15.6	36	48.1	12.2	18.3	56.7	23.3	25
Timothy	3.9		0.1	1.0	8.7	0.7		10
White Clover			0.6	7.7	6.0			2
Canada Thistle	1.5		4.6	2.5	2.0	7.7	5.7	1
Rough Fescue	0.8			0.2		1.7		
Parry's Oat grass	0.0		0.5					
Idaho Fescue	0.0							
Native Wheatgrasses	1.0		0.3			2.0		
Native Graminoids	11.5	2.0	0.0	0.9				3
Native Forbs	28.9	13.5	7.6	4.6	10.0	11.7		
Rose	2.4	58		0.3	23.3	4.0		
Snowberry		6					11.7	
Range Health Score	**34**	**64**	**25**	**28**	**51**	**66**	**57**	**63**
Moss	28	0	0	2.8	0	0	0	0
Bare Soil	0	0	0.7	12.2	0	0	3	0
Total Vegetation	96	100	73.3	34.5	100	100	100	100

Reclamation Plant Community

The reclamation treatment for these wellsites is assumed to be natural recovery with no information available on soil handling. Grassland plant communities in the Foothills Parkland and adjoining Foothills Fescue NSRs are typically dominated by a few native grasses including rough fescue, Parry's oat grass, Idaho fescue, native wheat grasses, June grass and sedges. The plant communities on these wellsites were mostly dominated by invasive agronomic grasses including awnless brome, Kentucky bluegrass, and timothy with variable amounts of white clover *(Trifolium repens)* and Canada thistle. Interesting to note the driest location within the Foothills Parkland on the Waldron Ranch showed the greatest degree of recovery, with a presence of rough fescue, native wheat grasses and a significant cover of other infilling native species of native grasses and native forbs. The range health score for this site was 'unhealthy' due to the lack of litter cover.

Site Stability

All of the wellsites except Nelson 2, showed stable site conditions with no evidence of soil erosion or increased human caused bare ground. The Nelson 2 site showed minor evidence of erosion and an increase in human caused bare ground due to localized heavy grazing pressure on the site. Otherwise, all sites were well vegetated and stable although cover of moss was notably absent except at the Waldron site.

Range Health

Range health scores ranged from 25 to 68 % which represents range health classes of 'unhealthy' to low 'healthy with problems'. The major factor impacting the relatively low scores was the modification of the plant community to a non-native character. Where range health reached the 'healthy with problems' status was largely due to abundant litter and stable soils. Rose *(Rosa acicularis)* and Snowberry *(Symphoricarpos albus)* were the principal shrub species.

Infill

Despite the lack of infilling of principal native grass species associated with foothills fescue grasslands, there was infilling of some native graminoids and a significant amount of native forbs on six of eight sites.

Succession of Disturbance Plant Communites Over Time

The general observation for these sites is that, with the exception of the Waldron Ranch site which exists in the driest portion of the Foothills Parkland NSR, the plant communities are largely modified to invasive agronomic species with very minor recovery of native species in the plant community. Despite this lack of recovery of native character, the sites are generally stable and well vegetated.

Performance of the Revegetation Strategy Over Time

The general conclusion for natural recovery in the absence of any knowledge about associated soil handling practices is that this strategy has not resulted in much recovery of the native character of these plant communities. The picture is further complicated as most of these sites are located in lower slope/valley bottom locations with cumulative impacts from other land use pressures.

5.2 Monitoring Results – Early Reclamation Tools (1963 to 1980) and Initial Minimum Disturbance Practices (1980 to 2000)

The sites summarized in Table 5-2 span the time frame of 1963 to 2000 and these two classes span the years reflecting the establishment and initial refinement of reclamation legislation and regulation in Alberta (See appendix C.2). Limited and anecdotal construction and reclamation records are available for these sites as well. All sites were located in the Foothills Parkland upland to the north of Chain Lakes. McPherson and Blades were constructed pre-1980 and Sears, Pekisko and Spruce constructed after 1980 during the time period when the initial minimum disturbance practices were under development. All five sites showed evidence of top soil stripping of the wellsite and soil replacement. There is no information about revegetation of McPherson and Blades wellsites. Sears and Spruce ranch sites were revegetated to the standard ESRD wheat grass cultivar mix of the day (Northern, Western, Slender wheat grasses). The Pekisko ranch site was revegetated to a mixture including Sheep fescue and Cicer milk vetch *(Astragalus cicer)*.

Table 5-2 Well sites constructed between 1963 and 2000 in the foothills region of Southwestern Alberta

Attribute	**Well Sites 1963 to 2000**			
Name	**McPherson**	**Blades**	**Sears**	**Pekisko**
Construction Year	**1970**	**1970**	**1983**	**1985**
Awnless Brome	2.5	8.3		0.5
Kentucky Bluegrass	67.5	13.3	4.1	19
Timothy	3.6	1.7	5.8	11.8
Sheep Fescue			43.2	6.0
White Clover	2.6	1.3	3.7	
Cicer Milkvetch				42.5
Rough Fescue				
Parry's Oat grass				
Idaho Fescue				
Native Wheatgrasses	3.8		2.3	
Native Graminoids		0.7	2.7	2.7
Native Forbs	1.0	10.7	3.4	
Rose	0.2	15.0		
Snowberry	0.1	3.3		
Range Health Score	**28**	**43**	**25**	**61**
Moss	0	0	30.5	0
Bare Soil	0.7	0	12.5	1.5
Total Vegetation	**99.5**	**100**	**83**	**98**

Pre-disturbance (or adjacent) Plant Community

Pre-disturbance plant communities for McPherson and Blades were dominated by Parry's oat grass but also showed a degree of modification with Kentucky bluegrass and timothy present. The other three sites developed post-1980 were dominated by Parry's oat grass, Idaho fescue, rough fescue and western porcupine grass.

Reclamation Plant Community

The pre-1980 sites at McPherson and Blades were largely modified communities dominated by Kentucky bluegrass, awnless brome and timothy with rose and snowberry shrub cover. On the post-1980 sites, the influence of the emerging seed mixtures of the day are reflected in the plant communities with Sheep fescue and Cicer milk vetch being dominant. The establishment and proliferation of Cicer milk vetch was so aggressive that it was observed along the access trail leading from the main access road, a full mile away from the old wellsite.

Site Stability

All of the wellsites showed stable site conditions with no evidence of soil erosion or increased human caused bare ground. All sites had abundant vegetation cover and Sears and Spruce ranch sites showed a remarkable amount of moss cover at about 35% at each site. The Sears ranch site had 12 % bare soil associated with livestock selectively grazing the old wellsite area.

Range Health

Range health scores ranged from 25 to 61 % which represents range health classes of 'unhealthy' to low 'healthy with problems'. Again, like the wellsites in the previous section, the major factor impacting the relatively low scores was the modification of the plant community to a non-native character. Where range health reached the 'healthy with problems' status was largely due to abundant litter and stable soils.

Infill

There was a general infilling of native graminoids and forbs but not of the major native grass species associated with this Natural Subregion. The Spruce ranch site showed the greatest infill with about 23% cover from native species.

Succession of Disturbance Plant Communites Over Time

On the pre-1980 sites succession was primarily to non-native species with limited infilling of natives or recovery to the offsite character of the plant community. On the post-1980 sites, succession was sharply influenced by cultivars that had been considered as acceptable substitutions of native species for the times they were seeded. Both Sheep fescue and Cicer milk vetch are no longer seen as suitable and in fact will contribute to a 'trending-to-modified' status in the long run. Somewhat surprisingly, neither the Sears or Spruce Ranch sites showed any persistent establishment of wheat grass cultivars as is commonly observed in the Dry Mixedgrass and Mixedgrass NSRs.

Performance of the Revegetation Strategy Over Time

The general conclusion here is that the seeding treatments employed for these five wellsites during the time frame of 1963 to 2000 did not show any measurable results in recovery to the native pre-disturbance plant communities.

5.2.1 Wildcat Hills Gas Field Development in the Montane NSR (1999 to 2002)

Project History and Reclamation Techniques

In 1999, Olympia Energy Inc. (Olympia) constructed three surface wells, a compressor facility, and associated pipelines and access trails on Providence Ranche, in the Wildcat Hills, northwest of Cochrane, Alberta, in the Montane NSR. The area affected by the gas field development is located along a valley bottom, surrounded by steep slopes covered with mature conifer forest to the west. To the east, the steep slopes are covered with Foothills rough fescue grasslands and aspen clones, with limber pine growing in the rocky ridge tops. Portions of the valley bottom have been disturbed historically by clearing activities to create additional grassland forage for cattle (AXYS 2004).

A conservation easement agreement with the Nature Conservancy of Canada was put into place with the landowner to protect the ecological integrity of the ranch. In 1999, AXYS Environmental Consulting Ltd. was contracted to assist Olympia with environmental assessment and design for wellsites, access trails and associated pipelines. Minimizing disturbance to the native plant communities was the primary goal adhered to in the location of suitable wellsites, access trails and pipelines. Horizontal directional drilling techniques were used by Olympia to access gas reserves located under steep, naturally vegetated terrain, from wellsites located on historically modified terrain, located in the valley bottom. Similarly, existing access trails were utilized for the location of access trails to the wellsites and pipeline routing. AXYS provided detailed pre-construction environmental assessments, environmental protection planning, and onsite environmental inspection through all phases of the development (AXYS 2004).

Two wells were drilled from surface lease locations in 1999, LSD 3-3-27-5 W5M (Monitoring Site 1) and LSD 6-9-27-5 W5M. Both wells were located on previously disturbed, modified pasture located in the valley bottom. Access trails and pipelines were located and constructed following previously disturbed ranch trails. Pipelines were installed within the access trail RoWs wherever possible. Minimal disturbance construction techniques were used to build a pipeline leading from the 15-4 wellsite to the western edge of the property. This area was seeded to primarily native seed mix including 25% rough fescue seed (Monitoring Site 6). A horizontal direction drill was implemented to avoid approximately 200 m of high quality rough fescue grasslands on the western leg of the pipeline. The initial development was completed in 1999 and the wellsites reclaimed and seeded for the production phase, the access trail upgraded and reclaimed, and the pipelines reclaimed and seeded. Specially designed, primarily native seed mixes were used for revegetating exposed topsoil, with the exception of a small 'natural recovery' area (Monitoring Site 2) located on the pipeline RoW at the north end of the property.

In 2000, Olympia drilled additional downhole locations from the existing 15-4 and 6-9 (Monitoring Site 8A) surface lease locations, and constructed a compressor station to improve drawdown from the reserve. To minimize the disturbance, the existing surface leases were extended to accommodate new drilling. By December 2000, the development was completed, but reclamation seeding of additional disturbances was not completed until September 2002 (AXYS 2004).

Reclamation Plant Community – Site 1 (Fenced Well Site)

This monitoring site was established on a reclaimed cut and fill slope on a north-facing slope above a well at LSD 15-4-27-5 W5M that was drilled and reclaimed in 1999. This area is transitional between a mixed conifer-aspen forest and rough fescue grassland. The plant community in the undisturbed monitoring reference area is a 'trending-to-modified' plant community (see Table 4-1 for definition) of Foothills rough fescue and Kentucky bluegrass. Off site Kentucky bluegrass cover levels fluctuate with seasonal moisture but averaged more than 10% cover (Appendix C.4).

The replaced topsoil was seeded in 1999 to Seed Mix 1. This wellsite has remained fenced for 14 years since seeding. In the first few years after seeding, the dominant cover species established from the seed mix, noticeably awned wheat grass, Sheep fescue and Northern wheatgrass, as well as common annual weedy species and dandelion. By year three, dominance shifted to perennial non-native grasses from the seedbank, Kentucky bluegrass and quack grass (Appendix C.4).

<u>Seed Mix 1 – 1999</u>

Awned wheat grass	10%
Northern wheat grass	10%
Western wheat grass	15%
Mountain brome	10%
Green needle grass	25%
Sheep fescue	20%
June grass	10%

Seed Mix 1 contains one non-native species, Sheep fescue. This species has in recent years been documented as invasive, not only establishing persistent cover on topsoil disturbances but also spreading into undisturbed native grassland (Kestrel Research Inc. and Gramineae Services Ltd. 2011). In 2014 Sheep fescue was observed at 4.1% cover in the native shrubland adjacent to the seeded wellsite. It is also the only species from the seed mix still present.

Fourteen years after seeding, the site is stable but in poor range health ('unhealthy'). The dominant species are Kentucky bluegrass, Canada thistle, white clover and Sheep fescue, none of which are native. Lack of grazing has reduced structural diversity. None of the native species in the mix were documented in the transect frames. One positive trend is infill of nine native perennial forbs, two sedges and one perennial shrub. However, the revegetation has not been successful in establishing a native plant community on a site that was 'trending-to-modified' to begin with.

Reclamation Plant Community – Site 8A (Fenced Wellsite)

This monitoring site was established on a cut and fill slope on a west-facing Overflow range site upslope of a well at LSD 6-9-27-5 W5M that was reclaimed in 2002. This area was previously disturbed, 'trending-to-modified' pasture located in the valley bottom. Dominant species on the undisturbed comparison area were Foothills rough fescue (18% cover), Canada thistle (13% cover) timothy (11% cover) and Kentucky bluegrass (8% cover) (Appendix C.4). The site was reclaimed in 2002 to a primarily native seed mix (Seed Mix 3) composed of 40% rough fescue seed.

Seed Mix 3 – 2002

Foothills Rough Fescue	40%
Slender wheat grass	12%
Northern wheat grass	12%
Streambank wheat grass	6%
Green needle grass	18%
June grass	6%
Mountain brome	6%

Twelve years after seeding the fenced well site is dominated by timothy, Kentucky bluegrass and Canada thistle, at 11%, 9% and 4% cover respectively. Only one species from the seed mix, mountain brome (*Bromus carinatus*) is found on the site at 2% cover. No rough fescue was documented on site, even though rough fescue seed made up 40% of the seed mix.

The site is stable, with no eveidence of soil erosion after 12 years, but in 'unhealthy' range condition, with reduced litter levels, infestation with noxious weeds and little structural diversity. One positive trend is infill of nine native perennial forbs. However, the revegetation has not been successful in establishing a native plant community on a site that was 'trending-to-modified' to begin with.

Reclamation Plant Community – Site 6 (Unfenced Pipeline RoW)

This monitoring site was established on a narrow strip of disturbed topsoil (1m wide) along a pipeline right-of-way in rolling grassland along the valley bottom. This area was once rough fescue grassland but historic heavy grazing has permitted the establishment of invasive non-native species; Kentucky bluegrass, awnless brome and timothy. The surrounding plant community is a Kentucky Bluegrass – Foothills Rough Fescue (Montane: C3) range plant community (Willoughby et al. 2008) in 'healthy' range condition. Monitoring plots in the undisturbed comparison documented native grasses Foothills rough fescue at a cover value of 5% and awned wheat grass cover at 5%. Dominant non-natives were Kentucky bluegrass at 13% and awnless brome cover at 6% (Appendix C.4).

The area was reclaimed in 1999 to a primarily native seed mix (Seed Mix 2) composed of 25% rough fescue seed.

Seed Mix 2 – 1999

Foothills Rough fescue	25%
Awned wheat grass	5%
Northern wheat grass	5%
Western wheat grass	7.5%
Mountain brome	5%
Green needle grass	12.5%
Sheep fescue	10%
June grass	5%

Total vegetation cover on the unfenced pipeline RoW averaged 37% in year one, 74% after two years and 62% cover after three years growth (AXYS 2004). Kentucky bluegrass remained the dominant cover species both on and off the recovering disturbance one, two and 14 years after reclamation.

Cover values for Kentucky bluegrass after 14 years recovery are 13% off site and 10% on the disturbance. Cover values of awnless brome after 14 years recovery are 6% off site and 7% on the disturbance. Species on the disturbance after 14 years that may have come from the seed mix include rough fescue (1.7% cover), awned wheat grass (0.5% cover), northern wheat grass (0.4% cover) and June grass (0.4% cover). Sixteen different native forb infill species were recorded on the disturbance. The reclaimed area range health score is 'healthy with problems', indicating increasing ecological function over time. Litter values and native plant diversity are higher than for the fenced sites.

With grazing, initial cover values were generally lower than on the fenced wellsites. In years one and two there was little evidence of the species in the seed mix establishing in areas where moderate grazing occurred during the summer of year one. Grazing on the reclaiming RoW also appeared to be heavier than in the surrounding pasture during the first two years after seeding (AXYS 2004). Wellsite areas, which were excluded from grazing, had a greater variety of grass species re-establishing on the disturbance in the first year. However, they also had more weed establishment (AXYS 2004) and in the long term they are 'unhealthy' and isolated from resource utilization.

5.3 Monitoring Results - 2000 to Present – Priority on Managing Surface Disturbance

The sites summarized in Table 5-3 were reclaimed post-2000 and reflect practice changes that consider the difficulty of restoration of Foothills fescue grasslands. The MFC wellsites were developed with matting placed over the intact grassland between January and July, resulting in minimum surface disturbance and permitting revegetation from the intact grassland sod and seedbank. At the Lewis ranch sites, the lower slopes of the wellsite remained unstripped. This area of intact sod was covered in geotextile and topsoil from the upper portion of the lease was placed onto the geotextile over winter. Soil was then carefully removed from the storage area and replaced on the stripped portion of the lease. Revegetation was accomplished on both areas of the lease with rough fescue plugs and over seeded to native grasses with a bunch type growth habit. Similarly, on both the Cross site and the Cross Gravel Pit sites, once stripped topsoil was replaced, revegetation was accomplished with seeding of rough fescue plugs plus over-seeding of native species with a bunch type growth habit.

Table 5-3 Well sites constructed post 2000 in the foothills region of Southwestern Alberta

Attribute	Well Sites Post 2000									
Name	**MFC 1 & 2**		**MFC 4 & 3**		**Lewis Ranch**			**Cross**	**Cross-Gravel Pit**	
Treatment	**Control**	**Matted**	**Control**	**Matted**	**Control**	**Stripped**	**No-Strip**	**Disturbed**	**Control**	**Disturbed**
Construction Year		**2005**		**2005**		**2007**	**2007**	**2008**		**2008**
Awnless Brome	5.9	6.4	7.2	10.5						5.0
Kentucky Bluegrass	6.1	6.3	8.3	3.5	24.2	46	22.5	55	6.0	26
Timothy	9.6	7.1	19.5	10.6		0.7		1.6		
Orchard grass					0.5	2.3				
Creeping Red Fescue						1.8		5.5		
Alfalfa								0.7		
Canada Thistle	4.7	1.2	7.8	0.2	0.5		0.3			
Rough Fescue			1.6		18.5	8.5	23.3	1.7	2.0	4.5
Parry's Oat grass	2.0	1.3	0.5							
Idaho Fescue					0.4	4.5				5.4
Native Wheatgrasses		0.5	0.5		0.6	2.2	8.3	2.0	7.3	0.8
Native Graminoids	2.4	5.8	12.2	3.0	2.9		0.1		27.7	2.4
Native Forbs	33.9	7.2	15	5.4	8.1	0.6	1.4	2.1	16.8	1.6
Rose	2.6								10.7	
Shrubby Cinquefoil	0.5	0.2	0.1	0.2						
Range Health Score	**67**	**53**	**63**	**62**	**67**	**68**	**73**	**41**	**69**	**64**
Moss	0	0	0	0	0	1.5	0	0.2	0.7	3.3
Bare Soil	0	0.3	0	0	0	0	0	2.7	5.8	0.7
Total Vegetation	**70**	**43.5**	**75**	**41.5**	**100**	**100**	**100**	**97.5**	**93.4**	**97**

Pre-disturbance (or adjacent) Plant Community

The pre-disturbance plant communities at all wellsites were native in character but had a significant component of invasive agronomic species including awnless brome, Kentucky bluegrass and timothy. In addition to these species, the MFC and Cross ranch sites included a minor cover of Parry's oat grass or rough fescue plus a significant component of native forbs and graminoids. The Lewis ranch site had the highest proportion of rough fescue which was co-dominant with Kentucky bluegrass.

Reclamation Plant Community

Of all the wellsites evaluated in this initial review of Foothills wellsites, these treatments provided some of the best examples of native species re-establishment with improved practices. Native infilling species ranged from 15 to 33 % depending on site and treatment. The complicating factor in interpreting these results is the profound influence of above average moisture levels in the region extending back to the time of the last drought year which was 2001. As such, even the most healthy plant communities show elevated levels of invasive agronomic species. It will be interesting to see how sites like these evolve through periods of dry or drought conditions when native species are normally much more competitive.

Site Stability

All of the wellsites showed stable site conditions with no evidence of soil erosion or increased human caused bare ground. All sites had abundant vegetation cover with very limited cover of bare soil. Trace to minor amounts of moss were recorded on Lewis, Cross and Cross – Gravel pit sites.

Range Health

Range health scores on disturbed wellsites ranged from 41 to 73% and overall were much higher than for disturbed sites reported in the earlier time categories. It's important to note that the control sites were in the mid to upper range of the 'healthy with problems' class, overall, largely due to the presence of invasive agronomic species, strongly influenced by a series of years with above average precipitation.

Infill

Looking across all reclamation treatments, the percentage of cover from infilling native species including rough fescue, Idaho fescue, native wheat grasses, native forbs and graminoids, ranged from 15 to 33% cover. The highest percentage cover of native infilling species was on the second MFC wellsite and the non-stripped Lewis wellsite location.

Succession of Disturbance Plant Communities Over Time

On the pre-2000 wellsites succession was primarily to non-native species with limited infilling of natives, or were sharply influenced by the cultivar seed mix of the day (e.g. Cicer milk vetch, Sheep fescue etc.) On the post-2000 wellsites some hopeful expressions of native species infilling and recruitment were evident including a very strong re-establishment of rough fescue on the Lewis wellsite where the surface topsoil had not been stripped.

Performance of the Revegetation Strategy Over Time:

The general conclusion here is that minimum disturbance practices such as matting appears to have enhanced the re-establishment of native infilling species. Plug seeding with associated native species from seed has produced one of the very few sites in the fescue grassland where rough fescue appear to be re-established as a dominant species in the plant community.

5.3.1 Matted Wellsites on 9-27-14-1 W5M in the Foothills Parkland – 2003

The 9-27-14-W5M surface lease is located on the Willow Springs Ranch. The land owner requested that the native fescue grassland and associated soils be minimally disturbed to reduce weed establishment and preserve the native vegetation. The oil company responded with installation of interlocking high density polyethylene rig mats rather than the removal of topsoil (Gramineae Services Ltd. 2006). Matting was placed in January 2003 across the entire wellsite. Mats were removed as construction operations were completed in each area, however, the majority of the site was matted until July 28th, 2003.

The wellsite is located in the Foothills Parkland NSR in an Overflow (Loamy) range site on the lower south-facing slopes of a pasture used for calving. The range plant community is currently Kentucky bluegrass – Timothy / Common dandelion (FPB4), a successional plant community developed under heavy grazing pressure. This field is used for calving. It is grazed annually at the same time of year, resulting in the loss most of the rough fescue from the plant community (Appendix C.6). The dominance of non-native invaders in this community make recovery to a more native plant community unlikely, even with prolonged rest, and especially on moister sites (DeMaere et al. 2012).

After the mats were removed in 2003, there was a complete cover of firmly compressed vegetative litter at least 1 cm thick remaining on the ground surface (Gramineae Services Ltd. 2006). This layer is still evident 11 years later.

Early recovery monitoring surveys were conducted in 2003 and 2005, during the first and third growing season after mat removal (Gramineae Services Ltd. 2006). Two paired transects were established to assess recovery of the grassland from an area where matting that was removed May 20th (Transects 1 and 2 Appendix C.6) and another area where matting was removed July 28th, well into the growing season (Transects 3 and 4 Appendix C.6).

The delayed removal of mats in 2003 until late July caused many broadleaved plants and native grasses to die or be severely reduced. Many plant species observed during initial recovery in 2003 were not observed in 2005. By 2005, which was a high rainfall year, a dense tall (1m) growth of non-native, invasive timothy grass caused stunting of many of the remaining broadleaved plants.

After 11 years recovery, the dominant plant community, both on site and off, is still Kentucky bluegrass – Timothy / Common dandelion (FPB4). The wellsite has been fenced with essentially no grazing the entire time. Timothy, awnless brome and Kentucky bluegrass are dominant on all sites. The range health of the grassland, scored as a modified plant community, is ‘healthy with problems’. The site is stable, but only one or two structural layers of plants are present. The persistent litter layer has suppressed the groundcover and shorter plants. On the matted sites, the number of native perennial forbs is still reduced compared to the surrounding grassland.

6 REFERENCES

Achuff, P. 1994. Natural Regions, Subregions and Natural History Themes of Alberta (Revised). Alberta Environmental Protection, Parks Service. Edmonton, Alberta.

Adams, B.W., Ehlert, R., Moisey, D. and McNeil, R. 2005. Rangeland Plant Communities and Range Health Assessment Guidelines for the Foothills Fescue Natural Subregion of Alberta (Pub. No. T/044). Rangeland Management Branch, Public Lands Division, Alberta Sustainable Resource Development. Lethbridge, AB. 85 pp.

Adams, B.W., G. Ehlert, C. Stone, M. Alexander, D. Lawrence, M. Willoughby, D. Moisey, C. Hincz, A. Burkinshaw, Jennifer Carlson and Kevin France. 2009. Range Health Assessment for Grassland, Forest and Tame Pasture. Public Lands and Forests Division, Alberta Sustainable Resource Development. Pub. No. T/044

Adams, B.W., J Richman, L. Poulin-Klein, K. France, D. Moisey and R.L. McNeil. 2013. Rangeland Plant Communities for the Mixedgrass Natural Subregion of Alberta. Second Approximation. Rangeland Management Branch, Policy Division, Alberta Environment and Sustainable Resource Development, Lethbridge, Pub. No. T/03940 103pp.

Adler, P.B., Raff, D.A. and Lauenroth, W.K. 2001. The effect of grazing on the spatial heterogeneity of vegetation. Oecologia 2001: 465-479.

Alberta Innovates Technology Futures. 2013. Native Plants. Vegreville, AB. http://www.albertatechfutures.ca/RDSupport/BioandIndustrialTechnologies/BioresourceTechnologies/CropandMicrobialFeedstocks/NativePlants.aspx. [Accessed March 15, 2013].

Alberta Sustainable Resource Development (ASRD) and LandWise Inc. 2010. Grassland Vegetation Inventory (GVI) Specifications. 5th Edition.90 pages. Government of Alberta, Edmonton, Alberta.

Alberta Sustainable Resource Development (ASRD). 2007. Range Survey Manual for Alberta Rangelands. Rangeland Management Branch. Edmonton, Alberta. Pub. No.: I/176.

AXYS Environmental Consulting Ltd. (AXYS). 2004. Environmental Monitoring Report; Providence Ranche and Olympia Energy Wildcat Hills Facilities, Cochrane, Alberta – Final. Prepared for Olympia Energy Inc., Calgary, Alberta.

AXYS Environmental Consulting Ltd. 2003. Express Pipeline Ltd. environmental monitoring final report. Prepared for Terasen Pipelines (Formerly Express Pipeline, a division of Alberta Energy Company Ltd. and TransCanada Pipelines Ltd.). Calgary, AB.

Bakker, J. 2012. Plant propagation protocol for Pacific Northwest Plants. Washington University, Seattle, WA. https://courses.washington.edu/esrm412/protocols/protocols_files/graminoids.htm.

Barner, J. 2009. Propagation protocol for production of Hesperostipa comata seeds; USDA FS - R6 Bend Seed Extractory, Bend, Oregon. In: Native Plant Network. University of Idaho, College of Natural Resources, Forest Research Nursery, Moscow, ID. http://www.nativeplantnetwork.org/Network/ViewProtocols.aspx?ProtocolID=3781.

Bartolome, J.W., Fehmi, J.S., Jackson, R.D. and Allen-Diaz, B. 2004. Response of a native perennial grass stand to disturbance in California's Coast Range Grassland. Restoration Ecology 12: 279-289.

Best, J.N. and Bork, E.W. 2003. Using transplanted plains rough fescue (Festuca hallii [Vasey] Piper) as an indicator of grazing in Elk Island National Park, Canada. Natural Areas Journal 23: 202-209.

Bork, E., Willms, W., Tannas, S. and Alexander, M. 2012. Seasonal patterns of forage availability in the fescue grasslands under contrasting grazing hstories. Rangeland Ecology and Management 65: 47-55.

Brierley J.A., B.D. Walker, C.J. Thomas, P.E. Smith and M.D. Bock (Editors). 2006. Alberta Soil Names File (Generation 3) User's Handbook. Prepared by: Land Resource Unit, Research Branch, Agriculture and Agri-Food Canada.

Brierley, J.A., T.C. Martin, D.J. Spiess. 2001. AGRASID 3.0. Agricultural Region of Alberta Soil Inventory Database Version 3.0. Agriculture and Agri-Food Canada, and Alberta Agriculture, Food and Rural Development. Edmonton, Alberta.

Buisson, E., Holl, K.D., Anderson, S., Corcket, E., Hayes, G.F., Torre, F., Peteers, A. and Dutoit, T. 2006. Effect of seed source, topsoil removal, and plant neighbor removal on restoring California coastal prairies. Restoration Ecology 14: 596-577.

Burton, P.J. and Burton, C.M. 2002. Promoting genetic diversity in the production of large quantities of native seed. Ecological Restoration 20: 117-123.

Calgary Regional Partnerships. 2010. Calgary metropolitan plan environment reposrt: strategies and actions. O2 Planning + Design Inc., Calgary, AB. http://calgaryregion.ca/dms/Website/reports/General/Regional-servicing-and-CMP-Implementation/Calgary-Metropolitan-Plan-Environmental-Report-Strategies-and-Actions-Part-One/Calgary%20Metropolitan%20Plan%20Environmental%20Report%3A%20Strategies%20and%20Actions%20(Part%201).pdf. [Accessed April 11, 2014].

DeMaere, C., Alexander, M. and M. Willoughby. 2012. Rangeland Plant Communities and Range Health Assessment Guidelines for the Foothills Parkland Natural Subregion of Alberta. Alberta Environment and Sustainable Resource Development, Lands Division. Pincher Creek, Alberta. Pub. No. T/274 85 pp. 136

Desserud, P.A. 2013. Wellsites reclaimed with native hay in Southewestern Alberta. Unpublished data, University of Calgary. Calgary, AB.

Desserud, P. and Naeth, M.A. 2011. Promising results restoring grassland disturbances with native hay (Alberta). Ecological Restoration 29: 215-219.

Desserud, P. and Naeth, M.A. 2013a. Establishment of a native bunch grass and an invasive perennial on disturbed land using straw-amended soil. Journal of Environmental Management 114: 540-547.

Desserud, P. and Naeth, M.A. 2013b. Promising results with rough fescue (Festuca hallii) seeding following disturbance, in Central Alberta. Native Plants Journal 14: 25-31.

Desserud, P., Gates, C.C., Adams, B. and Revel, R.D. 2010. Restoration of Foothills rough fescue grassland following pipeline disturbance in southwestern Alberta. Journal of Environmental Management 91: 2763-2770.

Douwes, H. and Willms, W. 2012. Long-term grazing study at Stavely, Alberta. Prairie Soils and Crops Journal 5: 116-122.

Downing, D. 2004. Ecovars™, native plant cultivars, site restoration, and genetic integrity: an information review. Prepared for Alberta Sustainable Resource Development. Edmonton, AB. 18 pp.

Dunster, J.A. and K.J. Dunster. 1996. Dictionary of Natural Resource Management. UBC Press. Vancouver.

Ewing, K. 2002a. Effects of initial site treatments on early growth and three-year survival of Idaho fescue. Restoration Ecology 2: 282-288.

Ewing, K. 2002b. Mounding as a technique for restoration of prairie on a capped landfill in the Puget Sound lowlands. Restoration Ecology 10: 289-296.

Ferdinandez, Y.S.N., Coulman, B.E. and Fu, Y. 2005. Detecting genetic changes over two generations of seed increase in an awned slender wheatgrass population using AFLP markers. Crop Science 45: 1064–1068.

Friesen, G.M. 2002. Native grasses: improving the seedling vigor and seed production of blue grama (Bouteloua gracilis) and prairie Junegrass (Koeleria macrantha) ecovarstm. University of Manitoba, 162 pp.

Government of Alberta. 2010. Weed Control Regulation, Weed Control Act. Regulation 19/2010. Alberta Queen's Printer, Edmonton, Alberta. Available at: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/acts6156

Gramineae Services Ltd. 2006. Compton Petroleum Surface Lease 9-27-14-1 W5M - Preserving a Native Grass Community – Draft - Unpublished. Prepared for: Compton Petroleum Corporation, Calgary.

Hammermeister, A.M. and Naeth, M.A. 1996. The native prairie revegetation research project: description of reclamation practices and research sites in the Dry Mixed Grass natural subregion. Canadian Association of Petroleum Producers (CAPP). Edmonton, AB. 74 pp.

Hardy BBT Limited 1989. Manual of plant species suitability for reclamation in Alberta – 2nd Edition. Alberta Land Conservation and Reclamation Council Report No. RRTAC 89-4. 436 pp.

Hayes, G.F. and Holl, K.D. 2003. Cattle grazing impacts on annual forbs and vegetation composition of mesic grasslands of California. Conservation Biology 17: 1694-1702.

Hough-Snee, N., Bakker, J.D. and Ewing, K. 2011. Long-term effects of initial site treatment on fescue in a novel prairie ecosystem. Ecological Restoration 29: 14-19.

Huddleston, R.T. and Young, T.P. 2004. Spacing and competition between planted grass plugs and preexisting perennial grasses in a restoration site in Oregon. Restoration Ecology 12: 546-551.

Hufford, K.M. and Mazer, S.J. 2003. Plant ecotypes: Genetic differentiation in the age of ecological restoration. Trends in Ecology and Evolution 18: 147-155.

Iverson, L.R. and Wali, M.K. 1982. Buried, viable seeds and their relation revegetation after surface mining. Journal of Range Management 35: 648-652.

Jordan, N.R., Larson, D.L. and S.C., H. 2008. Soil modification by invasive plants: effects on native and invasive species of mixed-grass prairies. Biological Invasions 10: 177-190.

Kaufmann, J., Bork, E.W., Blenis, P.V. and Alexander, M.J. 2013. Cattle habitat selection and associated habitat characteristics under free-range grazing within heterogeneous Montane rangelands of Alberta. Applied Animal Behaviour Science 146: 1-10.

Kestrel Research Inc. and Gramineae Services Ltd. 2011. Long Term Recovery of Native Prairie from Industrial Disturbance; Express Pipeline Revegetation Monitoring Project 2010. Prepared for: Kinder Morgan Canada, TransCanada PipeLines, ConocoPhillips Canada and Alberta Sustainable Resource Development Public Lands Division. Available at http://www.Foothillsrestorationforum.ca

Kiehl, K.K. and Wagner, C. 2006. Effect of hay transfer on long-term establishment of vegetation and grasshoppers on former arable fields. Restoration Ecology 14: 157-166.

Kupsch, T.T., K. France, J. Richman and R. McNeil. 2012. Rangeland Plant Communities and Range Health Assessment Guidelines for the Northern Fescue Natural Subregion of Alberta. Rangeland Management Branch, Lands Division, Alberta Environment and Sustainable Resource Development, Red Deer, Alberta. Pub. No. T/265. 77pp.

Lancaster, J., Neville, M. and Hickman, L. 2012. Long-term Revegetation Success of Industry Reclamation Techniques for Native Mixedgrass Prairie: Cypress Uplands and Majorville Uplands. Prepared for Petroluem Technology Alliance Canada (PTAC). http://www.Foothillsrestorationforum.ca. [Accessed January 31, 2013].

Landwise. 2003. Foothills Parkland Natural Subregion Range Classification Guide. Unpublished reference guide prepared for ESRD. 20 pages.

Larney, F.J., Akinremi, O.O., Lemke, R.L., Klaassen, V.E. and Janzen, H.H. 2005. Soil responses to topsoil replacement depth and organic amendments in wellsite reclamation. Canadian Journal of Soil Science 85: 307-317.

Majerus, M.E. 2009. Forage and reclamation grasses of the northern Great Plains and Rocky Mountains.Valley Printers.

McGinnies, W.J. 1987. Effects of hay and straw mulches on the establishment of seeded grasses and legumes on rangeland and a coal strip mine. Journal of Range Management 40: 119-121.

Mealor, B.A. and Hild, A.L. 2007. Post-invasion evolution of native plant populations: a test of biological resilience. Oikos 1493-1500.

Moisey, D.M., Bork, E.W. and Willms, W.D. 2005. Non-destructive assessment of cattle forage selection: A test of skim grazing in fescue grassland. Applied Animal Behaviour Science 94: 205-222.

Naeth, M.A. 1985. Ecosystem reconstruction following pipeline construction through solonetzic native rangeland in southern Alberta. Thesis. University of Alberta, Edmonton, AB.

Naeth, M.A. 1988. The impact of grazing on litter and hydrology in mixed prairie and fescue grassland ecosystems of Alberta. Dissertation. University of Alberta, Edmonton, AB.

Naeth, M.A., Chanasyk, D.S., Rothwell, R.L. and Bailey, A.W. 1991. Grazing impacts on soil water in mixed prairie and fescue grassland ecosystems. Canadian Journal of Soil Science 71: 313-325.

Native Plant Workling Group. 2000. Native plant revegetation guidelines for Alberta. Alberta Agriculture, Food and Rural Development and Alberta Environment. Edmonton, AB. 58 pp.

Natural Regions Committee 2006.Natural Regions and Subregions of Alberta. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. T?852

Neville, M. and Lancaster, J. 2008. Field observations of the recovery of native rangeland plant communities on Express Pipeline. Pincher Creek, AB. Pp. 30.

Neville, M., Adams, B.W., and Lancaster, J. 2013. Recovery Strategies for Industrial Development in Native Prairie for the Dry Mixedgrass Natural Subregion of Alberta. Prepared for Range Resource Management Program, Lands Division, ESRD, Lethbridge. 134pp.

Neville, M., J. Lancaster, B. Adams and P. Desserud. 2014. Recovery Strategies for Industrial Development in Native Prairie for the Mixedgrass Natural Subregion of Alberta – First Approximation. Prepared for: Range Resource Management Branch, Public Lands Division, Alberta Environment and Sustainable Resource Development.

Nurnberg, D. 1994. Germination, productivity, surviorship and competitive ability of six native grass species from the Northern Mixed-Grass prairie for use in prairie vegetation restoration. M.Sc. Thesis. University of Alberta, Edmonton, AB. 168 pp.

Ogle, D.G., Majerus, M.E., St, J., L., Tilley, D. and Jones, T.A. 2006. Needle-and thread. Hesperostipa comata. USDA NRCS plant guide. http://plants.usda.gov/plantguide/pdf/pg_heco26.pdf. [Accessed March 6].

Page, H.N. and Bork, E.W. 2005. Effect of planting season, bunchgrass species, and neighbour control on the success of transplants for grassland restoration. Restoration Ecology 13: 651-658.

Pahl, M.D. and Smreciu, A. 1999. Growing native plants of western Canada: common grasses and wildflowers. Alberta Agriculture, Food and Rural Development. Edmonton, AB. 118 pp.

Perry, L.G., Johnson, C., Alford, I.R., Vivanco, J.M. and Paschke1, M.W. 2005. Screening of grassland plants for restoration after spotted knapweed invasion. Restoration Ecology 13: 725-735.

Pokorny, M.L. and Mangold, J.M. 2009. Converting pasture land to native-plant-dominated grassland: A case study (Montana). Eclogical Restoration 27: 250-253.

Polster, D.F. 2014. Effective reclamation – lessons learned from 35+ years of work in field. Canadian Land Reclamation Association. Red Deer, AB.

Pritekel, C., Whittemore-Olson, A., Snow, N. and Moore, J.C. 2006. Impacts from invasive plant species and their control on the plant community and belowground ecosystem at Rocky Mountain National Park, USA. Applied Soil Ecology 32: 132-141.

Reis, R.E. and Hofmann, L. 1983. Numer of seedlings established from stored hay. Western Michigan University. Kalamazoo, MI.

Ridenour, W.L. and Ragan, M.C. 2003. Root herbivores, pathogenic fungi, and competition between *Centaurea maculosa* and *Festuca idahoensis*. Plant Ecology 169: 161-170.

Romo, J. and Lawrence, D. 1990. A review of vegetation management techniques applicable to Grasslands National Park. Canadian Parks Service technical Report 90-1/GDS. Environment Canada. Saskatoon, SK. 63 pp.

Sheley , R.L., Mangold, J.M. and Anderson, J.L. 2006. Potential for successional theory to guide restoration of invasive-plant-dominated rangeland. Ecologial Monographs 76: 365-379.

Sheley, R.L. and Bates, J.D. 2008. Restoring western juniper- (*Juniperus occidentalis*) infested rangeland after prescribed fire. Weed Science 56: 469-476.

Sherritt, D.E. 2012. *Festuca hallii* (vasey) Piper (plains rough fescue) and *Festuca campestris Rydb.* (Foothills rough fescue) Responses to Seed Mix Diversity and Mycorrhizae. University of Alberta, Edmonton, AB. 84 pp.

Sinton Gerling, H., Willoughby, M.G., Schoepf, A., Tannas, C. and Tannas, K. 1996. A Guide to Using Native Plants on Disturbed Lands. Alberta Agriculture, Food and Rural Development and Alberta Environmental Protection. Edmonton, AB. 247 pp.

Sinton, H.M. 2001. Prairie Oil and Gas: A Lighter Footprint. Alberta Environment. Edmonton, AB. 67 pp.

Smoliak, S., Adams, B.W., Schuler, B.G., Wroe, R.A., Klumph, S.G. and Willms, W.D. 1985. Forage production on selected native prairie sites in southern Alberta. Research Branch, Agriculture Canada, Lethbridge, AB.

Smreciu, E.A., Sinton, H.M., Walker, D.G. and Bietz, J.K. 2003. Establishing Native Plant Communities. Alberta Agriculture, Food and Rural Development, Alberta Environment and Alberta Sustainable Resource Development. Edmonton, AB.

Stevenson, M.J., Ward, L.K. and Pywell, R.F. 1997. Re-creating semi-natural communities: vacuum harvesting and hand collection of seed on calcareous grassland. restoration Ecology 5: 66-76.

Strong, W.L. and Leggat, K.R. 1992. Ecoregions of Alberta.Alberta Forestry, Lands and Wildlife. Edmonton, AB.

Tannas, K. 2001. Common plants of the western rangeland. Volume 1 grasses and grass-like species. Alberta Agriculture, Food and Rural Development. Edmonton, AB. 355 pp.

Tannas, K. 2003. Common Plants of the Western Rangelands. Volume 1, Grasses and Grass-like Species. Alberta Agriculture, Food and Rural Development. Olds College Press.

Tannas, S. 2011. Mechanisms Regulating *Poa pratensis L.* and *Festuca campestris Rybd.* Within the Foothills Fescue Grasslands of Southern Alberta. Dissertation. University of Alberta, Edmonton, AB. 362 pp.

Thrift, T.M., Mosley, T.K. and Mosley, J.C. 2013. Impacts from winter-early spring elk grazing in Foothills Rough Fescue grassland. Western North American Naturalist 73: 497-504.

Tyser, R.W., Asebrook, J.M., Potter, R.W. and Kurth, L.L. 1989. Roadside revegetation in Glacier National Park, U.S.A.: Effects of herbicide and seeding treatments. Restoration Ecology 6: 197-206.

Willoughby M.G., M.J. Alexander and B.W. Adams. 2008. Range Plant Community Types and Carrying Capacity for the Montane Subregion. Seventh Approximation. Sustainable Resource Development. Agriculture and Agri-Food Canada. Pub. No. T/136.

Wilson, M.V. and Clark, D.L. 2001. Controlling invasive Arrhenatherum elatius and promoting native prairie grasses through mowing. Applied Vegetation Science 4: 129-138.

Wilson, S.D. 2002. Prairies. In M.R. Perrow and A.J. Davy (eds.), Handbook of ecological restoration. Volume 2. Restoration in practice. Cambridge University Press. New York. Pp. 443-465.

Wilson, S.D., Bakker, J.D., Christian, J.M., Li, X., Ambrose, L.G. and Waddington, J. 2004. Semiarid old-field restoration: Is neighbor control needed? Ecological Applications 14: 476-484.

Woosaree, J. 2000. Market assessment of the native plant industry in western Canada. Prepared for Alberta Environment and Alberta Agriculture, Food and Rural Development by Alberta Research Council. Publication No: T/560. Vegreville, AB. 106 pp.

Woosaree, J. and James, B. 2006. Native plant species for revegetating oil and gas disturbances in the sandy soils of the Parkland ecoregion of Alberta. Alberta Research Council Inc. Vegreville, AB. 53 pp.

Woosaree, J. and McKenzie, M. 2015. Evaluating the revegetation success of Foothills Fescue grassland. Alberta Innovated-Technology Futures (AITF), Vegreville, AB. Pp. 23.

Appendix A Species Lists

A.1 Species Discussed in the Literature Review

Common Name	Cultivar	Scientific Name
Grasses		
Alkali bluegrass		Poa juncifolia Scribn.
Big bluegrass		Poa ampla Merr.
Bluebunch wheat grass	yes	Pseudoroegneria spicata (Pursh) A. Löve ssp. spicata
California oat grass		Danthonia californica Boland
Canada wildrye	yes	Elymus canadensis L.
Common wheat		Triticum aestivum
Early bluegrass		Poa cusiskii Vasey
Foothills rough fescue		Festuca campestris Rybd.
Green needle grass	yes	Nassella viridula (Trin.) Barkworth
Hooker's oat grass		Helictotrichon hookeri (Scribn.) Henr.
Idaho fescue		Festuca idahoensis Elmer
Intermediate oat grass		Danthonia intemedia Vasey
June grass	yes	Koeleria macrantha (Ledeb.) Schulte
Lemmons needle grass		Achnatherum lemmonii
Mountain brome	yes	Bromus carinatus Hook. & Arn.
Needle-and-thread grass		Hesperostipa comata (Trin. & Rupr.) Barkworth
Nodding brome	yes	Bromus anomalus Rupr. ex Fourn
Northern wheat grass	yes	Elymus lanceolatus (Scribn. & J.G. Sm.) Gould ssp. lanceolatus
Parry's oatgrass		Danthonia parryi Scribn.
Plains rough fescue		Festuca hallii
Prairie sandreed		Calamovilfa longifolia (Hook.) Scribn. var. longifolia
Richardson's needle grass		Achnatherum richardsonii (Link) Barkworth.
Rocky mountain fescue	yes	Festuca saximontana Rydb.
Sandberg bluegrass		Poa secunda J. Presl
Slender or awned wheat grass	yes	Elymus trachycaulus (Link) Gould ex Shinners ssp. subsecundus (Link) A.& D. Löve
Western porcupine grass		Hesperostipa curtiseta (A.S. Hitchc.) Barkworth
Western snowberry		Symphoricarpos occidentalis Hook.
Western wheat grass	yes	Pascopyrum smithii (Rydb.) A. Löve

Common Name	Cultivar	Scientific Name
Native forbs		
Aster		Aster spp.
Little club-moss		Selaginella densa Rydb.
Pasture sagewort		Artemisia frigida Willd.
Wild blue flax	yes	Linum lewisii Pursh
Wild lupine		Lupinus sericeus Pursh
Yarrow		Achillea millefolium L.
Non-native grasses and invasive grasses		
Crested wheatgrass		Agropyron cristatum (L.) Gaertn. ssp. pectinatum (Bieb.) Tzvelev
Dahurian rye	yes	Elymus dahuricus Turcz ex Giseb.
Kentucky bluegrass	yes	Poa pratensis L.
Quack grass		Elymus repens (L.) Gould.
Sheep fescue		Festuca ovina L.
Awnless brome		Bromus inermis Leyss. ssp. inermis
Timothy		Phleum pratense L.
Invasive forbs		
Annual hawkweed		Crepis tectorum L.
Canada thistle		Cirsium arvense (L.) Scop.
Hoary cress		Cardaria draba (Linnaeus) Desvaux
Leafy spurge		Euphorbia esulaL.
Spotted knapweed		Centaurea stoebe L.
Yellow sweet clover		Melilotus offinalis (L.) Lam

A.2 Species Listed by Scientific Name

Species Code	Scientific Name	Common Name
ACHIMIL	Achillea millefolium	common yarrow
AGOSGLA	Agoseris glauca	yellow false dandelion
AGRODAS	Elymus lanceolatus ssp. lanceolatus	Northern wheat grass
AGROPEC	Agropyron cristatum	crested wheat grass
AGROREP	Elytrigea repens var. repens	quack grass
ELYMLAN	Elymus lanceolatus ssp. lanceolatus	streambank wheat grass
AGROSCA	Agrostis scabra	rough hair grass
AGROSMI	Agropyron smithii	western wheat grass
AGROSPP	Agropyron species	wheat grass species
AGROSUB	Elymus trachycaulus var. subsecundus	awned wheat grass
AGROTRA	Elymus trachycaulus var. trachycaulus	slender wheat grass
ALLICER	Allium cernuum	nodding onion
AMELALN	Amelanchier alnifolia	saskatoon
ANDROCC	Androsace occidentalis	western fairy candelabra
ANDRSEP	Androsace septentrionalis	northern fairy candelabra
ANEMMUL	Anemone multifida	cut-leaved anemone
ANEMPAT	Anemone patens	prairie crocus
ANTEAPR	Antennaria aprica	low everlasting
ANTENEG	Antennaria neglecta	broad-leaved everlasting
ANTEPAR	Antennaria parvifolia	small-leaved everlasting
ARABSPP	Arabis species	cress species
ARCTUVA	Arctostaphylos uva-ursi	common bearberry
ARNIFUL	Arnica fulgens	shining arnica
ARTECAM	Artemisia campestris	plains wormwood
ARTEFRI	Artemisia frigida	pasture sagewort
ARTELUD	Artemisia ludoviciana	prairie sagewort
ASTECIL	Aster ciliolatus	Lindley's aster
ASTEERI	Aster ericoides	tufted white prairie aster
ASTEFAL	Aster falcatus	creeping white prairie aster
ASTELAE	Aster laevis	smooth aster
ASTESPP	Aster species	aster species
ASTRCIC	Astragalus cicer	Cicer milk vetch
ASTRDAS	Astragalus dasyglottis	purple milk vetch
ASTRSPP	Astragalus species	milk vetch species
ASTRVEX	Astragalus vexilliflexus	few-flowered milk vetch
AXYRAMA	Axyris amaranthoides	Russian pigweed
BOUTGRA	Bouteloua gracilis	blue grama
BROMBIE	Bromus biebersteinii	meadow brome

Species Code	Scientific Name	Common Name
BROMCAR	Bromus carinatus	keeled brome
BROMCIL	Bromus ciliatus	fringed brome
BROMINE	Bromus inermis	awnless brome
BROMPUM	Bromus inermis ssp. pumpellianus	pumpelly brome
CALAMON	Calamagrostis montanensis	plains reed grass
CALARUB	Calamagrostis rubescens	pine reed grass
CAMPROT	Campanula rotundifolia	harebell
CAPSBUR	Capsella bursa-pastoris	shepherd's-purse
CARELAN	Carex lanuginosa (Michx.)	Woolly sedge
CARELEP	Carex leptalea	bristle-stalked sedge
CAREOBT	Carex obtusata	blunt sedge
CAREPEN	Carex pensylvanica	sun-loving sedge
CAREPRA	Carex praegracilis	graceful sedge
CAREROS	Carex rossii	Ross' sedge
CARESPP	Carex species	sedge species
CARESPR	Carex sprengelii	Sprengel's sedge
CARESTE	Carex stenophylla	low sedge
CARUCAR	Carum carvi	caraway
CERAARV	Cerastium arvense	field mouse-ear chickweed
CHAMERE	Chamaerhodos erecta	chamaerhodos
CHENALB	Chenopodium album	lamb's-quarters
CHENLEP	Chenopodium leptophyllum	narrow-leaved goosefoot
CHENPRA	Chenopodium pratericola	goosefoot
CIRSARV	Cirsium arvense	Canada thistle
CIRSDRU	Cirsium drummondii	Drummond's thistle
CIRSFLO	Cirsium flodmanii	Flodman's thistle
CIRSVUL	Cirsium vulgare	bull thistle
COLLLIN	Collomia linearis	narrow-leaved collomia
COMAUMB	Comandra umbellata	bastard toadflax
DACTGLO	Dactylis glomerata	orchard grass
DANTINT	Danthonia intermedia	intermediate oat grass
DANTPAR	Danthonia parryi	Parry’s oat grass
DELPBIC	Delphinium bicolor	low larkspur
DODECON	Dodecatheon conjugens	mountain shooting star
DRABSP.	Draba sp.	Whitlow-grass species
EPILANG	Epilobium angustifolium	common fireweed
ERIGCAE	Erigeron caespitosus	tufted fleabane
ERIGSPP	Erigeron species	fleabane species
FAGOTAR	Fagopyrum tartaricum	buckwheat
FESTCAM	Festuca campestris	Foothills rough fescue
FESTIDA	Festuca idahoensis	Idaho fescue

Species Code	Scientific Name	Common Name
FESTOVI	Festuca ovina	sheep fescue
FESTRUB	Festuca rubra	red fescue
FRAGVIR	Fragaria virginiana	wild strawberry
GAILARI	Gaillardia aristata	gaillardia
GALETET	Galeopsis tetrahit	hemp-nettle
GALIBOR	Galium boreale	northern bedstraw
GENTAMA	Gentianella amarella	felwort
GERARIC	Geranium richardsonii	wild white geranium
GERAVIS	Geranium viscosissimum	sticky purple geranium
GEUMALE	Geum aleppicum	yellow avens
GEUMMAC	Geum macrophyllum	large-leaved yellow avens
GEUMTRI	Geum triflorum	three-flowered avens
GRINSQU	Grindelia squarrosa	gumweed
HAPLLAN	Haplopappus lanceolatus	lance-leaved ironplant
HEDYALP	Hedysarum alpinum	alpine hedysarum
HEDYBOR	Hedysarum boreale	northern hedysarum
HEDYSUL	Hedysarum sulphurescens	yellow hedysarum
HELIHOO	Helictotrichon hookeri	Hooker's oat grass
HEUCRIC	Heuchera richardsonii	Richardson's alumroot
HIERODO	Hierochloe odorata	Sweetgrass
HORDJUB	Hordeum jubatum	foxtail barley
JUNCBAL	Juncus balticus	wire rush
JUNIHOR	Juniperus horizontalis	creeping juniper
KOELMAC	Koeleria macrantha	June grass
LACTPUL	Lactuca pulchella	common blue lettuce
LAPPOCC	Lappula occidentalis	western bluebur
LATHOCH	Lathyrus ochroleucus	cream-colored vetchling
LEPIRAM	Lepidium ramosissimum	branched pepper-grass
LIATPUN	Liatris punctata	dotted blazingstar
LINASPP	Linaria species	toadflax species
LINAVUL	Linaria vulgaris	Toadflax
LINULEW	Linum lewisii	wild blue flax
LITHINC	Lithospermum incisum	narrow-leaved puccoon
LITHRUD	Lithospermum ruderale	woolly gromwell
LUPISER	Lupinus sericeus	silky perennial lupine
MEDILUP	Medicago lupulina	black medick
MELIALB	Melilotus alba	white sweet-clover
MELIOFF	Melilotus officinalis	yellow sweet-clover
MERTPAN	Mertensia paniculata	tall lungwort
MONAFIS	Monarda fistulosa	wild bergamot
MONONUT	Monolepis nuttalliana	spear-leaved goosefoot

Species Code	Scientific Name	Common Name
MUHLCUS	Muhlenbergia cuspidata	plains muhly
ORTHLUT	Orthocarpus luteus	owl-clover
ORTHSEC	Orthilia secunda	one-sided wintergreen
OXYTDEF	Oxytropis deflexa	reflexed locoweed
OXYTMON	Oxytropis monticola	late yellow locoweed
OXYTSER	Oxytropis sericea	early yellow locoweed
OXYTSPL	Oxytropis splendens	showy locoweed
OXYTSPP	Oxytropis species	locoweed species
PERIGAI	Perideridia gairdneri	squawroot
PHLEPRA	Phleum pratense	timothy
PHLOHOO	Phlox hoodii	moss phlox
PICEGLA	Picea glauca	white spruce
PLANMAJ	Plantago major	common plantain
POAARID	Poa arida	plains bluegrass
POACOM	Poa compressa L.	Canada bluegrass
POAGLA	Poa glauca Vahl	timberline bluegrass
POAPRA	Poa pratensis L.	Kentucky bluegrass
POASPP	Poa species	Bluegrass species
POLYARE	Polygonum arenastrum	common knotweed
POLYAVI	Polygonum aviculare	knot-weed
POLYSPP	Polygonum species	knot-weed
POPUBAL	Populus balsamifera	balsam poplar
POPUTRE	Populus tremuloides	aspen
POTEARG	Potentilla argentea	silvery cinquefoil
POTECON	Potentilla concinna	early cinquefoil
POTEFRU	Potentilla fruticosa	shrubby cinquefoil
POTEGRA	Potentilla gracilis	graceful cinquefoil
POTENOR	Potentilla norvegica	rough cinquefoil
POTEPEN	Potentilla pensylvanica	prairie cinquefoil
PRIMSPP	Primula species	Primula species
RANU_SP	Ranunculus species	buttercup species
RANUACR	Ranunculus acris L.	Tall buttercup
RANUCAR	Ranunculus acris	tall buttercup
RATICOL	Ratibida columnifera	prairie coneflower
RIBEOXY	Ribes oxyacanthoides	northern gooseberry
ROSAACI	Rosa acicularis	prickly rose
ROSAARK	Rosa arkansana	prairie rose
RUBUIDA	Rubus idaeus	wild red raspberry
RUMEACE	Rumex acetosa	green sorrel
SELADEN	Selaginella densa	prairie selaginella
SENEPSE	Senecio pseudaureus	thin-leaved ragwort

Species Code	Scientific Name	Common Name
SENESPP	Senecio species	ragwort species
SHEPCAN	Shepherdia canadensis	Canada buffaloberry
SISYMON	Sisyrinchium montanum	common blue-eyed grass
SISYSEP	Sisyrinchium septentrionale	pale blue-eyed grass
SMILSTE	Smilacina stellata	star-flowered Solomon's-seal
SOLICAN	Solidago canadensis	Canada goldenrod
SOLIMIS	Solidago missouriensis	low goldenrod
SOLIMUL	Solidago multiradiata	alpine goldenrod
SOLISPP	Solidago species	goldenrod species
SONCARV	Sonchus arvensis	perennial sow-thistle
STACPAL	Stachys palustris	marsh hedge-nettle
STELLOG	Stellaria longipes	long-stalked chickweed
STIPCOL	Stipa columbiana	Columbia needle grass
STIPCUR	Stipa curtiseta	western porcupine grass
STIPRIC	Stipa richardsonii	Richardson's needle grass
STIPVIR	Stipa viridula	green needle grass
SYMPALB	Symphoricarpos albus	Snowberry
SYMPOCC	Symphoricarpos occidentalis	Buckbrush
TARAOFF	Taraxacum officinale	common dandelion
THALVEN	Thalictrum venulosum	veiny meadow rue
THERRHO	Thermopsis rhombifolia	golden bean
THLAARV	Thlaspi arvense	Stinkweed
TRAGDUB	Tragopogon dubius	common goat's-beard
TRIFPRA	Trifolium pratense	red clover
TRIFREP	Trifolium repens	white clover
TRIFSPP	Trifolium species	clover species
TRIGMAR	Triglochin maritima	seaside arrow-grass
VICIAME	Vicia americana	wild vetch
VIOLADU	Viola adunca	early blue violet
VIOLCAN	Viola canadensis	western Canada violet
VIOLSPP	Viola species	violet species
XANTSTR	Xanthium strumarium	Cocklebur
ZIGAELE	Zigadenus elegans	white camas
ZIZIAPT	Zizia aptera	heart-leaved Alexanders

A.3 Species Listed by Common Name

Common Name	Scientific Name	Species Code
alpine goldenrod	Solidago multiradiata	SOLIMUL
alpine hedysarum	Hedysarum alpinum	HEDYALP
aspen	Populus tremuloides	POPUTRE
aster species	Aster species	ASTESPP
awned wheat grass	Elymus trachycaulus var. subsecundus	AGROSUB
awnless brome	Bromus inermis	BROMINE
balsam poplar	Populus balsamifera	POPUBAL
bastard toadflax	Comandra umbellata	COMAUMB
black medick	Medicago lupulina	MEDILUP
blue grama	Bouteloua gracilis	BOUTGRA
Bluegrass species	Poa species	POASPP
blunt sedge	Carex obtusata	CAREOBT
branched pepper-grass	Lepidium ramosissimum	LEPIRAM
bristle-stalked sedge	Carex leptalea	CARELEP
broad-leaved everlasting	Antennaria neglecta	ANTENEG
Buckbrush	Symphoricarpos occidentalis	SYMPOCC
buckwheat	Fagopyrum tartaricum	FAGOTAR
bull thistle	Cirsium vulgare	CIRSVUL
buttercup species	Ranunculus species	RANU_SP
Canada bluegrass	Poa compressa L.	POACOM
Canada buffaloberry	Shepherdia canadensis	SHEPCAN
Canada goldenrod	Solidago canadensis	SOLICAN
Canada thistle	Cirsium arvense	CIRSARV
caraway	Carum carvi	CARUCAR
chamaerhodos	Chamaerhodos erecta	CHAMERE
Cicer milk vetch	Astragalus cicer	ASTRCIC
clover species	Trifolium species	TRIFSPP
Cocklebur	Xanthium strumarium	XANTSTR
Columbia needle grass	Stipa columbiana	STIPCOL
common bearberry	Arctostaphylos uva-ursi	ARCTUVA
common blue lettuce	Lactuca pulchella	LACTPUL
common blue-eyed grass	Sisyrinchium montanum	SISYMON
common dandelion	Taraxacum officinale	TARAOFF
common fireweed	Epilobium angustifolium	EPILANG
common goat's-beard	Tragopogon dubius	TRAGDUB
common knotweed	Polygonum arenastrum	POLYARE
common plantain	Plantago major	PLANMAJ
common yarrow	Achillea millefolium	ACHIMIL
cream-colored vetchling	Lathyrus ochroleucus	LATHOCH
creeping juniper	Juniperus horizontalis	JUNIHOR

Common Name	Scientific Name	Species Code
creeping white prairie aster	Aster falcatus	ASTEFAL
cress species	Arabis species	ARABSPP
crested wheat grass	Agropyron cristatum	AGROPEC
cut-leaved anemone	Anemone multifida	ANEMMUL
dotted blazingstar	Liatris punctata	LIATPUN
Drummond's thistle	Cirsium drummondii	CIRSDRU
early blue violet	Viola adunca	VIOLADU
early cinquefoil	Potentilla concinna	POTECON
early yellow locoweed	Oxytropis sericea	OXYTSER
felwort	Gentianella amarella	GENTAMA
few-flowered milk vetch	Astragalus vexilliflexus	ASTRVEX
field mouse-ear chickweed	Cerastium arvense	CERAARV
fleabane species	Erigeron species	ERIGSPP
Flodman's thistle	Cirsium flodmanii	CIRSFLO
Foothills rough fescue	Festuca campestris	FESTCAM
foxtail barley	Hordeum jubatum	HORDJUB
fringed brome	Bromus ciliatus	BROMCIL
gaillardia	Gaillardia aristata	GAILARI
golden bean	Thermopsis rhombifolia	THERRHO
goldenrod species	Solidago species	SOLISPP
goosefoot	Chenopodium pratericola	CHENPRA
graceful cinquefoil	Potentilla gracilis	POTEGRA
graceful sedge	Carex praegracilis	CAREPRA
green needle grass	Stipa viridula	STIPVIR
green sorrel	Rumex acetosa	RUMEACE
gumweed	Grindelia squarrosa	GRINSQU
harebell	Campanula rotundifolia	CAMPROT
heart-leaved Alexanders	Zizia aptera	ZIZIAPT
hemp-nettle	Galeopsis tetrahit	GALETET
Hooker's oat grass	Helictotrichon hookeri	HELIHOO
Idaho fescue	Festuca idahoensis	FESTIDA
intermediate oat grass	Danthonia intermedia	DANTINT
June grass	Koeleria macrantha	KOELMAC
keeled brome	Bromus carinatus	BROMCAR
Kentucky bluegrass	Poa pratensis L.	POAPRA
knot-weed	Polygonum aviculare	POLYAVI
knot-weed	Polygonum species	POLYSPP
lamb's-quarters	Chenopodium album	CHENALB
lance-leaved ironplant	Haplopappus lanceolatus	HAPLLAN
large-leaved yellow avens	Geum macrophyllum	GEUMMAC
late yellow locoweed	Oxytropis monticola	OXYTMON

Common Name	Scientific Name	Species Code
Lindley's aster	Aster ciliolatus	ASTECIL
locoweed species	Oxytropis species	OXYTSPP
long-stalked chickweed	Stellaria longipes	STELLOG
low everlasting	Antennaria aprica	ANTEAPR
low goldenrod	Solidago missouriensis	SOLIMIS
low larkspur	Delphinium bicolor	DELPBIC
low sedge	Carex stenophylla	CARESTE
marsh hedge-nettle	Stachys palustris	STACPAL
meadow brome	Bromus biebersteinii	BROMBIE
milk vetch species	Astragalus species	ASTRSPP
moss phlox	Phlox hoodii	PHLOHOO
mountain shooting star	Dodecatheon conjugens	DODECON
narrow-leaved collomia	Collomia linearis	COLLLIN
narrow-leaved goosefoot	Chenopodium leptophyllum	CHENLEP
narrow-leaved puccoon	Lithospermum incisum	LITHINC
nodding onion	Allium cernuum	ALLICER
northern bedstraw	Galium boreale	GALIBOR
northern fairy candelabra	Androsace septentrionalis	ANDRSEP
northern gooseberry	Ribes oxyacanthoides	RIBEOXY
northern hedysarum	Hedysarum boreale	HEDYBOR
Northern wheat grass	Elymus lanceolatus ssp. lanceolatus	AGRODAS
one-sided wintergreen	Orthilia secunda	ORTHSEC
orchard grass	Dactylis glomerata	DACTGLO
owl-clover	Orthocarpus luteus	ORTHLUT
pale blue-eyed grass	Sisyrinchium septentrionale	SISYSEP
Parry’s oat grass	Danthonia parryi	DANTPAR
pasture sagewort	Artemisia frigida	ARTEFRI
perennial sow-thistle	Sonchus arvensis	SONCARV
pine reed grass	Calamagrostis rubescens	CALARUB
plains bluegrass	Poa arida	POAARID
plains muhly	Muhlenbergia cuspidata	MUHLCUS
plains reed grass	Calamagrostis montanensis	CALAMON
plains wormwood	Artemisia campestris	ARTECAM
prairie cinquefoil	Potentilla pensylvanica	POTEPEN
prairie coneflower	Ratibida columnifera	RATICOL
prairie crocus	Anemone patens	ANEMPAT
prairie rose	Rosa arkansana	ROSAARK
prairie sagewort	Artemisia ludoviciana	ARTELUD
prairie selaginella	Selaginella densa	SELADEN
prickly rose	Rosa acicularis	ROSAACI
Primula species	Primula species	PRIMSPP

Common Name	Scientific Name	Species Code
pumpelly brome	Bromus inermis ssp. pumpellianus	BROMPUM
purple milk vetch	Astragalus dasyglottis	ASTRDAS
quack grass	Elytrigea repens var. repens	AGROREP
ragwort species	Senecio species	SENESPP
red clover	Trifolium pratense	TRIFPRA
red fescue	Festuca rubra	FESTRUB
reflexed locoweed	Oxytropis deflexa	OXYTDEF
Richardson’s needle grass	Stipa richardsonii	STIPRIC
Richardson's alumroot	Heuchera richardsonii	HEUCRIC
Ross' sedge	Carex rossii	CAREROS
rough cinquefoil	Potentilla norvegica	POTENOR
rough hair grass	Agrostis scabra	AGROSCA
Russian pigweed	Axyris amaranthoides	AXYRAMA
saskatoon	Amelanchier alnifolia	AMELALN
seaside arrow-grass	Triglochin maritima	TRIGMAR
sedge species	Carex species	CARESPP
sheep fescue	Festuca ovina	FESTOVI
shepherd's-purse	Capsella bursa-pastoris	CAPSBUR
shining arnica	Arnica fulgens	ARNIFUL
showy locoweed	Oxytropis splendens	OXYTSPL
shrubby cinquefoil	Potentilla fruticosa	POTEFRU
silky perennial lupine	Lupinus sericeus	LUPISER
silvery cinquefoil	Potentilla argentea	POTEARG
slender wheat grass	Elymus trachycaulus var. trachycaulus	AGROTRA
small-leaved everlasting	Antennaria parvifolia	ANTEPAR
smooth aster	Aster laevis	ASTELAE
Snowberry	Symphoricarpos albus	SYMPALB
spear-leaved goosefoot	Monolepis nuttalliana	MONONUT
Sprengel's sedge	Carex sprengelii	CARESPR
squawroot	Perideridia gairdneri	PERIGAI
star-flowered Solomon's-seal	Smilacina stellata	SMILSTE
sticky purple geranium	Geranium viscosissimum	GERAVIS
Stinkweed	Thlaspi arvense	THLAARV
streambank wheat grass	Elymus lanceolatus ssp. lanceolatus	ELYMLAN
sun-loving sedge	Carex pensylvanica	CAREPEN
Sweetgrass	Hierochloe odorata	HIERODO
Tall buttercup	Ranunculus acris L.	RANUACR
tall buttercup	Ranunculus acris	RANUCAR
tall lungwort	Mertensia paniculata	MERTPAN
thin-leaved ragwort	Senecio pseudaureus	SENEPSE
three-flowered avens	Geum triflorum	GEUMTRI

Common Name	Scientific Name	Species Code
timberline bluegrass	Poa glauca Vahl	POAGLA
timothy	Phleum pratense	PHLEPRA
Toadflax	Linaria vulgaris	LINAVUL
toadflax species	Linaria species	LINASPP
tufted fleabane	Erigeron caespitosus	ERIGCAE
tufted white prairie aster	Aster ericoides	ASTEERI
veiny meadow rue	Thalictrum venulosum	THALVEN
violet species	Viola species	VIOLSPP
western bluebur	Lappula occidentalis	LAPPOCC
western Canada violet	Viola canadensis	VIOLCAN
western fairy candelabra	Androsace occidentalis	ANDROCC
western porcupine grass	Stipa curtiseta	STIPCUR
western wheat grass	Agropyron smithii	AGROSMI
wheat grass species	Agropyron species	AGROSPP
white camas	Zigadenus elegans	ZIGAELE
white clover	Trifolium repens	TRIFREP
white spruce	Picea glauca	PICEGLA
white sweet-clover	Melilotus alba	MELIALB
Whitlow-grass species	Draba sp.	DRABSP.
wild bergamot	Monarda fistulosa	MONAFIS
wild blue flax	Linum lewisii	LINULEW
wild red raspberry	Rubus idaeus	RUBUIDA
wild strawberry	Fragaria virginiana	FRAGVIR
wild vetch	Vicia americana	VICIAME
wild white geranium	Geranium richardsonii	GERARIC
wire rush	Juncus balticus	JUNCBAL
woolly gromwell	Lithospermum ruderale	LITHRUD
Woolly sedge	Carex lanuginosa (Michx.)	CARELAN
yellow avens	Geum aleppicum	GEUMALE
yellow false dandelion	Agoseris glauca	AGOSGLA
yellow hedysarum	Hedysarum sulphurescens	HEDYSUL
yellow sweet-clover	Melilotus officinalis	MELIOFF

Appendix B Monitoring Data – Range Health

B.1 Range Health Assessment Scores for Monitoring Plots

Range Health Question #	Q1 Native	Q1 Modified	Q2	Q3	Q4.1	Q4.2	Q5.1	Q5.2	Total
Potential Score	40	15	10	25	10	5	5	5	100
Site Code									
2BD	15	0	3	0	10	5	1	0	34
2BU	20	0	7	13	10	5	3	0	58
3AD	15	0	3	0	N/A	3	3	1	25
3AU	27	0	10	25	10	5	5	5	87
5AD	15	1	3	25	10	5	1	1	61
5AU	27	0	10	25	10	5	5	5	87
6BD	8	1	3	0	10	5	1	0	28
6BU	20	0	7	25	10	5	5	5	77
6CD	15	0	3	25	10	5	3	3	64
6CU	27	0	10	25	10	5	3	1	81
AW49952D	8	1	3	0	10	5	1	0	28
AW49952U	15	1	7	13	10	5	1	0	52
AW75774D	8	1	7	0	7	0	1	1	25
AW75774U	15	0	7	0	10	5	3	3	43
CROSS1D	8	1	3	13	10	5	1	0	41
GPD	15	0	7	25	10	5	1	1	64
GPU	27	0	10	13	10	5	3	1	69
HA1	8	1	7	13	10	5	3	1	48
HA10	15	0	7	13	10	5	1	0	51
HA3	15	0	10	25	10	5	1	0	66
HA5	8	1	7	25	10	5	1	0	57
HA6	15	1	3	25	10	5	3	1	63
HA7	15	0	3	0	10	5	3	1	37
HA9	15	0	7	0	10	5	3	3	43
LCD1	20	0	7	25	10	5	3	3	73
LCD2	15	0	7	25	10	5	3	3	68
LCU	20	0	3	25	10	5	3	1	67
MFC1U	15	0	10	25	10	5	1	1	67
MFC2D	15	1	7	13	10	5	1	1	53
MFC3D	15	1	0	25	10	5	3	3	62
MFC4U	15	0	7	25	10	5	1	0	63
JRT01	27	0	10	25	10	5	5	5	87
JRT02	15	1	10	25	10	5	5	5	76
JRT03	15	1	3	25	10	5	5	5	69
JRT04	40	0	10	13	10	5	5	5	88

Note: Scoring questions are presented in Appendix B.2

B.2 Range Health Assessment Scoring Questions

Q1	Integrity and ecological status Native: What kinds of plants are on the site? What is the plant community?
Q1Mod	Integrity and ecological status Modified: What kinds of plants are on the site? What is the plant community?
Q2	Plant community structure: Are the expected plant layers present?
Q3	Hydrologic function and nutrient cycling: Does the site retain moinsture? Is the expected amount of litter present?
Q4.1	Site stability Is the site subject to accelerated erosion?
Q4.2	Site stability Is there human-caused bare soil?
Q5.1	Are noxious weeds present on the site?
Q5.2	Infestation of the polygon with noxious weeds?

Range Health Score	< 50%	Unhealthy
	50 - 74%	Healthy with problems
	75-100%	Healthy

Appendix C Monitoring Data – Plant Community Inventory

C.1 Monitoring Sites Constructed Pre-1963

1930s

Sitecode	Treatment	Site Name	NSR	GVI	Elevation
AW49952D	Disturbed	Abandoned Wellsite 49952 RoW	FP	Lo (Tb)	1339
AW49952U	Undisturbed	Abandoned Wellsite 49952 offRoW	FP	Lo (Tb)	1348

Slope (%)	Aspect (Deg)	Lat	Long	UTM Zone	UTM E	UTM N
1	122	50.43174	114.28078			
2	158	50.43228	114.28033			

Site	AW49952D		Site	AW49952U
	% Cover			% Cover
Total Veg	**73.3**		**Total Veg**	**80.5**
Exposed Soil	**0.7**		**Exposed Soil**	**3.9**
Moss/Lichen	**0**		**Moss/Lichen**	**0**
Species	**% Cover**		**Species**	**% Cover**
POAPRA	48.1		POAPRA	35
CIRSARV	4.6		SYMPOCC	10.8
BROMBIE	3.7		CIRSARV	6.4
BROMINE	2		AGRODAS	3.4
ARTELUD	1.6		THERRHO	2
ANTEAPR	1.5		ARTELUD	1.3
ACHIMIL	1.1		ROSAACI	1
ASTEFAL	1.1		GALIBOR	0.7
VICIAME	0.8		CIRSDRU	0.4
ASTRDAS	0.6		ZIZIAPT	0.3
TRIFREP	0.6		ACHIMIL	0.2
DANTPAR	0.5		ANEMMUL	0.2
OXYTMON	0.5		VICIAME	0.2
TARAOFF	0.4		ASTEFAL	0.1
AGRODAS	0.3		ASTELAE	0.1
ANEMMUL	0.3		ASTRDAS	0.1
ASTELAE	0.1		TARAOFF	0.1
PHLEPRA	0.1			

1930s

Sitecode	Treatment	Site Name		NSR	GVI	Elevation
HA5	Disturbed	Helicopter Survey Transect 5		FP	Sy	
Slope (%)	**Aspect (Deg)**	**Lat**	**Long**	**UTM Zone**	**UTM E**	**UTM N**
		50.475673	114.33655			

Site	HA5
	% Cover
Total Veg	**100.0**
Exposed Soil	**0.0**
Moss/Lichen	**0.0**
Species	**% Cover**
POAPRA	23.3
BROMINE	22.3
SYMPOCC	11.7
CIRSARV	5.7
TARAOFF	1.7

Construction 1962

Sitecode	Treatment	Site Name		NSR	GVI	Elevation
2BD	Disturbed	Waldron Disturbed		FF	Lo	1362
2BU	Undisturbed	Waldron Undisturbed		FF	Lo	1362
Slope (%)	**Aspect (Deg)**	**Lat**	**Long**	**UTM Zone**	**UTM E**	**UTM N**
LVL	LVL	49.95158	114.14187			
LVL	LVL	49.95158	114.14187			

Site	2BD		Site	2BU
	% Cover			% Cover
Total Veg	**96**		**Total Veg**	**100**
Exposed Soil	**0**		**Exposed Soil**	**0**
Moss/Lichen	**28**		**Moss/Lichen**	**12.9**
Species	**% Cover**		**Species**	**% Cover**
POAPRA	15.6		POAPRA	25.5
POTEGRA	10.3		DANTPAR	10.7
CARESPP	7		GEUMTRI	9.9
ANTEAPR	5		ANTEPAR	5.8
SOLIMIS	4.4		STIPCUR	3.8
PHLEPRA	3.9		JUNIHOR	3.5
ARTELUD	2.4		GALIBOR	3.4
BROMINE	2.4		AGROSMI	3.3
ROSAARK	2.3		ACHIMIL	2.9
FRAGVIR	2		CAREOBT	2.9
POACOM	1.9		POTECON	2.8
ASTRCIC	1.5		SOLIMIS	2.8
CIRSARV	1.5		POTEFRU	2.3
GEUMTRI	1.5		VICIAME	2.1
ASTELAE	1.4		AGRODAS	1.5
JUNCBAL	1		THALVEN	1.2
ANEMPAT	0.8		FESTCAM	1.1
VICIAME	0.8		ANEMMUL	1
GALIBOR	0.7		ERIGSPP	1
AGROSUB	0.6		BROMINE	0.9
POTEFRU	0.6		OXYTSPP	0.9
ASTEERI	0.5		SISYMON	0.8
OXYTSPP	0.5		TRIGMAR	0.8
THERRHO	0.5		AGOSGLA	0.7
ACHIMIL	0.4		ASTEFAL	0.7
AGROSMI	0.4		HEDYALP	0.7
CAREPEN	0.4		LITHRUD	0.7
POTEPEN	0.4		FESTIDA	0.6
SISYMON	0.3		PHLOHOO	0.6
KOELMAC	0.2		ARTEFRI	0.5
POTEARG	0.2		CAREPEN	0.5
AGOSGLA	0.1		AGROSUB	0.3
ORTHLUT	0.1		ANTEAPR	0.3
			CIRSARV	0.3
			JUNCBAL	0.3
			KOELMAC	0.3
			MUHLCUS	0.2
			VIOLSPP	0.2

Construction Date 1962

Sitecode	Treatment	Site Name		NSR	GVI	Elevation
HA6	Disturbed	Helicopter Survey Transect 6		FP	Ov	
Slope (%)	**Aspect (Deg)**	**Lat**	**Long**	**UTM Zone**	**UTM E**	**UTM N**
		50.380853	114.28534			

Site	**HA6**
	% Cover
Total Veg	**0.0**
Exposed Soil	**0.0**
Moss/Lichen	**0.0**
Species	**% Cover**
BROMINE	70.0
POAPRA	25.0
PHLEPRA	10.0
TARAOFF	8.0
SOLIMIS	3.0
TRIFREP	2.0
CIRSARV	1.0

Construction Date 1962

Sitecode	Treatment	Site Name		NSR	GVI	Elevation
HA7	Disturbed	Helicopter Survey Transect 7		FP	Lo	
Slope (%)	**Aspect (Deg)**	**Lat**	**Long**	**UTM Zone**	**UTM E**	**UTM N**
		50.346646	114.351921			

Site	**HA7**
	% Cover
Total Veg	**98.3**
Exposed Soil	**1.3**
Moss/Lichen	**35.0**
Species	**% Cover**
TRIFREP	12.7
TARAOFF	7.7
POAPRA	7.0
POTEGRA	5.7
PHLEPRA	5.0
STIPCUR	5.0
OXYTSPP	4.3
CARESPP	3.7
AGROSUB	2.7
ANEMMUL	2.3
ROSAACI	1.0
AGOSGLA	0.7

Construction Date 1962

Sitecode	Treatment	Site Name		NSR	GVI	Elevation
HA9	Disturbed	Helicopter Survey Transect 9		FP	Lo	
Slope (%)	**Aspect (Deg)**	**Lat**	**Long**	**UTM Zone**	**UTM E**	**UTM N**
		50.379606	114.256976			

Site	HA9
	% Cover
Total Veg	**100.0**
Exposed Soil	**0.0**
Moss/Lichen	**0.0**
Species	**% Cover**
ROSAACI	15.0
POAPRA	13.3
BROMINE	8.3
GALIBOR	4.3
ARTELUD	3.3
SYMPOCC	3.3
PHLEPRA	1.7
FRAGVIR	1.3
TRIFREP	1.3
ASTELAE	1.0
CAREPEN	0.7
VICIAME	0.7

C.2 Monitoring Sites Constructed 1963 - 1980

1960s?

Sitecode	Treatment	Site Name	NSR	GVI	Elevation
AW75774D	Disturbed	Abandoned Wellsite 75774 RoW	FP	Tb	1322
AW75774U	Undisturbed	Abandoned Wellsite 75774 offRoW	FP	Lo	1341

Slope (%)	Aspect (Deg)	Lat	Long	UTM Zone	UTM E	UTM N
6	180	50.41283	114.29762			
7	180	50.4138	114.29833			

Site	AW75774D		Site	AW75774U
	% Cover			% Cover
Total Veg	**34.5**		**Total Veg**	**51**
Exposed Soil	**12.2**		**Exposed Soil**	**0.2**
Moss/Lichen	**2.8**		**Moss/Lichen**	**0.6**
Species	**% Cover**		**Species**	**% Cover**
POAPRA	12.2		POAPRA	14.2
TRIFREP	7.7		FESTCAM	4
BROMINE	7.1		BROMINE	3.8
CIRSARV	2.5		POTEFRU	3.4
PHLEPRA	1		ROSAACI	1.8
POTEGRA	0.9		ASTELAE	1.7
CERAARV	0.8		DANTPAR	1.6
FRAGVIR	0.7		GEUMTRI	1.4
ARTELUD	0.4		STIPCUR	1.2
SOLIMIS	0.4		THALVEN	1
STIPRIC	0.4		ACHIMIL	0.9
ACHIMIL	0.3		AGRODAS	0.9
ROSAARK	0.3		CAREPEN	0.9
VICIAME	0.3		OXYTSPL	0.8
FESTCAM	0.2		VICIAME	0.6
HEDYBOR	0.2		ARTEFRI	0.5
KOELMAC	0.2		GALIBOR	0.5
OXYTSER	0.2		OXYTMON	0.5
ASTRDAS	0.1		ASTEFAL	0.4
FESTIDA	0.1		GAILARI	0.4
GEUMALE	0.1		CAMPROT	0.3
LINULEW	0.1		ASTRSPP	0.2
POTEFRU	0.1		GEUMALE	0.2
ZIZIAPT	0.1		KOELMAC	0.2
			POTEGRA	0.2
			ANEMPAT	0.1
			ARTECAM	0.1
			LINULEW	0.1

1960s?

Sitecode	Treatment	Site Name		NSR	GVI	Elevation
6BD	Disturbed	McPherson Wellsite Disturbed		FP	Lo	1331
6BU	Undisturbed	McPherson Wellsite Undisturbed		FP	Tb (Lo)	1340
Slope (%)	**Aspect (Deg)**	**Lat**	**Long**	**UTM Zone**	**UTM E**	**UTM N**
LVL	LVL	50.40293	114.27051			
18	99	50.40402	114.27127			
Site	**6BD**		**Site**	**6BU**		
	% Cover			**% Cover**		
Total Veg	**99.5**		**Total Veg**	**100**		
Exposed Soil	**0.7**		**Exposed Soil**	**0**		
Moss/Lichen	**0**		**Moss/Lichen**	**0**		
Species	**% Cover**		**Species**	**% Cover**		
POAPRA	67.5		POAPRA	38		
CAREROS	19.3		ROSAACI	25.7		
AGROTRA	3.8		DANTPAR	14.5		
PHLEPRA	3.6		MONAFIS	8.1		
TRIFSPP	2.6		LUPISER	6.5		
BROMINE	2.5		LATHOCH	5.3		
TARAOFF	1.4		SMILSTE	3.9		
ARTELUD	1		ASTELAE	3		
ROSAACI	0.2		GALIBOR	2.4		
SYMPOCC	0.1		BROMINE	2.3		
			ACHIMIL	2.2		
			STIPVIR	1.8		
			ANEMMUL	1.6		
			ASTEERI	1		
			CARESPP	1		
			FRAGVIR	1		
			OXYTSPP	1		
			VICIAME	1		
			AGROSUB	0.9		
			ARTELUD	0.8		
			GEUMTRI	0.8		
			THERRHO	0.8		
			AMELALN	0.5		
			CAREOBT	0.5		
			POTEFRU	0.5		
			SOLIMIS	0.5		
			BROMCIL	0.3		
			CAMPROT	0.2		

C.3 Monitoring Sites Constructed 1981 - 2000

Construction Date 1981

Sitecode	Treatment	Site Name		NSR	GVI	Elevation
3AD	Disturbed	Sears Suncor Disturbed		FF	Lo (Tb)	1333
3AU	Undisturbed	Sears Suncor Undisturbed		FF	Lo (Tb)	1333
Slope (%)	**Aspect (Deg)**	**Lat**	**Long**	**UTM Zone**	**UTM E**	**UTM N**
LVL	LVL	50.09627	113.92057			
LVL	LVL	50.09627	113.92057			

Site	3AD		Site	3AU
	% Cover			**% Cover**
Total Veg	**83**		**Total Veg**	**100**
Exposed Soil	**12.5**		**Exposed Soil**	**0**
Moss/Lichen	**30.5**		**Moss/Lichen**	**0**
Species	**% Cover**		**Species**	**% Cover**
FESTRUB	43.2		DANTPAR	36.5
PHLEPRA	5.8		FESTCAM	5.6
POAPRA	4.1		POAPRA	4.6
TRIFREP	3.7		AGROSMI	3.6
JUNCBAL	1.7		STIPCUR	2
AGROSMI	1.5		ASTELAE	1.9
CAREOBT	1		AGROSUB	1.7
AGROSUB	0.8		FESTIDA	1.6
ASTELAE	0.8		GALIBOR	1.5
MELIALB	0.7		CAREOBT	1.3
ARTELUD	0.5		ROSAARK	0.9
VIOLSPP	0.5		VIOLSPP	0.6
FRAGVIR	0.3		MONAFIS	0.4
GRINSQU	0.3		PHLEPRA	0.4
THERRHO	0.3		GAILARI	0.2
			GEUMTRI	0.2

Construction date 1980s?

Sitecode	Treatment	Site Name		NSR	GVI	Elevation
5AD	Disturbed	Pekisko Creek Ranch Disturbed		M	No GVI	
5AU	Undisturbed	Pekisko Creek Ranch Undisturbed		M	No GVI	1566
Slope (%)	**Aspect (Deg)**	**Lat**	**Long**	**UTM Zone**	**UTM E**	**UTM N**
21	180	50.38705	114.42921			

Site	5AD		Site	5AU
	% Cover			**% Cover**
Total Veg	**98**		**Total Veg**	**100**
Exposed Soil	**1.5**		**Exposed Soil**	**0**
Moss/Lichen	**0**		**Moss/Lichen**	**1**
Species	**% Cover**		**Species**	**% Cover**
ASTRCIC	42.5		DANTPAR	36
POAPRA	19		FESTIDA	7.6
PHLEPRA	11.8		FESTOVI	4
FESTOVI	3.5		POAPRA	3.8
AGROPEC	2.5		POTEFRU	3.3
TARAOFF	0.9		ROSAARK	3.3
BROMINE	0.5		FESTCAM	2.6
			ANEMPAT	2.4
			LUPISER	2
			ASTELAE	1.5
			GALIBOR	1.5
			THERRHO	1.5
			POTEARG	1.3
			SOLIMIS	1.1
			CAREPEN	0.6
			FRAGVIR	0.6
			ASTEFAL	0.5
			GEUMTRI	0.5
			VICIAME	0.5
			COMAUMB	0.4
			ARCTUVA	0.3
			DANTINT	0.3
			ACHIMIL	0.2
			AGOSGLA	0.2
			PHLEPRA	0.2

1980s?

Sitecode	Treatment	Site Name		NSR	GVI	Elevation
6CD	Disturbed	Highes Wellsite Disturbed		FP	Lo (Tb)	1389
6CU	Undisturbed	Hughes Wellsite Undisturbed		FP	Lo (Tb)	1387
Slope (%)	**Aspect (Deg)**	**Lat**	**Long**	**UTM Zone**	**UTM E**	**UTM N**
15	265	50.46492	114.29337			
14	278	50.46591	114.26326			

Site	6CD		Site	6CU
	% Cover			% Cover
Total Veg	**100**		**Total Veg**	**100**
Exposed Soil	**0**		**Exposed Soil**	**0**
Moss/Lichen	**0**		**Moss/Lichen**	**0.4**
Species	**% Cover**		**Species**	**% Cover**
ROSAACI	58		POAPRA	14.5
POAPRA	36		FESTCAM	13.9
BROMINE	25.5		DANTPAR	7.2
SYMPOCC	6		ROSAACI	7.1
ASTELAE	5		LUPISER	6
ACHIMIL	2.1		VICIAME	3.7
CARESPP	2		ACHIMIL	3.6
LATHOCH	2		ASTELAE	3.5
GEUMMAC	1		BROMINE	2.7
VICIAME	1		GALIBOR	2.5
SMILSTE	0.8		POTEARG	2.5
GERARIC	0.6		SOLIMIS	2.5
ARTELUD	0.5		THERRHO	2
ERIGCAE	0.5		LATHOCH	1.7
			STIPVIR	1.7
			GEUMTRI	1.5
			AGOSGLA	1.1
			ARTELUD	1
			CAREOBT	1
			FRAGVIR	1
			AGROSUB	0.8
			ANEMMUL	0.7
			CIRSARV	0.7
			CARESPP	0.5
			POTEFRU	0.5
			ARTEFRI	0.3
			POTECON	0.3
			ASTEERI	0.2

C.4 Providence Ranch Gas Field (1999-2000)

Providence Ranch Site 1			**GVI** SwG	**UTM N**	5682649	**Elevation**	1348m	**Slope** 3% **Aspect** 0		**UTM Zone**	11N	**UTM E**	665462
Monitoring Year	**2000**		**2001**		**2014**	**Years post disturbance**	**1**	**Years post disturbance**	**2**	**Years post disturbance**	**3**	**Years post disturbance**	**14**
Year/Site	PR0001U	Year/Site	PR0101U	Year/Site	PR1401U	Year/Site	PR0001D	Year/Site	PR0101D	Year/Site	PR0201D	Year/Site	PR1401D
Treatment	**Undisturbed**	**Treatment**	**Undisturbed**	**Treatment**	**Undisturbed**	**Treatment**	**Disturbed**	**Treatment**	**Disturbed**	**Treatment**	**Disturbed**	**Treatment**	**Disturbed**
Component	**% Cover**	**Component**	**% Cover**	**Component**	**% Cover**	**Component**	**% Cover**	**Component**	**% Cover**	**Component**	**% Cover**	**Component**	**% Cover**
Total Veg	**95.7**	**Total Veg**	**127.5**	**Total Veg**	**61.5**	**Total Veg**	**2.9**	**Total Veg**	**19.3**	**Total Veg**	**79.5**	**Total Veg**	**87.5**
Exposed Soil	**0.2**	**Exposed Soil**	**0.6**	**Exposed Soil**	**9.8**	**Exposed Soil**	**0.0**	**Exposed Soil**	**0.1**	**Exposed Soil**	**0.2**	**Exposed Soil**	**2.1**
Moss/Lichen	**0.4**	**Moss/Lichen**	**0.8**	**Moss/Lichen**	**3.1**	**Moss/Lichen**	**49.5**	**Moss/Lichen**	**34.8**	**Moss/Lichen**	**0.4**	**Moss/Lichen**	**0.9**
Species	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**
POAPRA	90.4	FESTCAM	50.0	POAPRA	10.8	FAGOTAR	8.5	FESTOVI	14.5	POAPRA	30.2	POAPRA	19.5
POTEFRU	5.4	POAPRA	15.0	FRAGVIR	7.1	AGROSUB	8.3	AGROSUB	7.0	AGROREP	9.1	CIRSARV	9.4
ROSAACI	5.4	ROSAACI	15.0	SYMPALB	5.0	FESTOVI	5.3	PHLEPRA	4.6	AGROSUB	8.4	TRIFREP	9.1
FESTCAM	2.5	POTEFRU	6.3	FESTOVI	4.1	TARAOFF	5.3	STIPVIR	4.3	FESTOVI	6.8	FESTOVI	3.8
ASTELAE	2.1	LATHOCH	5.8	LATHOCH	3.9	AGRODAS	5.3	TARAOFF	3.9	TARAOFF	3.1	VICIAME	2.6
LITHRUD	2.1	SMILSTE	5.0	ASTECIL	3.0	GALETET	5.0	AGRODAS	3.8	AGRODAS	2.0	THALVEN	2.3
FRAGVIR	1.2	ACHIMIL	4.2	LINAVUL	2.9	POLYARE	3.8	BROMCAR	3.4	STIPVIR	2.0	AGROREP	2.1
GALIBOR	0.9	CAREOBT	3.8	ASTELAE	2.2	PHLEPRA	3.3	ACHIMIL	1.5	CIRSARV	1.8	FRAGVIR	1.1
GEUMTRI	0.8	FRAGVIR	3.8	PICEGLA	2.0	STIPVIR	3.3	FRAGVIR	1.5	SONCARV	1.8	ACHIMIL	1.0
POTEGRA	0.7	GALIBOR	3.8	SHEPCAN	2.0	XANTSTR	3.3	LAPPOCC	1.0	ACHIMIL	1.7	TARAOFF	0.9
AGROREP	0.4	ASTELAE	2.5	TARAOFF	1.7	AGROTRA	1.8	POAPRA	0.8	VICIAME	1.5	RIBEOXY	0.7
CAREOBT	0.4	GEUMTRI	2.5	VICIAME	1.7	CHENPRA	1.6	KOELMAC	0.6	PHLEPRA	0.8	CAREPRA	0.5
VICIAME	0.4	POPUTRE	2.5	THALVEN	1.6	HORDJUB	1.5	AGROSMI	0.5	ASTELAE	0.6	CARESPR	0.5
ACHIMIL	0.2	RANUACR	2.5	ACHIMIL	1.2	TRIFREP	1.5	AGROTRA	0.3	AGROSMI	0.3	PHLEPRA	0.5
LATHOCH	0.1	RUBUIDA	2.5	CIRSARV	1.2	AGROSMI	0.8	CIRSARV	0.3	HIERODO	0.3	SOLIMIS	0.4
SMILSTE	0.1	TARAOFF	0.8	TRIFREP	1.2	POAPRA	0.7	GALETET	0.3	RIBEOXY	0.3	ASTECIL	0.3
AGRODAS	0.1	BROMINE	0.4	ARCTUVA	1.0	GEUMALE	0.3	GEUMTRI	0.3	KOELMAC	0.3	BROMINE	0.2
AGROSUB	0.1	CAREPEN	0.4	ROSAACI	0.7	ACHIMIL	0.3	AGROSCA	0.1	LINASPP	0.3	LATHOCH	0.2
ALLICER	0.1	DANTPAR	0.4	GEUMALE	0.6	AGROREP	0.3	ANDRSEP	0.1	OXYTSER	0.3	SONCARV	0.2

Providence Ranch Site 1			GVI SwG	UTM N	5682649	Elevation	1348m	Slope 3% Aspect 0		UTM Zone	11N	UTM E	665462
Monitoring Year	2000		2001		2014	Years post disturbance	1	Years post disturbance	2	Years post disturbance	3	Years post disturbance	14
Year/Site	PR0001U	Year/Site	PR0101U	Year/Site	PR1401U	Year/Site	PR0001D	Year/Site	PR0101D	Year/Site	PR0201D	Year/Site	PR1401D
Treatment	Undisturbed	Treatment	Undisturbed	Treatment	Undisturbed	Treatment	Disturbed	Treatment	Disturbed	Treatment	Disturbed	Treatment	Disturbed
Species	% Cover	Species	% Cover	Species	% Cover	Species	% Cover	Species	% Cover	Species	% Cover	Species	% Cover
CAREPEN	0.1	POPUBAL	0.4	SMILSTE	0.4	CIRSARV	0.3	ASTELAE	0.1	THALVEN	0.3		
CERAARV	0.1	VIOLADU	0.4	AGRODAS	0.3	ANDROCC	0.1	LATHOCH	0.1	SISYMON	0.1		
DANTPAR	0.1	ZIGAELE	0.4	AGROREP	0.2	ASTELAE	0.1	LINASPP	0.1	ASTESPP	0.1		
HEUCRIC	0.1			GALETET	0.2	CAMPROT	0.1	OXYTSER	0.1	RUBUIDA	0.1		
TARAOFF	0.1			RUBUIDA	0.2	SISYMON	0.1	POTEFRU	0.1	VIOLADU	0.1		
				STIPCOL	0.2	ARABSPP	0.1	RUBUIDA	0.1	ZIZIAPT	0.1		
				AGROSUB	0.1	CAREPEN	0.1	SISYMON	0.1				
				BROMINE	0.1	FRAGVIR	0.1	VICIAME	0.1				
				PHLEPRA	0.1	KOELMAC	0.1						
				SISYMON	0.1	LINASPP	0.1						
				STELLOG	0.1	OXYTSPP	0.1						
				STIPVIR	0.1	RIBEOXY	0.1						
						THALVEN	0.1						
						VIOLADU	0.1						

Seed Mix 1 – 1999

Awned wheat grass	**10%**
Northern wheat grass	**10%**
Western wheat grass	**15%**
Mountain brome	**10%**
Green needle grass	**25%**
Sheep fescue	**20%**
June grass	**10%**

Providence Ranch Site 6			GVI Lo	Elevation	1363m	Slope (%)	0%	UTM Zone	11N	UTM E	664027	UTM N	5683850
Monitoring Year	**2000**		**2001**		**2014**	**Years post disturbance**	**1**	**Years post disturbance**	**2**	**Years post disturbance**	**3**	**Years post disturbance**	**14**
Site	PR0006U	Site	PR0106U	Site	PR1406U	Site	PR0006D	Site	PR0106D	Site	PR0206D	Site	PR1406D
Treatment	Undisturbed	Treatment	Undisturbed	Treatment	Undisturbed	Treatment	Disturbed	Treatment	Disturbed	Treatment	Disturbed	Treatment	Disturbed
Component	**% Cover**	**Component**	**% Cover**	**Component**	**% Cover**	**Component**	**% Cover**	**Component**	**% Cover**	**Component**	**% Cover**	**Component**	**% Cover**
Total Veg	**66.5**	**Total Veg**	**71.5**	**Total Veg**	**81.0**	**Total Veg**	**31.8**	**Total Veg**	**36.3**	**Total Veg**	**41.0**	**Total Veg**	**82.0**
Exposed Soil	**0.5**	**Exposed Soil**	**0.0**	**Exposed Soil**	**0.0**	**Exposed Soil**	**0.1**	**Exposed Soil**	**0.0**	**Exposed Soil**	**0.1**	**Exposed Soil**	**0.9**
Moss/Lichen	**4.1**	**Moss/Lichen**	**7.5**	**Moss/Lichen**	**3.2**	**Moss/Lichen**	**40.0**	**Moss/Lichen**	**14.9**	**Moss/Lichen**	**2.7**	**Moss/Lichen**	**1.6**
Species	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**
POAPRA	83.0	POAPRA	24.0	POAPRA	13.2	POAPRA	31.4	POAPRA	48.4	POAPRA	47.9	POAPRA	10.1
CAREOBT	5.0	ROSAACI	15.0	BROMINE	6.1	TARAOFF	1.6	TARAOFF	14.1	TARAOFF	12.5	BROMINE	6.8
FRAGVIR	3.7	POTEGRA	13.5	AGROSUB	5.4	PHLEPRA	1.3	AGROSUB	4.1	PHLEPRA	1.6	FRAGVIR	3.6
TARAOFF	1.1	AGOSGLA	12.5	FESTCAM	5.0	KOELMAC	0.9	PHLEPRA	3.9	ACHIMIL	0.6	ASTRVEX	3.4
PHLEPRA	0.8	ACHIMIL	9.0	POTEGRA	3.2	AGRODAS	0.4	ACHIMIL	0.6	FRAGVIR	0.4	TARAOFF	3.2
AGROSUB	0.5	CAREOBT	7.0	ROSAARK	3.0	ASTELAE	0.4	BROMINE	0.6	BROMCAR	0.3	AGROTRA	2.6
GENTAMA	0.5	SMILSTE	6.5	DANTPAR	2.5	STIPVIR	0.4	POTEGRA	0.6	FESTCAM	0.3	PHLEPRA	2.1
GEUMTRI	0.5	TARAOFF	6.0	GEUMTRI	2.1	ACHIMIL	0.2	AGRODAS	0.4	GEUMTRI	0.3	FESTCAM	1.7
HEUCRIC	0.5	BROMINE	4.0	TARAOFF	1.7	FESTCAM	0.1	AGROTRA	0.3	CAMPROT	0.1	POTEGRA	1.6
ROSAACI	0.5	THERRHO	4.0	PHLEPRA	1.5	AGROSUB	0.1	POTEPEN	0.3	POTEGRA	0.1	ROSAARK	1.0
THERRHO	0.5	VICIAME	4.0	AGRODAS	1.4	ANDRSEP	0.1	BROMCAR	0.1			THERRHO	1.0
ACHIMIL	0.2	GALIBOR	3.5	ASTRVEX	1.3	CAREPEN	0.1	ANDRSEP	0.1			VICIAME	1.0
CAREPEN	0.2	FRAGVIR	3.0	VICIAME	1.3	POACOM	0.1	CAREPEN	0.1			LATHOCH	0.9
CERAARV	0.2	HEDYALP	3.0	ACHIMIL	1.0	POTEFRU	0.1	FRAGVIR	0.1			HEDYBOR	0.8
KOELMAC	0.2	FESTCAM	1.5	THERRHO	0.8	POTEGRA	0.1	OXYTSER	0.1			ACHIMIL	0.7
ANDRSEP	0.1	CERAARV	1.1	AGROTRA	0.5	ROSAACI	0.1					ASTELAE	0.7
BROMINE	0.1	AGROSUB	1.0	CALAMON	0.3							AGROSUB	0.5
GALIBOR	0.1	PHLEPRA	1.0	CAREOBT	0.2							OXYTDEF	0.5
POTEGRA	0.1	SOLIMIS	1.0	OXYTSPL	0.2							AGRODAS	0.4
SOLIMIS	0.1	AGROSCA	0.6	SOLIMIS	0.2							KOELMAC	0.4
		KOELMAC	0.6	AGOSGLA	0.1							OXYTSPL	0.4
		CAMPROT	0.5	CAMPROT	0.1							SOLIMIS	0.4

Providence Ranch Site 6			GVI Lo	Elevation	1363m	Slope (%)	0%	UTM Zone	11N	UTM E	664027	UTM N	5683850
Monitoring Year	2000		2001		2014	Years post disturbance	1	Years post disturbance	2	Years post disturbance	3	Years post disturbance	14
Site	PR0006U	Site	PR0106U	Site	PR1406U	Site	PR0006D	Site	PR0106D	Site	PR0206D	Site	PR1406D
Treatment	Undisturbed	Treatment	Undisturbed	Treatment	Undisturbed	Treatment	Disturbed	Treatment	Disturbed	Treatment	Disturbed	Treatment	Disturbed
Component	**% Cover**	**Component**	**% Cover**	**Component**	**% Cover**	**Component**	**% Cover**	**Component**	**% Cover**	**Component**	**% Cover**	**Component**	**% Cover**
Total Veg	**66.5**	**Total Veg**	**71.5**	**Total Veg**	**81.0**	**Total Veg**	**31.8**	**Total Veg**	**36.3**	**Total Veg**	**41.0**	**Total Veg**	**82.0**
Exposed Soil	**0.5**	**Exposed Soil**	**0.0**	**Exposed Soil**	**0.0**	**Exposed Soil**	**0.1**	**Exposed Soil**	**0.0**	**Exposed Soil**	**0.1**	**Exposed Soil**	**0.9**
Moss/Lichen	**4.1**	**Moss/Lichen**	**7.5**	**Moss/Lichen**	**3.2**	**Moss/Lichen**	**40.0**	**Moss/Lichen**	**14.9**	**Moss/Lichen**	**2.7**	**Moss/Lichen**	**1.6**
Species	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**
		GAILARI	0.5									GALIBOR	0.2
		OXYTSER	0.5									POTEPEN	0.2
												THALVEN	0.2
												DANTPAR	0.1

Seed Mix 2 – 1999

Foothills Rough fescue	**25%**
Awned wheat grass	**5%**
Northern wheat grass	**5%**
Western wheat grass	**7.5%**
Mountain brome	**5%**
Green needle grass	**12.5%**
Sheep fescue	**10%**
June grass	**5%**

Providence Ranch Site 8A			GVI Lo	Elevation	1406m	Slope (%)	20%	Aspect	225
UTM Zone	11N	UTM E	664027	UTM N	5683850				

Monitoring Year	2001	Years post disturbance	12
Site	PR0108U	Site	PR1408D
Treatment	Undisturbed	Treatment	Disturbed
Component	**% Cover**	**Component**	**% Cover**
Total Veg	**45.8**	**Total Veg**	**64.5**
Exposed Soil	**1.5**	**Exposed Soil**	**1.2**
Moss/Lichen	**10.3**	**Moss/Lichen**	**15.7**
Species	**% Cover**	**Species**	**% Cover**
FESTCAM	18.2	POAPRA	11.3
VICIAME	17.9	PHLEPRA	9.1
FRAGVIR	12.9	CIRSARV	4.0
CIRSARV	12.5	SOLICAN	3.0
PHLEPRA	11.1	BROMBIE	2.6
ACHIMIL	9.3	STACPAL	2.6
GALIBOR	8.9	BROMINE	2.3
LATHOCH	8.6	ACHIMIL	1.8
TARAOFF	7.9	ARTELUD	1.8
POAPRA	7.5	TARAOFF	1.7
CAREPEN	7.1	ASTELAE	1.5
ROSAACI	6.8	BROMCAR	1.5
AGOSGLA	5.4	VICIAME	1.4
THERRHO	4.3	POTEGRA	0.8
VIOLCAN	4.3	LACTPUL	0.7
CARESPP	2.5	AGROSUB	0.5
AGROSUB	2.1	AGOSGLA	0.3
EPILANG	2.1	AGROREP	0.1
BROMINE	1.1		
THALVEN	1.1		
POACOM	0.4		
ASTRDAS	0.4		
CAMPROT	0.1		

Seed Mix 3 – 2002

Foothills Rough Fescue	**40%**
Slender wheat grass	**12%**
Northern wheat grass	**12%**
Streambank wheat grass	**6%**
Green needle grass	**18%**
June grass	**6%**
Mountain brome	**6%**

C.5 Monitoring Sites Constructed 2001 - Present

Construction Date post 2000

Sitecode	Treatment	Site Name		NSR	GVI	Elevation
CROSS1D	Disturbed	Cross Wellsite Disturbed		FF	Lo	1212
Slope (%)	**Aspect (Deg)**	**Lat**	**Long**	**UTM Zone**	**UTM E**	**UTM N**
2	173	50.15263	113.9807			

Site	CROSS1D
	% Cover
Total Veg	**97.5**
Exposed Soil	**2.7**
Moss/Lichen	**0.2**
Species	**% Cover**
POAPRA	55
FESTRUB	5.5
AGROSUB	2
FESTCAM	1.7
PHLEPRA	1.6
ARTELUD	1.5
MEDILUP	0.7
CIRSVUL	0.4
TARAOFF	0.4
ASTELAE	0.2

Construction Date post 2000

Sitecode	Treatment	Site Name	NSR	GVI	Elevation
GPD	Disturbed	Gravel Pit Disturbed	FF	Gr (Lo)	1146
GPU	Undisturbed	Gravel Pit Undisturbed	FF	Gr (Lo)	1147

Slope (%)	Aspect (Deg)	Lat	Long	UTM Zone	UTM E	UTM N
25	202	50.13785	113.91495			
3	155	50.1367	113.91676			

Site	**GPD**		**Site**	**GPU**
	% Cover			**% Cover**
Total Veg	**97**		**Total Veg**	**93.4**
Exposed Soil	**0.7**		**Exposed Soil**	**5.8**
Moss/Lichen	**3.3**		**Moss/Lichen**	**0.7**
Species	**% Cover**		**Species**	**% Cover**
POAPRA	26		BOUTGRA	24.3
FESTIDA	5.4		ROSAACI	10.7
BROMINE	5		AGRODAS	7.3
FESTCAM	4.5		POAPRA	6
POACOM	1.6		ARTEFRI	4.4
ARTELUD	1.5		THERRHO	4.1
AGROSUB	0.6		GALIBOR	2.1
AGROTRA	0.2		ANTEAPR	2
MELIOFF	0.1		FESTCAM	2
			LUPISER	1.7
			CAREPEN	1.4
			STIPCUR	1.1
			CAREOBT	0.9
			ASTEERI	0.8
			ANEMMUL	0.5
			SOLIMIS	0.5
			LIATPUN	0.3
			SELADEN	0.3
			RATICOL	0.1

Construction Date 2002

Sitecode	Treatment	Site Name		NSR	GVI	Elevation
LCD1	Disturbed	Lewis Deeded Method 1		FF	Lo	
LCD2	Disturbed	Lewis Deeded Method 2		FF	Lo	
LCU	Undisturbed	Lewis Deeded Undisturbed		FF	Lo	1319
Slope (%)	**Aspect (Deg)**	**Lat**	**Long**	**UTM Zone**	**UTM E**	**UTM N**
		49.76986	114.075			
		49.76986	114.075			
6	270	49.76986	114.075			
Site	**LCD1**		**Site**	**LCD2**	**Site**	**LCU**
	% Cover			**% Cover**		**% Cover**
Total Veg	**100.0**		**Total Veg**	**100.0**	**Total Veg**	**99.7**
Exposed Soil	**0.0**		**Exposed Soil**	**0.0**	**Exposed Soil**	**0.2**
Moss/Lichen	**0.0**		**Moss/Lichen**	**1.5**	**Moss/Lichen**	**0.0**
Species	**% Cover**		**Species**	**% Cover**	**Species**	**% Cover**
FESTCAM	23.3		POAPRA	46.0	POAPRA	24.2
POAPRA	22.5		FESTCAM	8.5	FESTCAM	18.5
AGROSMI	3.9		FESTIDA	4.5	LUPISER	3.8
FESTIDA	3.8		DACTGLO	2.3	ARTELUD	2.5
AGRODAS	2.0		AGROSMI	2.2	STIPVIR	1.5
AGROTRA	1.5		FESTRUB	1.8	ACHIMIL	0.9
ARTELUD	1.4		PHLEPRA	0.7	CAREPEN	0.9
AGROSUB	0.9		ARTELUD	0.6	AGRODAS	0.6
DACTGLO	0.5				SOLIMIS	0.6
CIRSARV	0.3				CIRSARV	0.5
STIPCUR	0.1				FESTIDA	0.4
					STIPCUR	0.3
					ASTEFAL	0.2
					CAREOBT	0.2
					GALIBOR	0.1

C.6 MFC Compton Matted Wellsite (2003)

Construction date 2003

MFC Compton Matted Wellsite - Transects 1 & 2				NSR: FP	GVI: Lo	Elevation	1307
Slope (%)	**Aspect (Deg)**	**Lat**	**Long**	**UTM Zone**	**UTM E**	**UTM N**	
5	174	50.20576	114.05117	11N	710409	5565666	
Years post disturbance	**2005**	**Years post disturbance**	**2014**	**Monitoring Year**	**2**	**Monitoring Year**	**11**
Site	JRT01	Site	MFC1U	Site	JRT02	Site	MFC2D
Treatment	**Undisturbed**	**Treatment**	**Indisturbed**	**Treatment**	**Disturbed**	**Treatment**	**Disturbed**
	% Cover		**% Cover**		**% Cover**		**% Cover**
Total Veg		**Total Veg**	**70.0**	**Total Veg**		**Total Veg**	**43.5**
Exposed Soil	**0.5**	**Exposed Soil**	**0.0**	**Exposed Soil**	**0.0**	**Exposed Soil**	**0.3**
Moss/Lichen	**0.5**	**Moss/Lichen**	**0.0**	**Moss/Lichen**	**0.0**	**Moss/Lichen**	**0.0**
Species	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**
POAPRA	39.1	PHLEPRA	9.6	POAPRA	52.5	PHLEPRA	7.1
ASTELAE	33.8	POTEGRA	6.9	PHLEPRA	40.8	BROMINE	6.4
DANTPAR	32.7	POAPRA	6.1	BROMBIE	37.2	POAPRA	6.3
PHLEPRA	23.2	BROMINE	5.9	LUPISER	12.9	CAREPEN	5.8
BROMBIE	16.2	CIRSARV	4.7	STIPSPP	9.8	ARTELUD	4.4
POTEGRA	10.2	LATHOCH	4.6	AGROSUB	7.7	DANTPAR	1.3
AGROSUB	8.1	ASTELAE	3.8	DANTPAR	6.9	CIRSARV	1.2
ASTEFUL	8.1	ACHIMIL	3.4	AGRODAS	4.4	GALIBOR	1.0
GALIBOR	8.0	GERAVIS	3.1	AGOSGLA	4.1	ASTELAE	0.7
LUPISER	7.3	ROSAARK	2.6	ARTELUD	2.2	ROSAARK	0.6
LATHOCH	6.9	LUPISER	2.5	ROSAWOO	2.2	ACHIMIL	0.5
ACHIMIL	5.9	FRAGVIR	2.1	POTEGRA	2.0	THALVEN	0.5
STIPSPP	3.8	DANTPAR	2.0	KOELMAC	1.9	AGRODAS	0.3
VICIAME	3.8	GALIBOR	1.9			AGROSUB	0.2
GEUMTRI	3.4	CARELAN	1.4			POTEFRU	0.2
THALVEN	2.1	POTEARG	1.2			CAMPROT	0.1
KOELMAC	1.5	VICIAME	1.1				
GERAVIS	1.1	STIPRIC	0.9				
ROSAWOO	0.9	ASTEFAL	0.8				
FRAGVIR	0.7	AGOSGLA	0.7				
GENTAME	0.7	HAPLLAN	0.7				
		TRIFREP	0.6				
		POTEFRU	0.5				
		TARAOFF	0.4				
		MONAFIS	0.3				
		ASTRDAS	0.2				
		THALVEN	0.2				
		CARESPP	0.1				

MFC Compton Matted Wellsite - Transects 3 & 4				NSR: FP	GVI: Ov (Lo)	Elevation	1301
Slope (%)	**Aspect (Deg)**	**Lat**	**Long**	**UTM Zone**	**UTM E**	**UTM N**	
5	290	50.20665	114.04974	11N	710518	5565777	
Years post disturbance	**2005**	**Years post disturbance**	**2014**	**Monitoring Year**	**2**	**Monitoring Year**	**11**
Site	JRT04	Site	MFC4U	Site	JRT03	Site	MFC3D
Treatment	**Undisturbed**	**Treatment**	**Indisturbed**	**Treatment**	**Disturbed**	**Treatment**	**Disturbed**
	% Cover		**% Cover**		**% Cover**		**% Cover**
Total Veg		**Total Veg**	**75.5**	**Total Veg**		**Total Veg**	**41.5**
Exposed Soil	**0.0**	**Exposed Soil**	**0.0**	**Exposed Soil**	**0.0**	**Exposed Soil**	**0.0**
Moss/Lichen	**0.0**	**Moss/Lichen**	**0.0**	**Moss/Lichen**	**0.0**	**Moss/Lichen**	**0.0**
Species	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**
AGROSUB	25.9	PHLEPRA	19.5	PHLEPRA	78.5	PHLEPRA	10.6
ASTESPP	20.5	CARESPP	8.6	POAPRA	30.8	BROMINE	10.5
DANTPAR	19.7	POAPRA	8.3	CARESPP	18.9	POAPRA	3.5
FESTCAM	17.4	CIRSARV	7.8	CALAMON	12.7	TARAOFF	3.3
PHLEPRA	17.0	THALVEN	7.7	MUHLASP	11.9	THALVEN	3.3
GEUMTRI	16.4	BROMINE	7.2	BROMSPP	8.6	CARELAN	2.5
POAPRA	12.7	TRIFREP	4.3	FRAGVIR	2.0	GALIBOR	0.9
POTEGRA	10.0	CARELAN	2.6	GALIBOR	1.1	TRIFREP	0.6
AGOSGLA	9.2	TARAOFF	2.4	AGROSTO	0.7	ACHIMIL	0.5
FRAGVIR	9.2	FESTCAM	1.6	ASTESPP	0.7	CAREPEN	0.5
STIPSPP	7.5	ACHIMIL	1.1	THALVEN	0.7	ASTRSPP	0.2
GALIBOR	3.8	PERIGAI	1.1			CIRSARV	0.2
ACHIMIL	2.8	GALIBOR	1.0			FRAGVIR	0.2
BROMSPP	2.5	AGOSGLA	0.8			HIERODO	0.2
AGRODAS	2.4	CAREPEN	0.8			POTEFRU	0.2
ASTRFLE	2.0	POTEGRA	0.7			RANUCAR	0.1
CALAMON	2.0	ASTRDAS	0.6				
LATHOCH	2.0	DANTPAR	0.5				
MUHLASP	0.9	LATHOCH	0.5				
VICIAME	0.7	VICIAME	0.5				
ZIZIAPT	0.7	HAPLLAN	0.4				
		VIOLSPP	0.4				
		AGRODAS	0.3				
		ASTELAE	0.3				
		AGROSCA	0.2				
		AGROSUB	0.2				
		POTEFRU	0.1				