DRAFT

Recovery Strategies for Industrial Development in Native Prairie

for the

Mixedgrass

Natural Subregion of Alberta

Mixedgrass Natural Subregion

Natural Recovery—Majorville Uplands

Pipeline through fescue grassland

Draft Framework # 2

April 2013

RECOVERY STRATEGIES FOR INDUSTRIAL DEVELOPMENT IN NATIVE PRAIRIE

FOR THE MIXEDGRASS NATURAL SUBREGION OF ALBERTA

APRIL 2013

Draft Framework # 2 for PTAC

Prepared for:

RANGE RESOURCE MANAGEMENT BRANCH
PUBLIC LANDS DIVISION
ALBERTA ENVIRONMENT AND SUSTAINABLE RESOURCE DEVELOPMENT

Alberta Environment and Sustainable Resource Development

Petroleum Technology Alliance Canada

PTAC PETROLEUM TECHNOLOGY ALLIANCE CANADA

Prepared by:

GRAMINEAE SERVICES LTD., KESTREL RESEARCH INC. AND DESSERUD ENVIRONMENTAL LTD.

In Association with:

PARTICIPANTS OF THE RECOVERY STRATEGIES FOR INDUSTRIAL DEVELOPMENT
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Thanks team!

Marilyn Neville and *Jane Lancaster*

Preface

Reclamation practices following industrial disturbance in native prairie landscapes have been steadily evolving since the early 1980s. Industrial activity in native prairie has also been steadily increasing. The Mixedgrass Natural Subregion of Alberta is rich in petroleum resources with a large and diverse development infrastructure in native prairie. Recently, the development of renewable resources such as wind energy is also taking place, requiring a similar development infrastructure in native prairie as well. As the demand for development has increased, so has public pressure to reduce the impact of industrial disturbance and the cumulative effects of multiple activities on native prairie ecosystems.

Over time the focus of reclamation practices in native prairie has shifted from controlling soil erosion and establishing sustainable grass cover to development planning with pre-disturbance assessment and implementation procedures designed to facilitate the restoration of ecosystem structure, health and function. This need for a shift in focus from reclamation to restoration was acknowledged in the 2010 Reclamation Criteria for Wellsites and Associated Facilities in Native Grasslands (Alberta Environment 2011). The recovery strategies presented here have been developed to support the intent of the 2010 Criteria for Grasslands and to provide guidance for reclamation practitioners, contractors, landowners and Government of Alberta regulatory authorities. The strategies are not intended to be prescriptive, but rather strive to present options and pathways to enable selection of the most appropriate recovery strategy for the type of industrial disturbance on a site specific basis. Their purpose is to provide the expectations of what is required to reach the outcome of restoration over time.

This manual builds on existing guidelines and information sources such as *Restoring Canada's Native Prairies, A Practical Manual* (Morgan et al 1995), *A Guide to Using Native Plants on Disturbed Lands* (Sinton Gerling et al 1996), *Native Plant Revegetation Guidelines for Alberta* (Native Plant Working Group 2000), *Prairie Oil and Gas, A Lighter Footprint (Sinton 2001)* and *Establishing Native Plant Communities* (Smreciu et al 2003). While these guides continue to be excellent information sources, this manual incorporates new knowledge sources and technical innovations that have been developed since 2003. The upstream oil and gas industry has made major changes to the way wellsites and associated infrastructures are developed in native prairie. Minimal disturbance best management practices are now the norm in native prairie. Realizing the reclamation challenges faced for development in native prairie and the benefits gained from minimizing the footprint of disturbance, other industries are modifying their construction practices.

This manual is presented as a first approximation recognizing that revision will be required as our knowledge of native prairie plant communities and their response to recovery to industrial disturbance increases. Revision will also be required as reclamation practitioners use this approximation and industry responds to the challenges of native plant community restoration with new technology designed to reduce the industrial footprint in native prairie landscapes.

The development of the Natural Regions and Subregions of Alberta (Natural Regions Committee 2006) dichotomy as the first level of ecological classification in Alberta assists practitioners with the understanding of restoration opportunities and limitations within the Subregion context. The development of the Grassland Vegetation Inventory, Range Plant Community Guides and Range Health Assessment protocol by the Alberta Environment and Sustainable Resource Development (ESRD) Range Resource Management Program (RRMP) has greatly increased our understanding of native grassland ecosystems. These tools were developed to facilitate a more complete understanding of the ability of native plant communities to respond and adapt to natural disturbance regimes such as fire, grazing, drought, and predation. These tools are now being applied to assess and manage man-made disturbances. The tools are incorporated into pre-disturbance site assessment, development planning and reclamation certification for native grasslands, creating the need for a tool which provides guidance on appropriate recovery strategies for each Natural Subregion. These guidelines focus on recovery strategies for the Mixedgrass Natural Subregion.

The on-going Recovery Strategies for Industrial Development in Native Prairie Project will eventually address all Natural Subregions within the Grassland Natural Region. Projects are underway through the partnership established between Alberta Environment and Sustainable Resource Development (ESRD) and Petroleum Technology Alliance Canada (PTAC) to capture the key experience and learnings that have accumulated over the past 10 to 20 year period since minimum disturbance practice was first established.

The Mixedgrass Natural Subregion is unique in the challenges it presents to restoring disturbance from industrial development. Much of the Mixedgrass native prairie has been lost to cultivation and fragmented by industrial activity. The soils and climate of the Mixedgrass promote the spread of invasive non-native plants where soil disturbance has occurred. A restoration risk analysis is a critical step in assessing restoration strategies prior to and after disturbance. Minimal disturbance construction procedures, and natural recovery or assisted natural recovery where appropriate, are the most effective strategies for restoring native plant communities in the Mixedgrass. Alternate strategies for large disturbances not suited to natural recovery and severely degraded sites are defined and discussed in the context of new restoration tools and recent publications.

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Abbreviations

ACIMS........Alberta Conservation Information Management System
AENV........Alberta Environment
AGRASID........Agricultural Region of Alberta Soil Information Database
AI........Alberta Innovates
AUPRF........Alberta Upstream Petroleum Research Fund
cm........centimetre
EAP........Enhanced Approval Process
EBIPM........Ecologically Based Invasive Plant Management
EPP........Environmental Protection Plan
ERS........Ecological Range Site
ERCB........Energy Resources Conservation Board
ESRD........Alberta Environment and Sustainable Resource Development
ESRRA........Ecological Site Restoration Risk Analysis
Express........Express Pipeline
FWMIS........Fish and Wildlife Management Information System
g........gram
GPS........global positioning system
GVI........Grassland Vegetation Inventory
ha........hectare
IL........Information Letter
kg........kilogram
km........kilometre
LAT........Landscape Analysis Tool
m........metre
MG........Mixedgrass Natural Subregion
MGPCG........Mixedgrass Plant Community Guide
NEB........National Energy Board
NSR........Natural Subregion
PCF........Prairie Conservation Forum
PNC........Potential Natural Community
PNT........Protective Notation
PTAC........Petroleum Technology Alliance Canada
RoW........right-of-way
RPC........Reference Plant Community
RRMP........Range Resource Management Program
wt........weight

1 A SHIFT TO FOCUS IN RESTORATION

Why is ecological restoration important for our native grassland ecosystems? We have lost much of our original native grasslands in the Mixedgrass Natural Subregion to cultivation and we continue to stress these important ecosystems with an increasingly large industrial footprint. If we are to conserve what remains of our native prairie for future generations, then we must continue to improve our reclamation practices and recovery strategies in native prairie landscapes. Our focus must shift from reclamation to restoration.

Ecological restoration is defined as "*the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed*" (Society for Ecological Restoration 2004). There is an increasing public awareness of the remaining native grassland ecosystems and the ecological goods and services they provide for Albertan's. The amount of industrial activity taking place in native grasslands has increased dramatically since the early 1990s. The purpose of this document is to provide reclamation practitioners, landowners, land managers and regulatory authorities with a suite of recovery strategies for industrial disturbances in native grasslands. It is designed to dovetail with the *2010 Reclamation Criteria for Wellsites and Associated Facilities for Native Grasslands* (Alberta Environment 2011) by providing a pathway for decision making focused on choosing and implementing the recovery strategy that will restore ecological health, function and operability to the disturbed site. In the 2010 Grassland Criteria, there is a greater emphasis on native grassland plant communities as indicators of equivalent land capability. Equivalent Land Capability is defined in the 2010 Criteria "*as the condition in which ecosystem processes are functioning in a manner that will support the production of goods and services consistent in quality and quantity as present prior to disturbance*". The bar has been raised and now we must meet the challenge.

The most important factors in reducing the cumulative effects of industrial disturbance in native prairie landscapes include:

- Avoidance of native prairie through pre-development planning;
- Where avoidance is not possible, reducing the footprint of impact to prairie soils and native plant communities through pre-disturbance site assessment;
- Implementing the best available technology, construction practices and equipment to reduce the disturbance to soils and native plant communities; and
- Understanding the important role timing plays in the outcome of development activities in native prairie and the timeline required to achieve restoration.

2 OVERVIEW OF MIXEDGRASS NATURAL SUBREGION

The first step in restoration planning requires an understanding of Alberta's regional ecological land classification system. The Natural Regions and Subregions of Alberta have provided the provincial ecological context within which resource management activities have been planned and implemented since the 1970s. The current revision entitled "*Natural Regions and Subregions of Alberta*" (Natural Regions Committee 2006) builds on two previous classifications: *Ecoregions of Alberta* (Strong and Leggat 1992) and *Natural Regions and Subregions and Natural History Themes of Alberta* (Achuff1994). Copies of the current revision are available at:
http://www.tpr.alberta.ca/parks/heritageinfocentre/docs/NRSRcomplete%20May_06.pdf

It is important to understand the ecological diversity of the Grassland Natural Region and the unique restoration challenges offered in each Natural Subregion. The Natural Subregion dichotomy is the first level of ecological classification in Alberta and assists practitioners with the understanding of restoration opportunities and limitations within the Subregion context. This publication focuses on the Mixedgrass Natural Subregion.

2.1 Physiography, Soils, Climate, and Vegetation of the Mixedgrass Natural Subregion

The Mixedgrass Natural Subregion (Mixedgrass) occurs in five geographic areas extending north from the United States border to the Red Deer River (Figure 1, Figure 2). The largest area occurs on the plains to the east of the Foothills Fescue Natural Subregion and to the west of the Dry Mixedgrass Natural Subregion. This plain borders the Northern Fescue Natural Subregion to the north. This area includes the Lethbridge Plain, the Vulcan Plain, The Blackfoot Plain and the Standard Plain ecodistricts. Smaller areas of Mixedgrass occur in four highland ecodistricts. The Majorville Upland occurs east of and adjacent to the plains to the north of the Lethbridge Plain. The Cypress Hills Upland surrounds the Cypress Hills Escarpment and Plateau. The Sweetgrass Upland occurs as a band along the lower slopes of the Sweetgrass Hills along the United States border, and the Milk River Upland occurs along the eastern portion of the Milk River Ridge (Adams et al. 2013, McNeil 2004). It is important to understand the differences between the ecodistricts that occur in the Mixedgrass (Figures 3 through 7). Topography, elevation, soils and climate have played a major role in the development of unique, sustainable native plant communities.

The Mixedgrass accounts for 19.8% of the Grassland Natural Region Area and 2.9% of the area of Alberta (ASIC 2001). The soils of the Mixedgrass are very productive. Hence, since settlement, the prairie has been highly fragmented by cultivation. Approximately 31% of the original 4.6 million acres of Mixedgrass prairie remain today (Adams et al 2013). The plains are mostly cultivated with scattered remnant prairies. More extensive native rangelands occur at higher elevations on the slopes of the Cypress Hills, and the Sweetgrass, Milk River and Majorville Upland Ecodistricts (Natural Regions Committee 2006).

The boundaries of the Mixedgrass correspond closely to the boundaries of the Agricultural Regions of Alberta Soil Information Database (AGRASID) Soil Correlation Areas (SCAs) 2 and 3 (ASCI 2001). The plains portion of the Mixedgrass, including the Majorville Upland is correlated with SCA3, while the Cypress Hills, and the Sweetgrass and Milk River Uplands are in SCA2 (Adams et al. 2013).

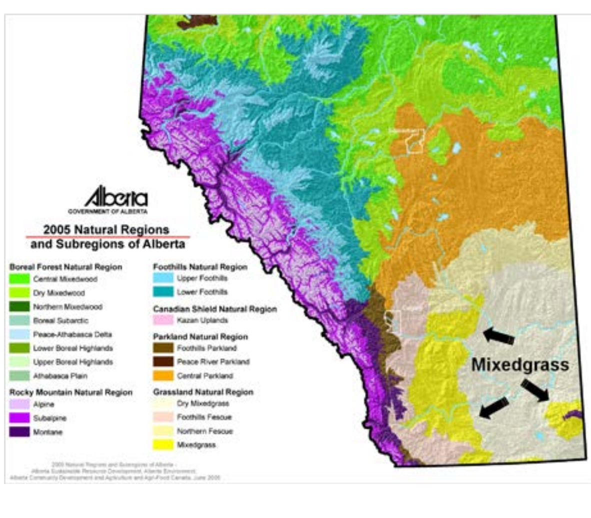
The Mixedgrass is dominated by Dark Brown Chernozemic soils. Parent materials are dominantly glacial till with lesser occurrences of glacio-lacustrine, glacial-fluvial and eolian parent materials. Topography in the plains ecodistricts is dominantly undulating to hummocky. Topography in the highland ecodistricts is hummocky to inclined (Adams et al. 2013).

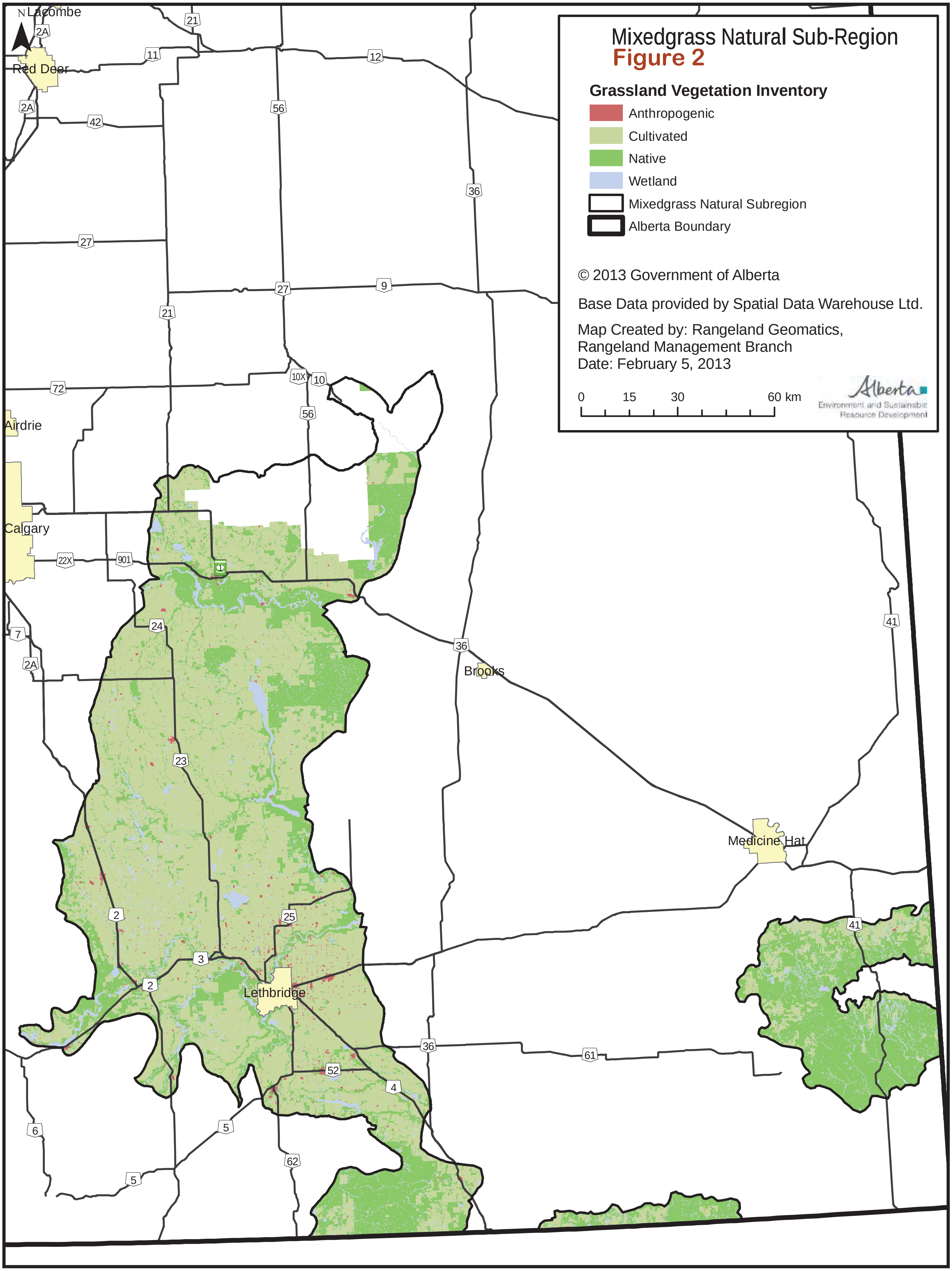
The climate of the Mixedgrass is characterized by short summers with warm days and cool nights. Mean summer temperatures are about 15°C and mean annual temperature is about 5°C (Adams et al. 2005). The Mixedgrass has slightly moister and somewhat cooler summers and milder winters than the Dry Mixedgrass Natural Subregion (Dry Mixedgrass) to the east. Even cooler and moister conditions prevail at higher elevations in the Mixedgrass highland ecodistricts. The milder winters are due to the influence of the Chinook winds. These strong, warm, westerly winds are a significant factor influencing restoration potential once the native prairie vegetation has been removed. Winter thawing of frozen soils presents challenges for operating heavy equipment on native prairie vegetation. The potential for soil loss due to wind erosion is a significant factor that must be considered in development planning. The fertile Dark Brown Chernozemic soils, combined with adequate average annual precipitation, provides the opportunity for non-native plants to invade and colonize disturbed soils, especially in areas fragmented by cultivation.

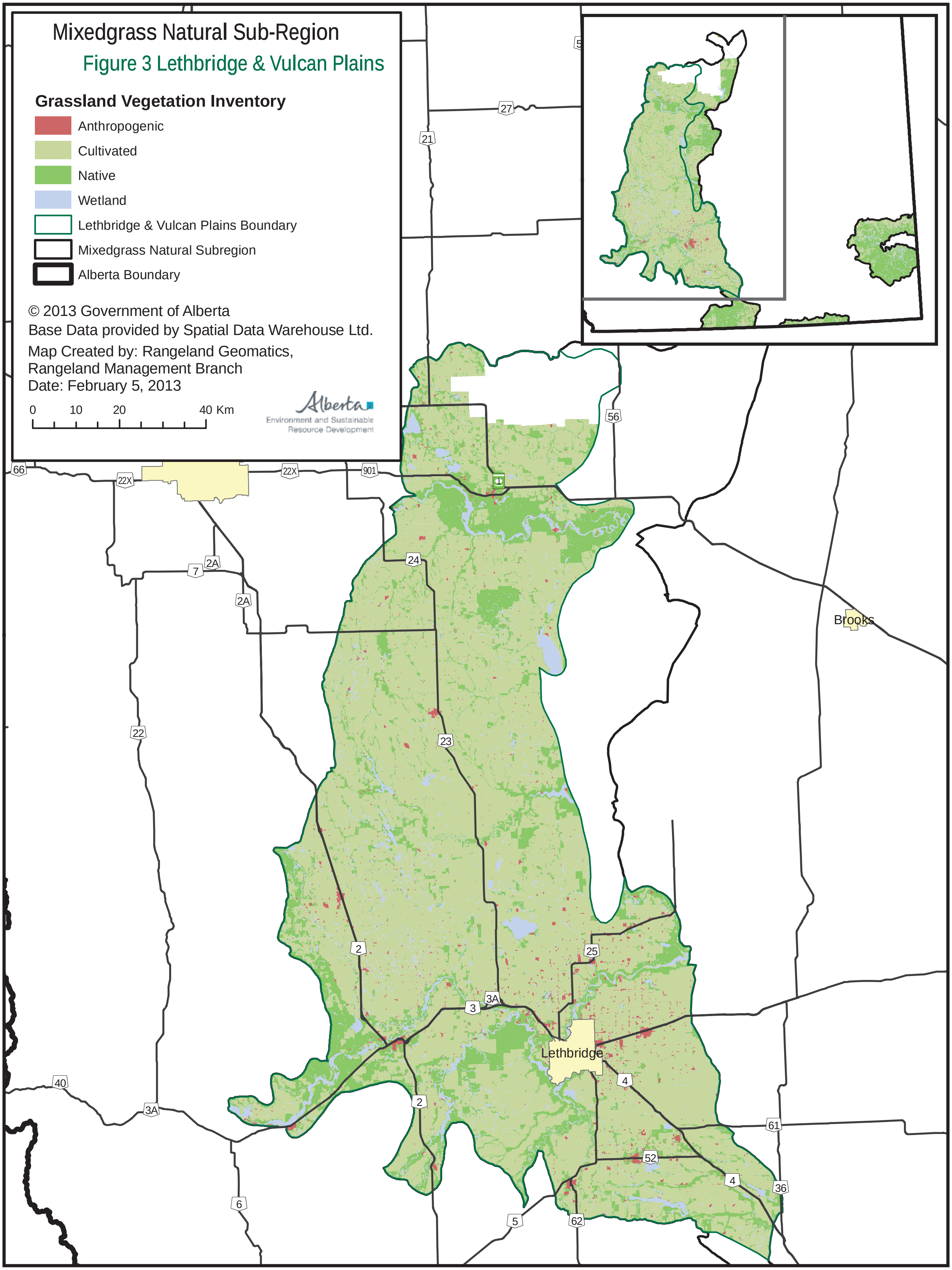
The native grassland plant communities of the Mixedgrass are strongly influenced by regional factors. In the Mixedgrass, elevated regional landforms rising above broad plains, combined with soils and climatic factors related to differences in elevation, produces unique and varied native grassland plant communities. The plains ecodistricts of the Mixedgrass (Lethbridge, Vulcan, Blackfoot and Standard Plains) support native plant communities similar to the Dry Mixedgrass, typically needle-and-thread grass (*Stipa comate*), blue grama grass (*Bouteloua gracilis*), with northern wheatgrass (*Agropyron dasystachyum*). In the Majorville Upland, western porcupine grass (*Stipa curtiseta*) replaces needle-and-thread grass as the dominant species. The lower slopes of the Cypress Hills Upland support June grass (*Koeleria macrantha*), northern and western wheatgrass (*Agropyron smithii*), and needle-and-thread grass communities. Higher elevations support plains rough fescue (*Festuca hallii*), western porcupine grass, and sedge (*Carex species*) communities. The Milk River Upland and the slopes of the Sweetgrass Upland support northern wheatgrass, June grass, sedge communities and Idaho fescue (*Festuca idahoensis*), northern wheatgrass, sedge communities. It is important to note that plains rough fescue plant communities can also occur in the transition areas between the Mixedgrass and the Northern Fescue Natural Subregion to the north, and the Foothills Fescue Natural Subregion to the west. Rough fescue plant communities should be avoided as they are very difficult to restore. A more detailed description of the Mixedgrass is provided in the Mixedgrass Range Plant Community Guide (Adams et al. 2013). The most current approximation can be found on the Alberta Environment and Sustainable Resource Development (ESRD) website at: http://www.srd.alberta.ca

> Fertile Dark Brown Chernozemic soils combined with adequate annual precipitation provide the opportunity for non-native plant invasion to occur, especially in areas fragmented by cultivation.

Figure 1 - Natural Subregions of Alberta




Mixedgrass Natural Sub-Region
Figure 2
Grassland Vegetation Inventory
Anthropogenic
Cultivated
Native
Wetland
Mixedgrass Natural Subregion
Alberta Boundary
© 2013 Government of Alberta
Base Data provided by Spatial Data Warehouse Ltd.
Map Created by: Rangeland Geomatics,
Rangeland Management Branch
Date: February 5, 2013
0 15 30 60 km
Alberta
Environment and Sustainable Resource Development
N
Lacombe
Red Deer
Airdrie
Calgary
Brooks
Medicine Hat
Lethbridge


Mixedgrass Natural Sub-Region
Figure 3 Lethbridge & Vulcan Plains
Grassland Vegetation Inventory
Anthropogenic
Cultivated
Native
Wetland
Lethbridge & Vulcan Plains Boundary
Mixedgrass Natural Subregion
Alberta Boundary
© 2013 Government of Alberta
Base Data provided by Spatial Data Warehouse Ltd.
Map Created by: Rangeland Geomatics,
Rangeland Management Branch
Date: February 5, 2013
0 10 20 40 Km
Alberta
Environment and Sustainable Resource Development
Brooks
Lethbridge
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21
56
66
22X
22X
901
1
24
7
2A
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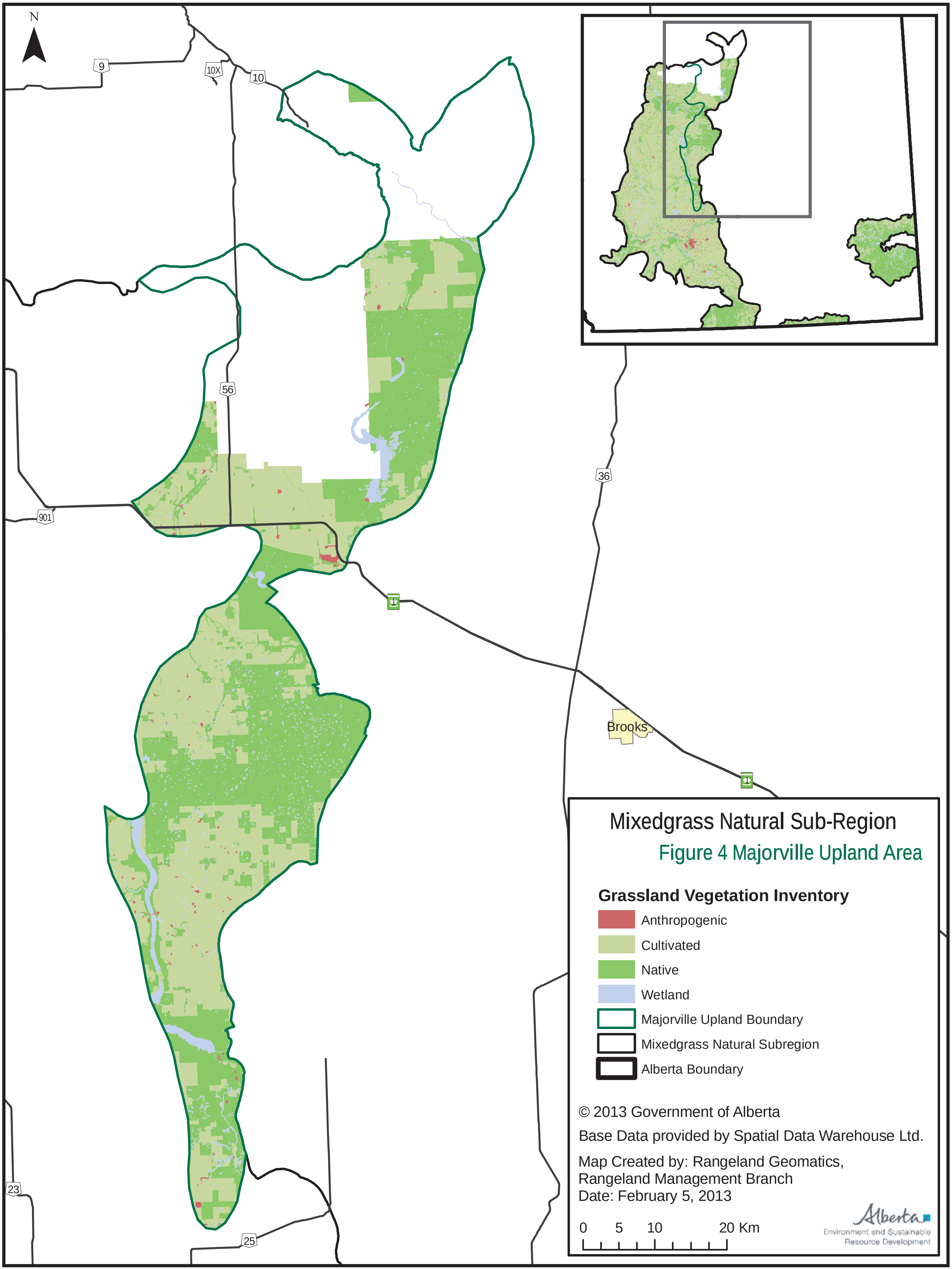
6
5
62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901
36
1
Brooks
23
25
Mixedgrass Natural Sub-Region
Figure 4 Majorville Upland Area
Grassland Vegetation Inventory
Anthropogenic
Cultivated
Native
Wetland
Majorville Upland Boundary
Mixedgrass Natural Subregion
Alberta Boundary
© 2013 Government of Alberta
Base Data provided by Spatial Data Warehouse Ltd.
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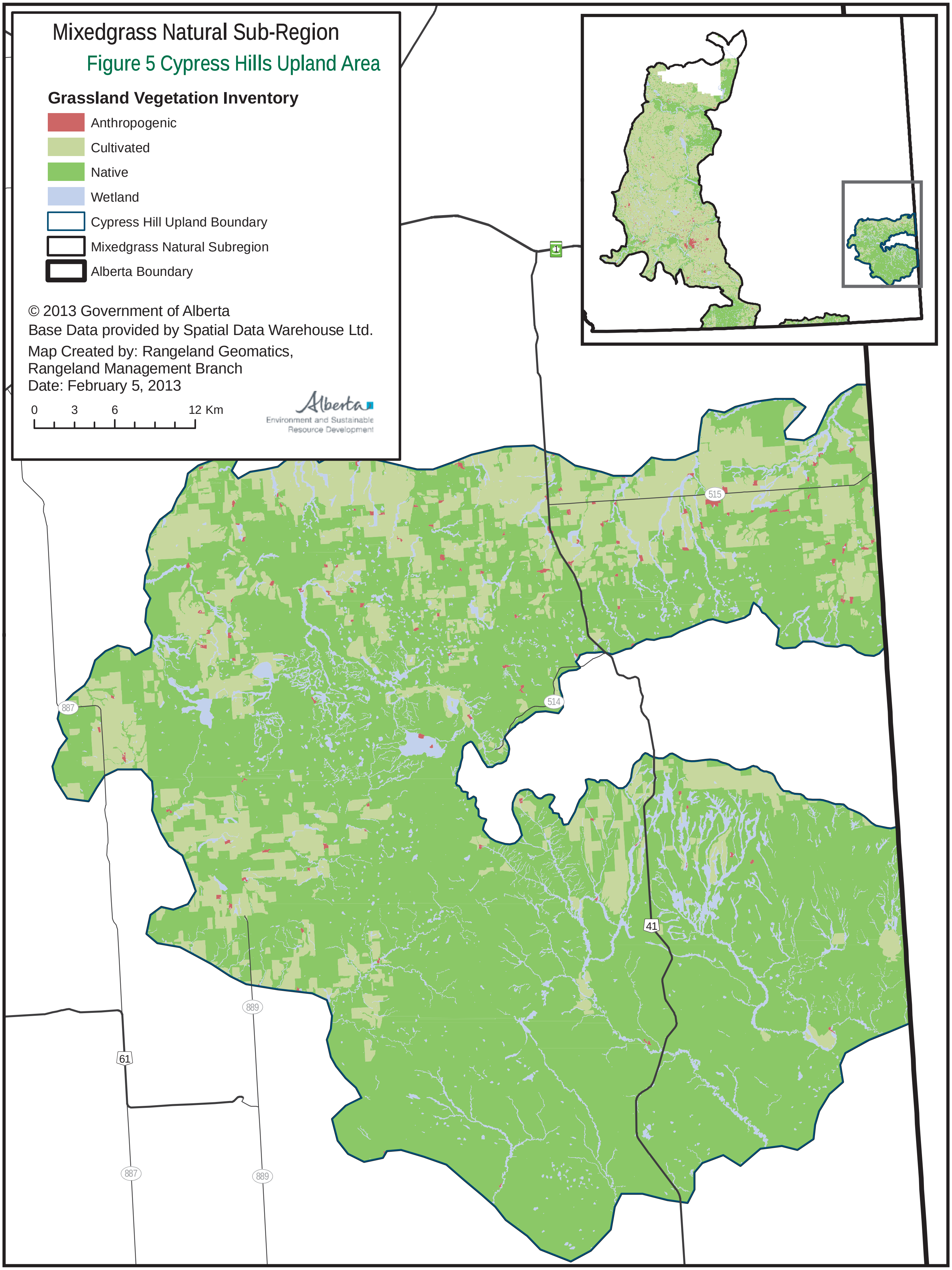
Mixedgrass Natural Sub-Region
Figure 5 Cypress Hills Upland Area
Grassland Vegetation Inventory
Anthropogenic
Cultivated
Native
Wetland
Cypress Hill Upland Boundary
Mixedgrass Natural Subregion
Alberta Boundary
© 2013 Government of Alberta
Base Data provided by Spatial Data Warehouse Ltd.
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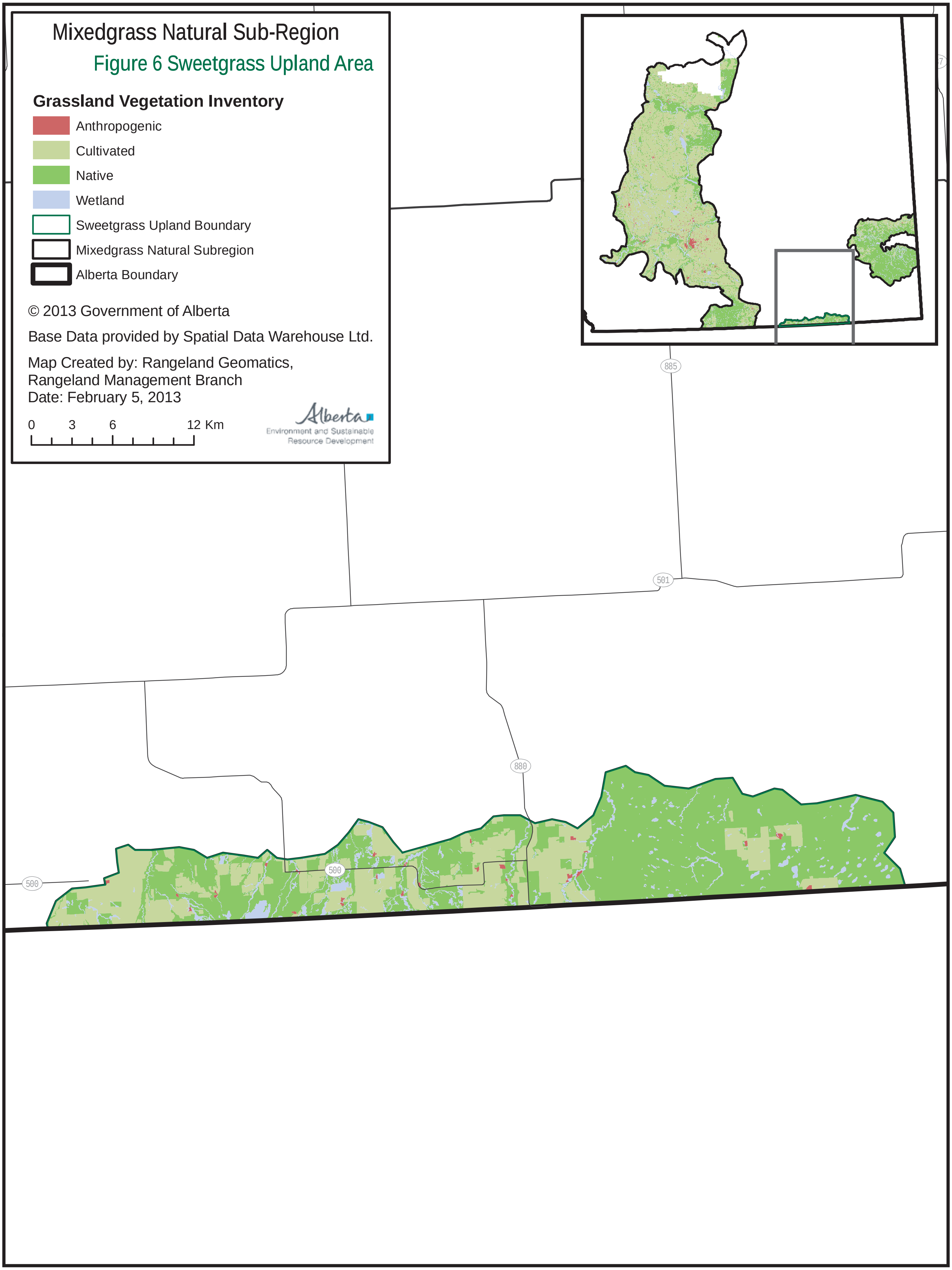
Alberta
Environment and Sustainable Resource Development
515
514
887
41
889
61
1


Mixedgrass Natural Sub-Region
Figure 6 Sweetgrass Upland Area
Grassland Vegetation Inventory
Anthropogenic
Cultivated
Native
Wetland
Sweetgrass Upland Boundary
Mixedgrass Natural Subregion
Alberta Boundary
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Base Data provided by Spatial Data Warehouse Ltd.
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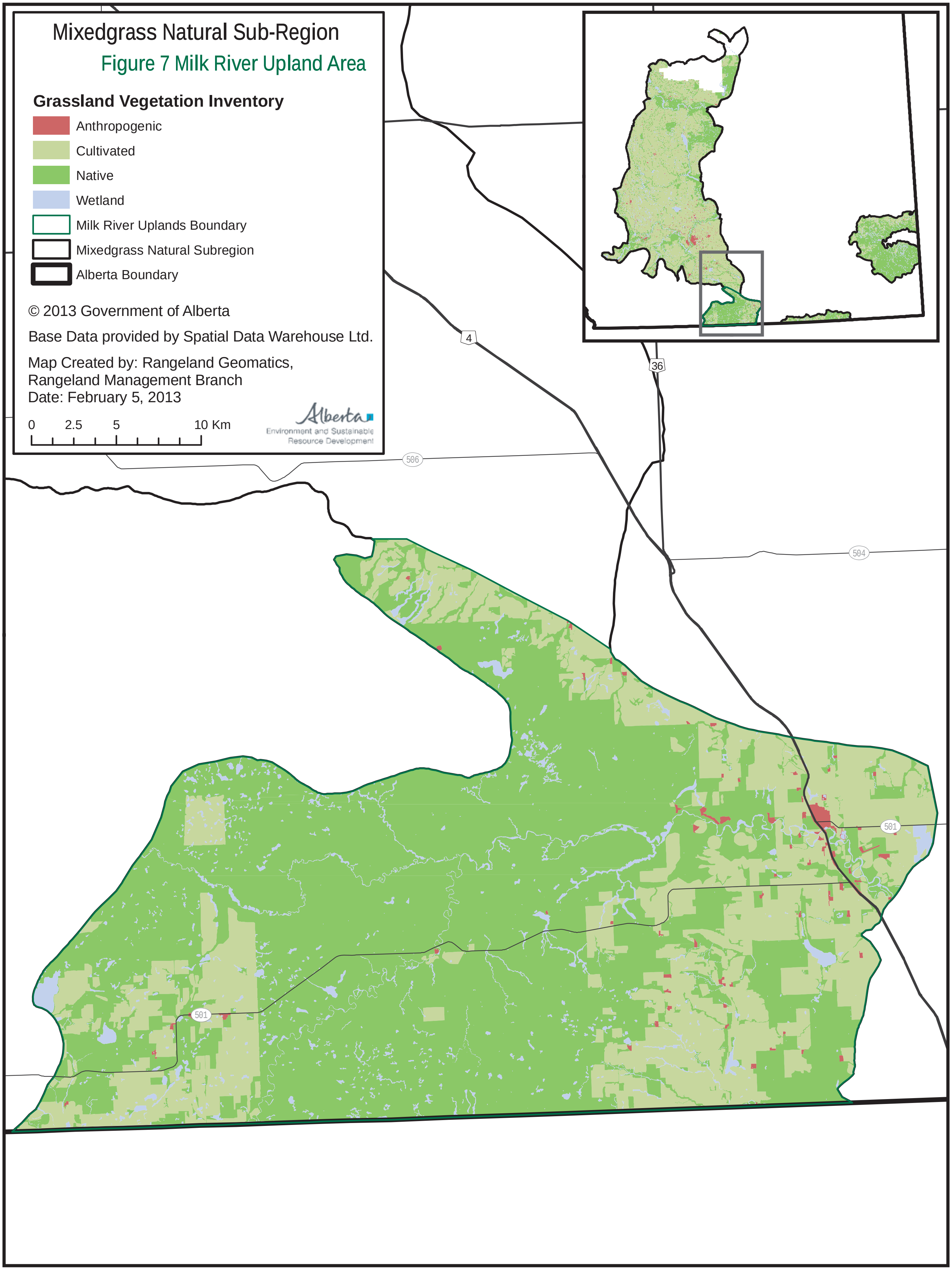
Mixedgrass Natural Sub-Region
Figure 7 Milk River Upland Area
Grassland Vegetation Inventory
Anthropogenic
Cultivated
Native
Wetland
Milk River Uplands Boundary
Mixedgrass Natural Subregion
Alberta Boundary
© 2013 Government of Alberta
Base Data provided by Spatial Data Warehouse Ltd.
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Rangeland Management Branch
Date: February 5, 2013
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Resource Development
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501
501

2.2 Types of Industrial Activity

There are numerous types of industrial activities operating in the native grassland ecosystems of the Mixedgrass. Currently, oil and gas production and the associated infrastructure is an important industry within the Mixedgrass. Exploration and development has occurred on both private and public lands, and on cultivation as well as native prairie. Several large diameter pipeline corridors cross extensive tracts of Mixedgrass native grassland. Coal is strip-mined to create electricity and gravel is extracted to construct and maintain transportation corridors. Agriculture is the dominant land use. Large tracts of land are under cultivation for both dry land and irrigated crop production. The ranching industry continues to utilize native grasslands for livestock production.

Recently the quest to develop renewable forms of energy has seen the development of wind farms and the upgrading of electrical transmission corridors. The cumulative effects of industrial activity in the Mixedgrass are significant, and the long term impact of surface soil disturbance on the ecological integrity of these grasslands is not well understood.

2.3 Managing Surface Disturbance

The importance of managing surface disturbance and maintaining the integrity of native plant communities during industrial development in native prairie has been formally recognized since 1992. The following information letters, principles and guidelines have been developed by collaborative stakeholder working groups for the Energy Resources Conservation Board (ERCB) http://www.ercb.ca/

IL 92-12 (ERCB IL92-12) (Rescinded and replaced by ERCB IL2002-1)

This information letter informed industry that agronomic grasses could not be used in reclamation seed mixes in native prairie.

IL 96-9 Revised Guidelines for Minimizing Disturbance in Native Prairie (ERCB IL 96-9); and

IL 2002-1 Principles for Minimizing Surface Disturbance in Native Prairie and Parkland Areas (ERCB IL 2002-1)

These information letters informed industry of the importance of native prairie and parkland areas and the need to minimize surface disturbance through all phases of development activities when undertaking development activities in these area. IL 2002-1 recognizes the importance of the Parkland Natural Region.

Petroleum Industry Activity in Native Prairie and Parkland Areas, Guidelines for Minimizing Surface Disturbance (Native Prairie Guidelines Working Group 2002)

This document was prepared by a working group comprised of representatives from government agencies having jurisdiction over petroleum industry activities in native prairie and parkland areas. It provides specific direction for all phases of petroleum development activity including seismic and geophysical programs. Key general guidelines include:

- Avoidance of native prairie and parkland landscapes if at all possible;
- The use of previously disturbed areas such as existing access roads and prairie trails; and
- The requirement for special planning measures, field based environmental assessments, minimal disturbance construction techniques and the use of native plant materials or natural recovery during site reclamation.
- The importance of weed control is emphasized and environmental monitoring is recommended.

Prairie Oil and Gas: A Lighter Footprint (Sinton et al 2001)

This booklet provides information, photos and illustrations about best development practices to reduce the impacts of oil and gas activities on prairie and parkland landscapes. It focuses on a "cradle to the grave" approach that ensures care taken during one phase of development is not undone at another stage.

A lighter footprint requires a "cradle to the grave" approach.

Recommended Principles and Guidelines for Wind Energy Development in Native Prairie
*(*Foothills Restoration Forum Technical Advisory Committee 2011)

This document recommends principles and guidelines for wind energy developments similar to the principles and guidelines developed by the petroleum industry. The document was developed by a multi-stakeholder working group co-ordinated by the Foothills Restoration Forum and is available at http://www.foothillsrestorationforum.ca.

Alberta Prairie Conservation Forum Action Plan 2011 to 2015

The vision embedded in the Prairie Conservation Forum (PCF) 2011 to 2015 Action Plan is to ensure the biological diversity of Alberta's prairie and parkland ecosystems is secure through the thoughtful and committed stewardship of all Albertans. To achieve the vision, three important long term outcomes are the focus of the PCF Action Plan:

- Maintain large prairie and parkland landscapes;
- Conserve connecting corridors for biodiversity;
- Protect isolated native habitats.

To reduce the footprint and the cumulative effects of industrial development in the prairie landscape these three important outcomes must be considered early in any development planning process. The 2011 Action Plan and valuable further information on the importance of prairie conservation is found on the Alberta Prairie Conservation Forum Website at: http:// www.albertapcf.org

3 TOOLS FOR THE RESTORATION TOOLBOX

Implementing improved recovery strategies involves not just practice change on the ground but also utilizing many new tools designed to understand site characteristics and plant communities linked to landforms and soils. These tools will improve reclamation best practices and restoration potential at all stages of development, from pre-development planning through long term monitoring to evaluating reclamation and restoration success.

3.1 Grassland Vegetation Inventory

The Grassland Vegetation Inventory (GVI) represents the Government of Alberta's first comprehensive biophysical vegetation and anthropogenic inventory of the Grassland Natural Region. GVI provides mapped information of landscape scale soil/landform features and vegetation cover for use in planning and management of rangelands, fish and wildlife, wetlands, land use and reclamation. Developed by ESRD, the Grassland Vegetation Inventory is comprised of ecological range sites based on soils and vegetation information for areas of native vegetation and general land use for non-native areas (agricultural, industrial, and urban areas). It also includes a coarse hydrological feature layer. A user manual entitled "*Specifications for the Use and Capture of Grassland Vegetation Inventory (GVI) Data 5th Edition" (*Alberta Sustainable Resource Development and LandWise Inc. 2011) is available on the web.

GVI data is available either by contacting the Resource Information Management Branch Data Distribution (within ESRD) or obtaining website information from:

http://www.srd.alberta.ca/MapsPhotosPublications/Maps/ResourceDataProductCatalogue/ForestVegetationInventories.aspx and http://www.albertapcf.org/

3.2 Range Plant Community Guides

The Mixedgrass Range Plant Community Guide is an essential reference for identifying common plant communities and conducting range health assessments in the Mixedgrass Natural Subregion of Alberta. The guide provides plant community descriptions by ecological range site, which can be linked to the GVI site types. The plant community that is an expression of site potential is referred to as the reference plant community (RPC) since it represents the potential natural community for comparison in range health assessment. The plant community guides have been compiled from data collected from detailed vegetation inventories and the extensive system of reference areas established across the province by the ESRD Range Resource Management Program (RRMP). The guides are available on the ESRD website and are updated on a regular basis as new data is gathered.

http://srd.alberta.ca/LandsForests/GrazingRangeManagement/documents/MixedgrassSubregionAssessmentGuidelines.pdf

3.2.1 Navigating the Mixedgrass Range Plant Community Guide

The Mixedgrass Range Plant Community Guide (MGPCG) contains vital information to determine which ecodistrict your project is located in and common range plant communities found in each ecodistrict. Key steps to finding information for your project area are:

1. Identify the ecodistrict the project area is located in (MGPCG Figure 2: Ecodistricts in the Mixedgrass NSR);
2. Identify the major soil series and associated ecological range sites found in the ecodistrict (MGPCG Table 4: Major Soils and their Associated Ecological Range Sites by Ecodistrict). The ecological range site will be mapped at a landscape scale in the GVI data layer (this needs to be ground truthed). The soil series and the ecological range site will help determine which range plant communities may be found in the project area;
3. Then find MGPCG Table 10: Ecological Range Sites and Reference Plant Communities in the Mixedgrass Natural Subregion), which links ecodistricts with ecological range site and reference plant communities (or the potential native plant community under light disturbance);
4. Check MGPCG Tables 11 to 13 to identify successional and modified communities associated with the reference plant communities. This table will show the suite of range pant communities potentially present in the project area under different grazing pressure.
5. Once you are standing on the site, work through the Key to Range Plant Communities or read through the descriptions of the communities identified in MGPCG Tables 11 to 13.
6. Understanding the ecological range site and range plant communities within a proposed project site is vital to conducting an ecological risk assessment for project planning.

3.3 Range Health Assessment

The Range Health Assessment protocol and the Range Health Assessment Field Workbook developed by the ESRD – RRMP have been used to assess, monitor and manage Alberta's rangeland since 2003. The field workbook is available on the web at:

http://www.srd.alberta.ca/LandsForests/GrazingRangeManagement/documents/RangelandHealthAssessmentforGrasslandForestTamePasture-Revised-Apr2009.pdf

The assessment approach builds on the traditional range condition concept that considers plant community type in relation to site potential, but adds new and important indicators of natural processes and functions. The methodology provides a visual system that allows users to readily see changes in range health and to provide early warning when management changes are needed. Understanding range health is an important component of a restoration risk assessment. In the context of reclamation after disturbance, they provide a measure of ecosystem recovery.

Range health is defined as the ability of rangeland to perform certain key functions. These functions include: net primary production, maintenance of soil/site stability, capture and beneficial release of water, nutrient and energy cycling, and functional diversity of plant species. Workbook Table 1 (reproduced below) from the Range Health Field Workbook describes the functions of healthy rangelands and why they are important.

Table 1 – Functions of Healthy Rangelands

Rangeland Functions	*Why Is the Function Important?*
Productivity	• Healthy range plant communities are very efficient in utilizing available energy and water resources in the production of maximum biomass • Forage production for livestock and wildlife • Consumable products for all life forms (e.g. insects, decomposers etc.)
Site Stability	• Maintain the potential productivity of rangelands • Protect soils that have taken centuries to develop • Supports stable long-term biomass production
Capture and Beneficial Release of Water	• Storage, retention and slow release of water • More moisture available for plant growth and other organisms • Less runoff and potential for soil erosion • More stable ecosystem during drought
Nutrient Cycling	• Conservation and recycling of nutrients available for plant growth • Rangelands are thrifty systems not requiring the input of fertilizer
Plant Species Diversity	• Maintains a diversity of grasses, forbs, shrubs and trees • Supports high quality forage plants for livestock and wildlife • Maintains biodiversity, the complex web of life

The range health assessment questions detailed in the field workbook are indirect measures of the following indicators:

1. Integrity and Ecological Status
2. Community Structure
3. Hydrologic Function and Nutrient Cycling
4. Site Stability
5. Noxious Weeds

An evaluation of each indicator using the methods and scoring system detailed in the field workbook indicates whether these important ecological functions are being performed.

Range health assessment is an important tool for monitoring the management of the multiple use activities taking place on grasslands. The use of a common assessment method for all man-made impacts on grasslands could facilitate more accurate cumulative effects assessment and lead to further improved land management and communication in the future. Range health assessment is an important component of the 2010 Reclamation Criteria for Grasslands and annual training programs for reclamation practitioners are being offered through the Foothills Restoration Forum. Reclamation Criteria training is also supported annually by the Alberta Institute of Agrologists.

Figure 8 - Standardized Grassland Assessment Tools

3.4 Ecological Site Restoration Risk Analysis

The Ecological Site Restoration Risk Analysis (ESRRA) is a pathway for determining the ability of the components of an ecological range site to recover from the direct impact of industrial activity. This involves an understanding of the characteristics of the site, soils, landscape type, moisture regime and associated plant community. The ESRRA report, prepared by ESRD –RRMP in consultation with ESRD Rangeland Agrologists and Land Use Specialists can be found in the information portal on the Foothills Restoration Forum website at http://www.foothillsrestorationforum.ca

Restoration risk will affect your potential restoration outcome

In the Mixedgrass the following factors affect restoration potential:

1. Climatic processes such as available moisture and temperature during the critical periods of germination and emergence. In the Mixedgrass, elevation plays an important role in seasonal precipitation accumulation and mean temperature. Cooler and moister growing conditions prevail in the upland ecodistricts compared to the lower elevation plains.

2. The resistance the site can afford to non-native plant invasion. Non-native plants of concern include Prohibited Noxious and Noxious Weeds listed under the Alberta Weed Control Act and aggressive agronomic plants such as crested wheatgrass (*Agropyron cristatum, A. sibiricum*), Kentucky bluegrass (*Poa pratensis*) and sweet clover (*Melilotus spp.*). Aggressive non-native grass species such as downy brome (*Bromus tectorum*) and Japanese brome (*Bromus japonicas*) are of particular concern in the Mixedgrass due to their adaptation to semi-arid conditions and disturbed soils. These species are particularly of concern in the Sweetgrass and Milk River Uplands. It has been observed that within the Grassland Natural Region the potential for non-native plant invasion on disturbed upland soils decreases as soil fertility, topsoil depths and soil moisture decreases. For example, the Black Loamy soils of the Foothills Fescue Natural Subregion are much more prone to non-native plant invasion than the drier climatic conditions and Dark Brown soils of the Mixedgrass Natural Subregion. The same characteristics of soils, landscape type, moisture regime and associated plant community can be applied at the ecological range site level. For example within the Mixedgrass, Overflow range sites are more prone to non-native plant invasion than Sands or Blowout range sites.
3. The total area of the development footprint, the amount of development related soil disturbance and the extent that the native plant communities are fragmented within the footprint are interrelated factors which affect the restoration potential.
4. The potential for accelerated soil erosion beyond what would normally occur under undisturbed conditions varies according to the soil and landscape characteristics of the ecological range site. Factors include soil texture, landscape position, slope and the amount of bare soil present in the reference plant community.
5. Some ecological range sites are more adapted to soil disturbance than others. For example, wind erosion is a physical process inherent to the reference plant communities of Choppy Sand Hills ecological range sites. Coarse textured soils, significant amounts of bare soil and plants uniquely adapted to colonizing the bare soil, are essential factors which maintain the habitat for many species of concern or at risk. Natural recovery facilitates the ecological processes. Seeding can deter these processes and alter the plant community composition.
6. Adjacent land use also affects restoration potential. Remnant native prairie areas in highly fragmented landscapes are of particular concern. Close proximity to transportation corridors or tame pasture seeded to invasive non-native agronomic plants such as crested wheatgrass, Kentucky bluegrass, awnless brome (*Bromus inermis*) or sweet clover can limit restoration potential. Industrial disturbances surrounded by localized areas invaded by weeds and non-native invasive plants, can also limit restoration potential.
7. The range health of the rangeland plant communities surrounding the disturbance plays an important role in restoration potential.
8. The grazing intensity both long term and present on pastures affected by industrial development must be factored into the restoration potential.

These factors which indicate site sensitivity to development impacts and restoration potential should be used in the ecological risk analysis to determine:

- If avoidance is the best strategy; or
- The most appropriate mitigation to reduce the impact of development through minimal disturbance and best management practices designed to reach the expected outcome of restoration over time.

Figure 9 - Drier is Better

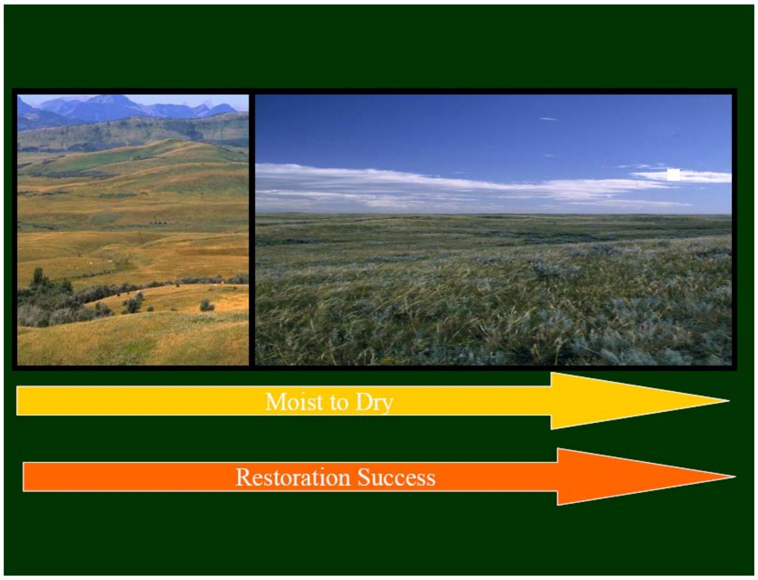

Image Courtesy of Barry Adams, ESRD Rangeland Management Branch

4 PROMOTING NATIVE PLANT COMMUNITY SUCCESSION

4.1 Reflecting on Past History

Prior to the European settlement of the Canadian prairies, a number of key ecosystem processes shaped the native prairie landscape, (Bradley and Wallis 1996). Chief among these were recurring drought, grazing and fire. These naturally occurring ecosystem processes were in balance, each providing a specific function that maintained a cycle of adaptation and renewal within the system over time.

Human development activity since the early 1900's has resulted in increased levels of surface soil disturbance due to cultivation for agricultural crop production. Cultivation was not a feature of the natural system.

Following the extensive cultivation and abandonment of prairie landscapes, Canadian plant ecologist Robert Coupland observed recovery of native plant communities in approximately 20 years depending on the size of the cultivated area, distance to the supply of native seed stock, the degree of aridity of the years following, and duration of tillage (Coupland 1961). However, the recovery of the groundcover structural layer composed of moss and lichen in the Dry Mixedgrass and Mixedgrass appears to take much longer. Large areas of south eastern Alberta, especially in the Special Areas, have recovered to native grasslands, having once been abandoned cultivation during the dustbowl conditions of the 1920s and 1930s.

Photo courtesy of Dennis Milner, Medicine Hat

The history of reclamation in the grasslands of Alberta can be divided into four periods:

Pre- 1972

There was little in the way of policy and regulation. Soil handling was not defined and most disturbances were allowed to recover naturally.

1972 to 1985

Early reclamation practices were developed, the emphasis was placed on soil conservation and seeding with agronomic grasses such as crested wheatgrass to provide reliable vegetative cover to prevent soil erosion.

1985 to 1993

During this period reclamation practices focused on soil handling and erosion control. To facilitate precision in soil handling procedures, the area of surface soil disturbance required for projects drastically increased. This led to fragmentation of native plant communities and increased the risk of aggressive non-native plant invasion.

1993 to the Present

During this period, the importance of the native grassland plant communities' role in ecological function has been recognized. The focus of reclaiming industrial disturbances has shifted towards minimizing the footprint of industrial disturbance and where that is not possible, revegetating disturbed soils with native plant cultivars.[1] However, there are issues associated with the use of native plant cultivars. Some cultivars are more robust in stature than the same species exhibits in the wild, resulting in altered plant community structure. The genetic source of many cultivars originates in climates and ecosystems far from Alberta's Grassland Natural Region. Some cultivars delay the process of succession because they display a competitive advantage over the wild species and are very persistent in the stand.

4.2 Understanding the Process of Succession

Native plant communities are not static, but rather constantly adapting to changes in the local environment over time. The 2010 Grassland Reclamation Criteria recognizes the importance of change over time. This process is referred to as succession. The Range Health Assessment Field Workbook (Adams et al. 2009) provides an overview of the process of succession. The workbook provides "Some Important Ecological Concepts" found on page 14. These concepts include:

- **Plant communities** are mixtures of plant species that interact with one another.
- **Succession** is the gradual replacement of one plant community by another over time.
- **Successional pathways** describe the predictable pathway of change in the plant community as it is subjected to different types and levels of disturbance over time.
- **Primary Succession** is the process of plant community development from bare soil, starting with pioneer species then progressing through the seral stages listed below.
- **Secondary Succession** is the process of plant community development after an established plant community is subject to additional disturbances like fire and grazing.
- **Seral stages** are each step along a successional pathway.
- Seral stages begin at the pioneer stage of **early seral** and progress upward in succession to **mid-seral**, then **late seral** and finally **potential natural community (PNC)** since we use it as the "reference" for comparison.
- **Reference plant community (RPC)** is the term we use for the potential natural plant community since we use it as the "reference" for comparison.
- An **ecological site** is a distinct kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation.

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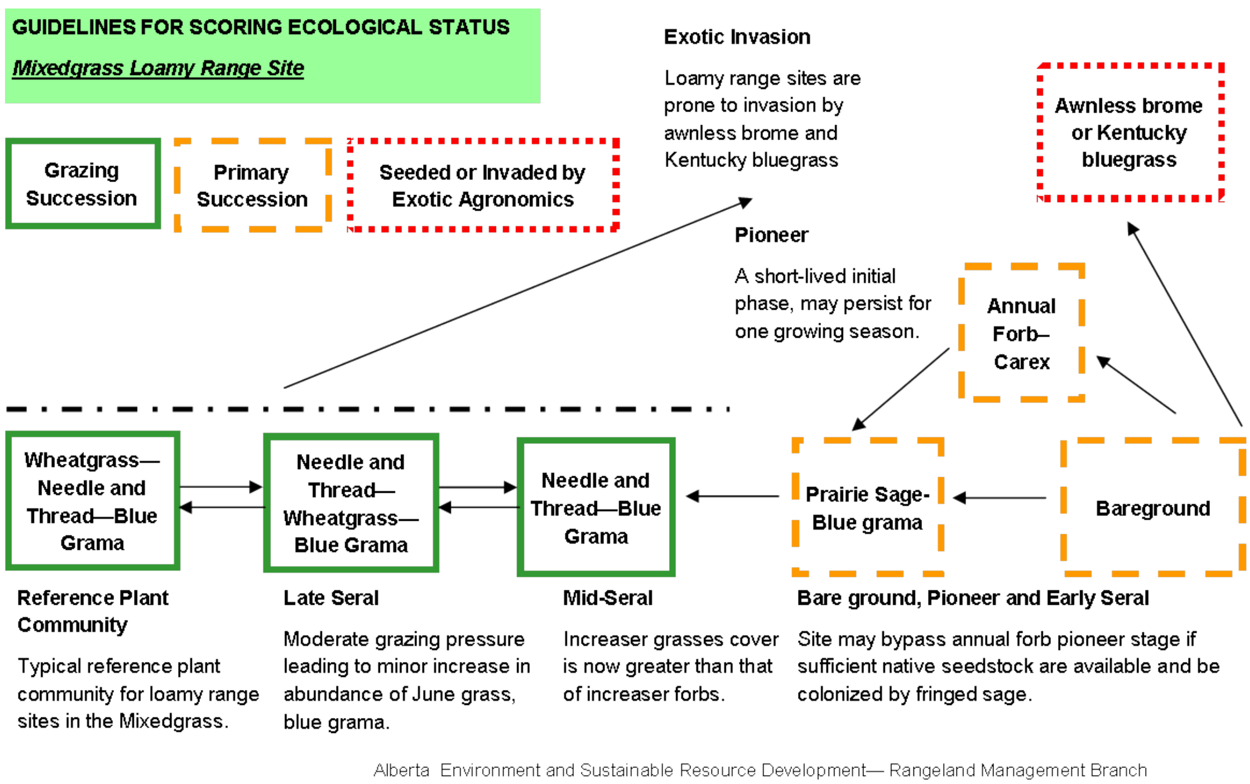
[1] . A cultivar is a plant variety which has undergone genetic restriction through selection by plant breeders, and which has been registered by a certifying agency. Cultivars for several native grasses are available in Canada and have been widely used in the reclamation industry. Examples include: Walsh western wheatgrass, Elbee northern wheatgrass, and Leodorm green needle grass.

- **Ecological status** is the degree of similarity between the present plant community and the reference plant community. Plant communities are **modified** when the disturbance has altered them to non-native species (like awnless brome, timothy (*Phleum pretense*) or Kentucky bluegrass) with a composition of greater than 70% non-native species. Note: The relatively high threshold composition of 70% non-native to define a modified community was selected as our general scientific knowledge of plant community recovery is still quite limited and further study is necessary to better establish a hard tipping point towards a permanent shift of the plant community to a none native state.

Figure 10 is an example of a successional pathway diagram that serves to capture our understanding of how plant communities respond to disturbance based on current knowledge. The green boxes highlight the portion of grassland succession that we currently know the most about, namely the impact that light, moderate and heavy grazing have on the plant communities. The brown boxes illustrate the area of current and future emphasis to better understand the pathway of plant community succession from bare soil and the red boxes illustrate dramatic changes that may occur when invasive species subvert the path of recovery. We know much less about these dimensions of plant succession with reduced confidence in predicting outcomes. None the less, this successional tool provides a foundation for capturing and sharing key learnings and for using this knowledge to improve our development practices.

Figure 10 – Guidelines for Scoring Ecological Status



It is important to note that the pioneer, early and mid-seral stages in Figure 10 can contain non-targeted species that still function for erosion control and moisture retention such as Russian thistle or fringed sage. They stabilize the soils and help facilitate the process of succession over time.

4.3 Industrial Disturbance and the Process of Plant Community Succession

Appendix B includes case studies summarized from long term monitoring projects undertaken by this project team to gather native plant community recovery data and subsequent learnings relevant to the preparation of this manual. The reports are entitled "*Long Term Recovery of Native Prairie from Industrial Disturbance, Express Pipeline Revegetation Monitoring Project 2010" (Kestrel Research Inc. and Gramineae Services Ltd. 2011), "Long Term Revegetation Success of Industry Reclamation Techniques for Native Mixedgrass Prairie" (*Lancaster et al. 2012) and *Natural Recovery on Minimal Disturbance Well Sites in the Mixedgrass NSR – 2012 Monitoring (* Appendix B Case Studies*).* The purpose of these case studies is to provide industry and the Government of Alberta with much needed data on the long term revegetation success of reclamation techniques used in native prairie. The case studies present data, discussion and recommendations relevant to the Mixedgrass (Appendix B Case Studies). A species list has been included as Appendix F. The complete reports are posted in the Information Portal on the Foothills Restoration Forum website at http://www.foothillsrestorationforum.ca.

A key learning from the interpretation of the Express case study data was the definition of successional phases of the recovering plant communities following pipeline construction. Table 2 provides these definitions from bare ground resulting from soil profile disturbance associated with construction practices such as topsoil stripping, grading and trenching. **Annual forb species often referred to as nuisance weeds such as kochia (*Kochia scoparia*), Russian thistle (*Salsola kali*) and the goosefoots (*Chenopodium spp*.) play an important role in site stabilization and moisture retention in the pioneer stage. The role these pioneer species play in the continuum of succession may not be recognized by landowners and reclamation practitioners. Nor is the time frame required for the process of succession to take place. Patience is required to reach the restoration outcome.**

Patience is required to reach the restoration outcome

Table 2 – Definitions of Successional Phases of Recovering Plant Communities

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

* Invasive non-native plants that are known to replace native species and establish permanent dominance in grassland communities include crested wheatgrass, Kentucky bluegrass, awnless brome and sheep fescue (*Festuca ovina*) in the Mixedgrass NSR.

5 PREPARING THE PATHWAY

5.1 Planning to Reduce Disturbance

Pre-disturbance planning is the first step in identifying the footprint of industrial development in native grassland ecosystems. It provides the opportunity to avoid disturbance to native grasslands by locating development on cultivation and previously disturbed lands dominated by non-native vegetation cover. Alberta Energy and Utilities Board, Information Letter IL 2002-1 (ERCB IL2002-1); *Principles for Minimizing Surface Disturbance In Native Prairie and Parkland Areas* alerts and directs industry regarding the importance of avoiding disturbance in native prairie, and the need to minimize disturbance should avoidance not be possible. The principles apply to all industrial activity in native prairie. Guidelines have been developed for petroleum industry activity (Native Prairie Working Group 2002) and have been implemented widely and successfully by the industry. Other industries are encouraged to develop industry specific guidelines.

5.1.1 Pre-Disturbance Site Assessment

Pre-disturbance site assessment is the decision-making process that enables productive and cost effective development planning. In the Mixedgrass, this sequential process is key in determining the location of the proposed industrial site and associated facilities with the least amount of impact to native grasslands.

Guidelines for pre-disturbance site assessment include:

Initial project notification: Engage qualified environmental professionals with experience in native grassland ecosystems and the challenges faced for industrial development. Determine the size and scope of the project, including the infrastructure necessary for full development.

Delineate local study area boundaries on the most recent air photo or fine scale satellite imagery available. This is the area surrounding the proposed target(s) that will be directly affected by development activity. The area should be large enough to include the maximum allowable movement of the proposed target(s) on the landscape. Conduct land titles searches and Surface Land Searches (available through Government of Alberta agencies) to determine if any instruments, protective notations, or conservation easements are in place.

If public lands are involved, the ESRD Enhanced Approval Process (EAP) will apply[2]. Consult the Enhanced Approval Manual available online and use the Landscape Analysis Tool (LAT) to determine landscape sensitivities and base features associated with the proposed project (http://www.srd.alberta.ca/formsOnlineServices/EnhancedApprovalProcess/Default.aspx). LAT provides linkage between landscape sensitivities, the proposed location and activity, and the applicable sensitivity section approval standards and operating conditions. The search may indicate Protective Notations (PNT) which alert industry to specific sensitivities where additional conditions and a non-routine application will apply.

Consult regional and municipal planning documents. Conduct a search for Environmentally Significant Areas, using the Provincial Update 2009 version available on the web. Map all possible constraints.

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[2] At the time of preparing this document, the Government of Alberta is in transition to a new, single regulator known as the Alberta Energy Regulator. Once operational, this change in regulatory jurisdiction and responsibility will be reflected in a future draft.

Map the proposed development target area using standard cartographic coordinates. Map a maximum spatial adjustment buffer around the target(s). The buffer will provide the area on the landscape within which the target(s) can be moved and still remain effective.

Overlay the GVI data layer for the area on photographic imagery. The GVI attribute table which accompanies the data layer provides a coarse filter of biophysical, anthropogenic and land use features mapped as a series of polygons, lines, and points. Map existing anthropogenic features too small to be included in the GVI data layer, including well sites and flow lines.

Are anthropogenic features available within the target zones? If so, is shared use of the landscape feature possible? For example is moving a well site to cultivated lands, or shared access agreements for roads and trails possible?

Adjust target(s) to minimize footprint in undeveloped GVI site types (i.e. undisturbed and more or less intact native plant communities)

Map current documented ACIMS, FWMIS data, and Historic Resource Values. Consult the "*Recommended Land Use Guidelines for Protection of Selected Wildlife Species and Habitat within Grassland and Parkland Natural Regions of Alberta*" to determine any setback requirements for species at risk wildlife (Fish and Wildlife Division, Sustainable Resource Development, 2011). Highlight areas with potential habitat for Species at Risk.

Use GVI attribute table, and Range Plant Community Guide to flag GVI site types sensitive to disturbance. Consult and incorporate soils information from AGRASID and regional soils maps where available. Implement desktop survey of groundwater resources.

Identify potential construction issues and explore possible options. Contour or digital elevation mapping is very useful at this stage.

Adjust target(s) to avoid or minimize disturbance where possible. Adjust to the defined outcome expectation of restoration that aligns with the 2010 Grassland Reclamation Criteria.

Notify and consult landowners/lease holders: Local knowledge and experience can be very important at this point in the planning process. Landowner/lease holder concerns can be addressed and incorporated into the development plan at this stage.

Legal survey: Implementing the legal survey at this point in the planning process reduces the potential cost of multiple surveys by providing the opportunity to avoid sensitive environmental features through desktop analysis, and incorporating landowner concerns through the consultation process.

Conduct field verification of GVI site types, wildlife surveys, rare plant and plant community surveys and Historic Resource clearance. Determine the scope of the field verification to the size, type of development, landscape sensitivity and the timeframe when development takes place. Specific timeframes for wildlife and vegetation assessments will apply. In the Mixedgrass, a general timeframe for field work is May 15 to September 15. Document plant community types and dominant species to establish restoration goals. Establish a baseline for ground water monitoring if required.

Final adjustment to the legal survey based on field verification, environmental studies, construction constraints and continued landowner consultation.

Conduct Range Health Assessment and field characterization of soils within project footprint. Establish off site controls for comparison. Document local area weed and invasive plant concerns.

Reduce landscape impacts through reduced impact best management practices. Consider new development practices technologies that reduce the impact to soils, landscape, vegetation, water and wildlife resources.

Prepare clearly defined reduced impact construction plans and reclamation practices, with expected restoration strategies and outcomes. Prepare a detailed and site specific environmental protection plan (EPP).

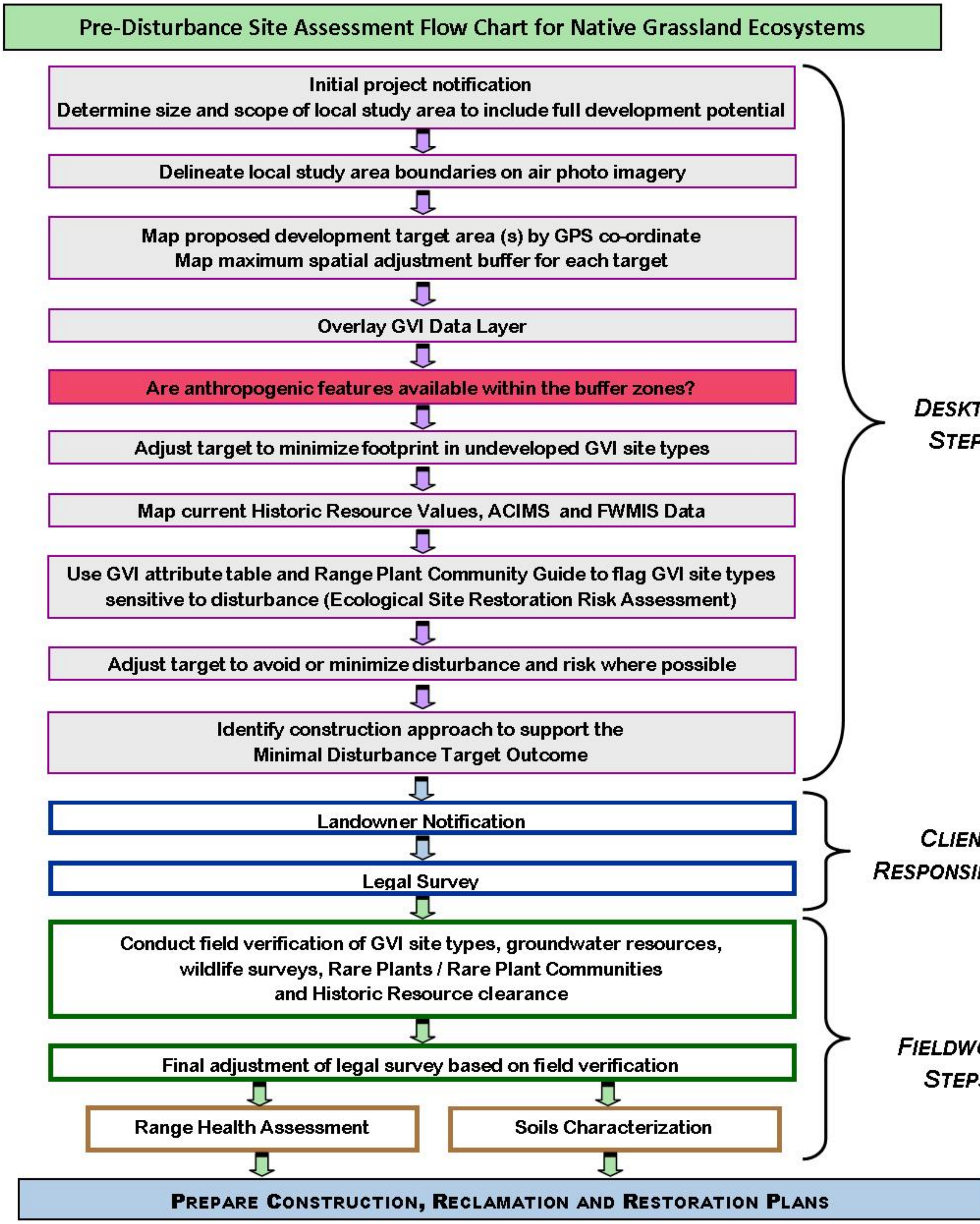
Ensure the EPP, with construction, reclamation and restoration plans are incorporated into contract documents. Where appropriate to the development type and construction plan include interim restoration planning to reduce the disturbance and bridge the gap between the operations phase and decommissioning.

Engage informed and experienced contractors committed to meeting the expected outcome of native prairie restoration.

Monitor to ensure contractual compliance.

Sidebar: Communicates a progressive message to analyze, adapt and improve practices.

Figure 11 - Pre-Disturbance Site Assessment Flowchart for Native Grassland Ecosystems



5.1.2 Incorporating Local Knowledge

Industrial development activity proposed in native prairie is often controversial within landowner, First Nations and environmental stakeholder groups who value the prairie landscape. Early notification and transparent communication with stakeholder groups is an essential component of pre-development planning.

The importance of local knowledge should never be underestimated and Use Respect!

5.1.2.1 Notify and Consult with Landowners and/or Lease Holders

When working with landowners or grazing lease holders the following are some concepts that can facilitate the process:

- Communication is extremely important. Ranchers have learned from experience what works and what does not work on their land.
- Specific guidelines for notification and consultation are required on public land grazing leases and public lands grazing reserves and are included in the Integrated Standards and Guidelines of the Enhanced Approval Process.
- When consulting private landowners incorporate the specific requests of the landowner within the limits of existing legislation.
- Healthy native grasslands are an important asset to the ranching industry.
- Industry must recognize the importance of water resources to the ranching industry.
- When planning industrial facilities it is important to recognize that sources of industrial noise such as compressor stations do impact cattle distribution within the fenced management unit.
- Allow for settlement of soils over the trench when constructing minimal disturbance pipelines and flowlines. Subsidence over trench line can be a safety concern and a pipe integrity issue if sinkholes develop over time.
- Depending on the type of industrial development and the extent of soil disturbance, the amount of available forage on the ranch may be reduced for many years. The rancher will have to adjust their management plan to compensate for the impact of the development. The recovering disturbance needs to be able to tolerate grazing as soon as possible. The developer needs to understand this and work with the rancher to reduce the impact.
- Climate and the timing of activity need to be considered to determine the time frame for a positive plant community successional trend to be established on the disturbance. Hope for a minimum of five years, but expect seven years or more depending on moisture conditions.
- Confine disturbance to what is absolutely necessary.
- Access control and weed management are two key issues of concern. These issues extend beyond the initial development phase, through the operations phase and to decommissioning and abandonment.
- Reclamation fencing is often left in place well beyond when it is needed for vegetation establishment. The neglected fencing is often not maintained and becomes a liability for the rancher. Fencing must be removed to ensure the site can withstand grazing and to promote the process of plant community succession.

- Once vegetation is established, grazing is an important management tool.
- Concerns were expressed by workshop participants during the consultation process of this project that the Enhanced Approval Process (EAP) lacked sufficient checks and balances to ensure best management practices and minimal disturbance principles and guidelines are implemented during industrial development. There were concerns that the EAP eliminates vital communication with landowners and land managers.
- Maintain that vital communication link through the operations phase. Use respect!

5.1.2.2 Ensure Compliance with Regional Land Use Policy

The Mixedgrass Natural Subregion encompasses a number of federal, provincial and regional policy directives regarding land use. Specific geographic areas where development in native prairie is managed under specific land use policy through legislation include:

- Alberta Environment and Sustainable Resource Development (ESRD) is the ministry that works with the municipalities to ensure land used for specified industrial activities ("specified land"[3]) is reclaimed[4]. ESRD provides guidelines for reclamation and remediation, issues approvals for development activity, and is responsible for remediation and reclamation certification at decommissioning and abandonment.
- Special Areas Board Policy which includes specific requirements of the Environmental Review Program and Policy 06-06 provides specific direction regarding the expected outcome of development activity;
- The Public Lands Act and the ESRD Enhanced Approval Process (EAP) for upstream oil and gas development on public lands, specifically the Integrated Standards and Guidelines. Also any historic terms and conditions specified in the development approval are grandfathered and compliance is required; and
- Indian Oil and Gas Canada is the responsible authority for oil and gas exploration and development on specified First Nations Reserves. Exploration and development planning and activities are federally regulated and must be compliant with the Canadian Environmental Assessment Act.

5.2 Selecting the Recovery Strategy

Selecting the most appropriate recovery strategy for the size and type of disturbance is key to restoration success in the Mixedgrass. Industrial developments evolve in three phases:

1. ***Initial exploration and development activity required to access the resource.*** This can include the detailed planning, consultation and approval process, followed by the construction of the infrastructure required for oil and gas production, wind power development, mines, burrow pits or other related industrial activity. Incorporating the principles for minimizing disturbance to the native prairie ecosystem through detailed project planning with informed construction best practices and procedures are the most important recovery strategies at this phase.

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[3] See Glossary

[4] At the time of preparing this document, the Government of Alberta is in transition to a new, single regulator known as the Alberta Energy Regulator. Once operational, this change in regulatory jurisdiction and responsibility will be reflected in a future draft.

2. ***Production*** which includes the construction of further infrastructure required to bring the product to market. This can include the construction of pipelines, pump stations, compressor stations, transmission lines, battery sites, access and associated infrastructure required to service the production of the resource. Typically this phase can last for many years. The focus should be to reduce the footprint of disturbance and wherever possible to set the stage for the process of recovery at decommissioning and abandonment. Interim reclamation planning for this phase should reduce the footprint of disturbance to the soils and native plant communities by reclaiming infrastructure no longer required, stabilizing and maintaining the integrity of the soils, and promoting the long term recovery of the native plant communities that have been impacted by development activity. Think of it as a maintenance program that sets the pathway to reach the final outcome of ecological site restoration over time.
3. ***Decommissioning and abandonment*** is the final phase when resource production is either not commercially viable, or the development is at the "end of life". It is the process that precedes reclamation and remediation certification on "specified lands."

Figure 12 provides pathways for selecting the appropriate strategy for non-linear sites, including sites with reduced soil disturbance (for example less than 25% of the leased area for a single production site). This guideline generally refers to shallow gas wells and associated infrastructure where much of the development activity takes place on unstripped soils.

Sites with significant soil disturbance encompassing more than 25% of the lease area (for example more than $36m^2$ within a lease area of 120 by 120 meters) refers to oil wells, oil production batteries, decommissioned sour gas wells, contaminated wellsites where soil remediation has taken place or topsoil has been imported, fully stripped wellsites, decommissioned compressor or pumping stations and reclaimed access roads. Other industrial sites such as mines, burrow pits, and turbine sites on wind farms fall into this category.

The shape of the soil disturbance and the edge to disturbance area ratio are important factors in determining the appropriate recovery pathways and strategies. For example, in the Mixedgrass natural recovery will be more successful on soil disturbances that are located in close proximity to and/or surrounded by undisturbed native grassland. Figure 13 provides guidance for linear disturbances with significant soil disturbance. Examples are large diameter pipelines that have been stripped full width and graded, strip mines, and graded access roads.

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

Recovery strategies include: natural recovery, assisted natural recovery and the use of native seed mixes.

5.2.1 Natural Recovery

Natural recovery is defined as the "long term re-establishment of diverse native ecosystems by the establishment in the short term of early successional species. This involves revegetation from soil seedbank and/or natural encroachment" (Alberta Environment 2010). Natural recovery is linked to minimal disturbance industrial development procedures which minimize the disturbance to the soils and native vegetation. Examples include: minimal disturbance shallow gas wells that are drilled and operated with the native sod and soils intact except for a small area at well centre, and pipeline construction where the only soil disturbance is over the trenchline**.** In rough fescue-dominated areas in the Mixedgrass NSR, it is important to retain sod, as deep-rooted plains rough fescue will not tolerate soil stripping (Desserud 2013).

The pre-disturbance native vegetation recovers from the procedure providing the rangeland is healthy, the impact is short term, and development is conducted under dry or frozen ground conditions. This is the most important mitigation principle when implementing minimal disturbance and relying on natural recovery as the recovery strategy to promote restoration over time.

The pre-disturbance native vegetation recovers from the procedure providing the rangeland is healthy, the impact is short term, and development is conducted under dry or frozen ground conditions.

Natural recovery relies on the native seed bank present in the uppermost layer of the topsoil, seed rain from the surrounding undisturbed native plant community, and native plant propogules (rhizomes and crowns) present in the disturbed soil to revegetate areas where soil disturbance has occurred. Examples of soil disturbance include: wellsites or access roads where topsoil stripping and grading has been necessary and pipeline construction where topsoil stripping has occurred.

When considering natural recovery, it is important to conduct an ecological risk assessment to determine the ecological status and range health of the native grassland surrounding the disturbance.

Does the native plant community have the resources to re-establish on the disturbed soils? Many species in the Mixedgrass are uniquely adapted to site conditions. Ecological range sites that are naturally adapted to disturbance like Sands demonstrate better success for natural recovery on large disturbances than Loamy range sites with large disturbances (see Appendix B, Section B.1.3).

Are the key indicator species present with the sufficient vigour and reproductive capability to colonize the site?

Is the landscape fragmented such that sources of invasive species nearby may also colonize the disturbance?

Does the timing and intensity of grazing promote recovery or put it at risk? Clear communication with landowners or grazing lease holders is necessary to understand their grazing management requirements and whether natural recovery is compatible.

The fragmented native prairie landscape in the Mixedgrass presents additional challenges for invasive non-native plant management. It is important to know whether non-native invasive plants are present in the on-site community, or in the surrounding area near the site. In the Mixedgrass, invasive plants such as downy brome (*Bromus tectorum*), Japanese brome (*Bromus japonicus*), awnless brome (*Bromus inermis*), crested wheat grass (*Agropyron cristatum, A. sibiricum*), Kentucky bluegrass (*Poa pratensis*), sweet clover (*Melilotus officinalis*), alsike clover (*Trifolium hybridum*), Canada thistle (*Cirsium arvense*), common dandelion (*Taraxacum officinale*), toad flax (*Linaria spp*.), wormwood absinthe (*Artemesia absinthium*) and leafy spurge (*Euphorbia esula*) are known to invade bare ground and are very difficult to eradicate.

The following key learnings, regarding the use of natural recovery in the Mixedgrass have been summarized from the case studies conducted for this project (included as Appendix B).

Performance of Natural Recovery on Loamy and Limey Ecological Range Sites in the Majorville Upland Ecodistrict

Use of natural recovery as the strategy for narrow linear disturbances on Loamy and Limey ecological range sites in the Majorville Upland resulted in a positive successional trend towards the recovery of the disturbance over the trenchline (Appendix B Case Studies). Range health scores have increased on all trenchline monitoring sites from 2008 to 2011 indicating that the process of infill is occurring. Exposure of bare ground over the trenchline has decreased from 2008 to 2011 and total vegetation has increased within the sample sites.

In the initial years of natural recovery (four growing seasons post-construction) western wheatgrass (*Agropyon smithii*), northern wheatgrass (*Agropyron dasystachyum*), green needle grass (*Stipa viridula*) and sedge species (*Carex spp*.) play an important role in colonizing the bare soil. Pasture sagewort (*Artemesia frigida*) plays an important role in providing initial cover and shade for emerging graminoids.

Over the long term (eleven years post-construction), western and northern wheatgrasses increase in percent cover, stabilizing the soils with their ability to produce a network of rhizomes within the soil. Green needle grass also increases in cover as it is well adapted to disturbance. As the colonizing species provide initial structure over the soil surface, needle-and-thread grass seed rain from the adjacent undisturbed grassland is trapped within the bare soil spaces enabling the uniquely adapted seed to germinate, emerge and increase in cover over time. Pasture sagewort continues to play an important role in the forb component of the plant community but decreases in cover over time. Other disturbance related forbs continue to provide infill and the species composition varies over time depending on available moisture and site conditions in the area surrounding the disturbance.

Performance of Natural Recovery on Large Diameter Pipeline on Loamy Ecological Range Sites in the Cypress Upland Ecodistrict on Express Pipeline

Natural recovery was problematic on the Mixedgrass plains rough fescue natural recovery trial site conducted on Express Pipeline in the Cypress Upland (Appendix B Case Studies). Exposed topsoil remained relatively bare for the first three years, lacking the flush of colonizing annuals typical of Dry Mixedgrass natural recovery trial sites. After 14 years, plains rough fescue is notably absent from the plant community. Although diverse, the plant community does not reflect the proportional cover of species in the reference plant community. There was an increase of undesirable non-native Kentucky bluegrass present in relatively low cover values on the control. This species is able to capitalize on disturbances and expand cover when it is present in undisturbed grasslands. The timing and duration of livestock grazing can also affect the success of natural recovery, particularly in plains rough fescue plant communities. Summer grazing has detrimental effects on seedling survival. This result highlights the additional challenge of re-establishing rough fescue on disturbed topsoils.

Performance of Natural Recovery on Minimal Disturbance Well Sites

Natural recovery is a largely successful strategy for recovery of native Mixedgrass range plant communities on range that has a health score of “healthy” or “healthy with problems” (see Appendix B3). Key observations for 2012 monitoring sites on Blowout range sites in the Sweetgrass Upland after ten years recovery are:

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

For loamy range sites in the Majorville, Lethbridge and Vulcan Plains ecodistricts, the Wheatgrass - Needle-&-Thread (MGA21) range plant community is a reference plant community. Key observations for natural recovery sites with health scores of “healthy” or “healthy with problems” are:

- Sites tend to have comparable numbers or a few more species on disturbance and more native forbs on disturbance than on undisturbed sites;

- Introduced species on disturbance include goat's beard, common dandelion, flixweed and lamb's quarters;
- Invasive species present despite healthy range condition on undisturbed areas include crested wheatgrass, and both crested wheatgrass and Canada thistle on disturbances;
- Dominant natural recovery species are western wheatgrass, needle-and-thread and blue grama (see Appendix 3B).

Factors to consider in the risk assessment for minimal disturbance well sites are the availability of native seed on site related to grazing pressure, erosion risk and the proximity of sources of invasive species.

Site position and location can affect the success of natural recovery. A well site on thin Loamy soils on an upper west-facing slope has experienced topsoil deflation in the five years since construction. The site is moderately grazed and is dominated by exposed crusted soil and annual weeds. This site is downwind of an intensive livestock operation which may also contribute weed seed through wind transport.

A well site in thin Loamy soils on an upper east-facing slope recovered well. This site is on a slight lee slope and surrounded by native prairie in good range health.

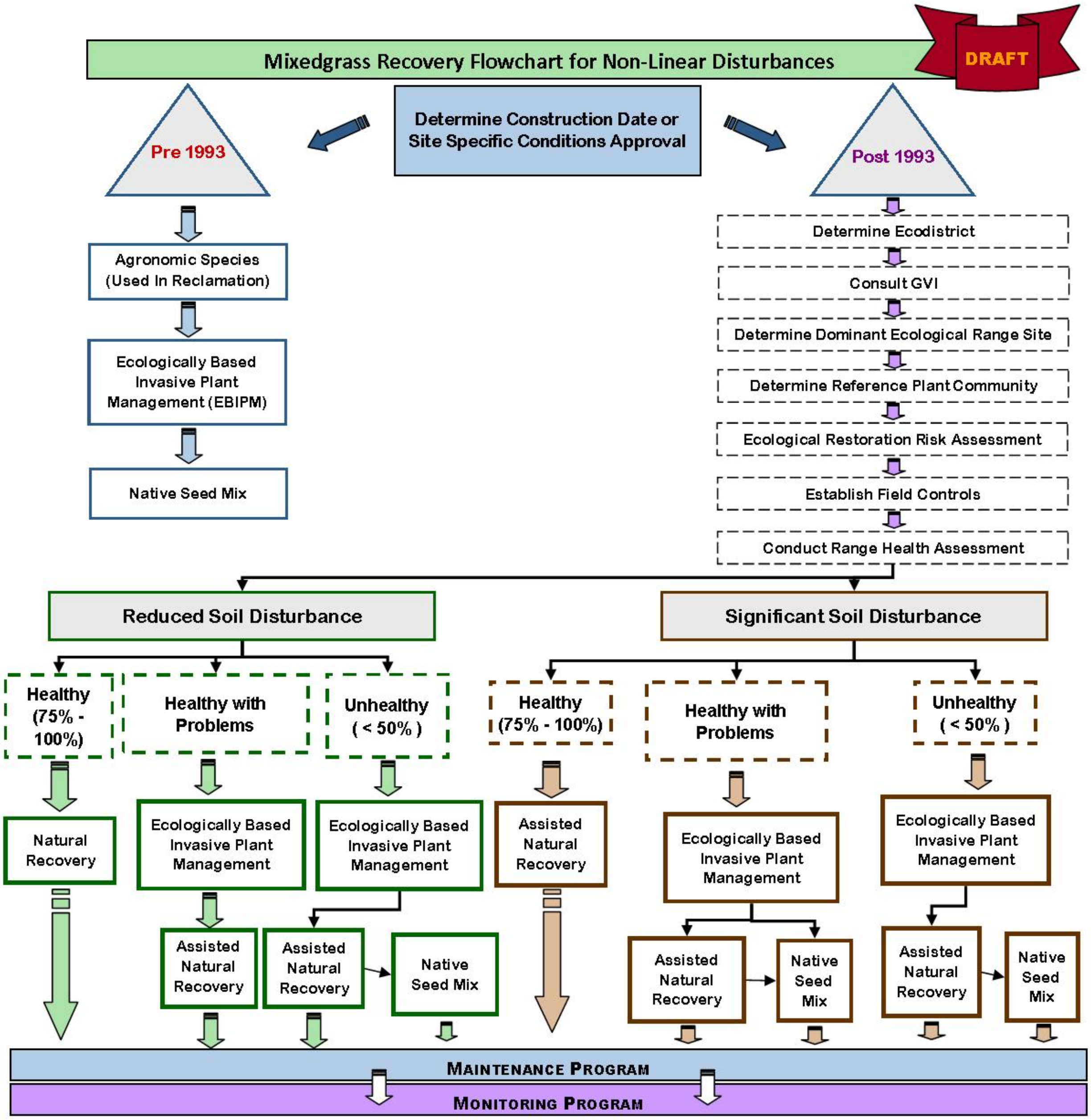
The Timing of Topsoil Stripping and Replacement affects the Success of Natural Recovery

Where soil disturbance is necessary, the timing of topsoil stripping and replacement can have a dramatic effect on the success of this strategy. Soil handling in the fall after the seed set of most species is more successful than at other times of the year. It is important to reduce the timeframe between topsoil stripping and replacement. It is also important not to re-disturb an area left to recover naturally. Ideally topsoil stripping and replacement should occur when the native vegetation is dormant (mid-summer to early winter in the Mixedgrass) and within the same year (Kestrel Research Inc. and Gramineae Services Ltd. 2011).

It is difficult to specify a timeframe for recovery. Depending on the type of disturbance, the native plant community and available moisture during the early years following soil disturbance recovery could take anywhere from 5 to 20 years or more. It is important to recognize the role annual weeds and forbs play in stabilizing the site during the early years of recovery. The timeframe for when indicator species will infill the site is dictated by on-going environmental site conditions. For example, extended periods of drought, salt laden soil, or above average moisture can affect the timeframe for recovery in a negative or positive way.

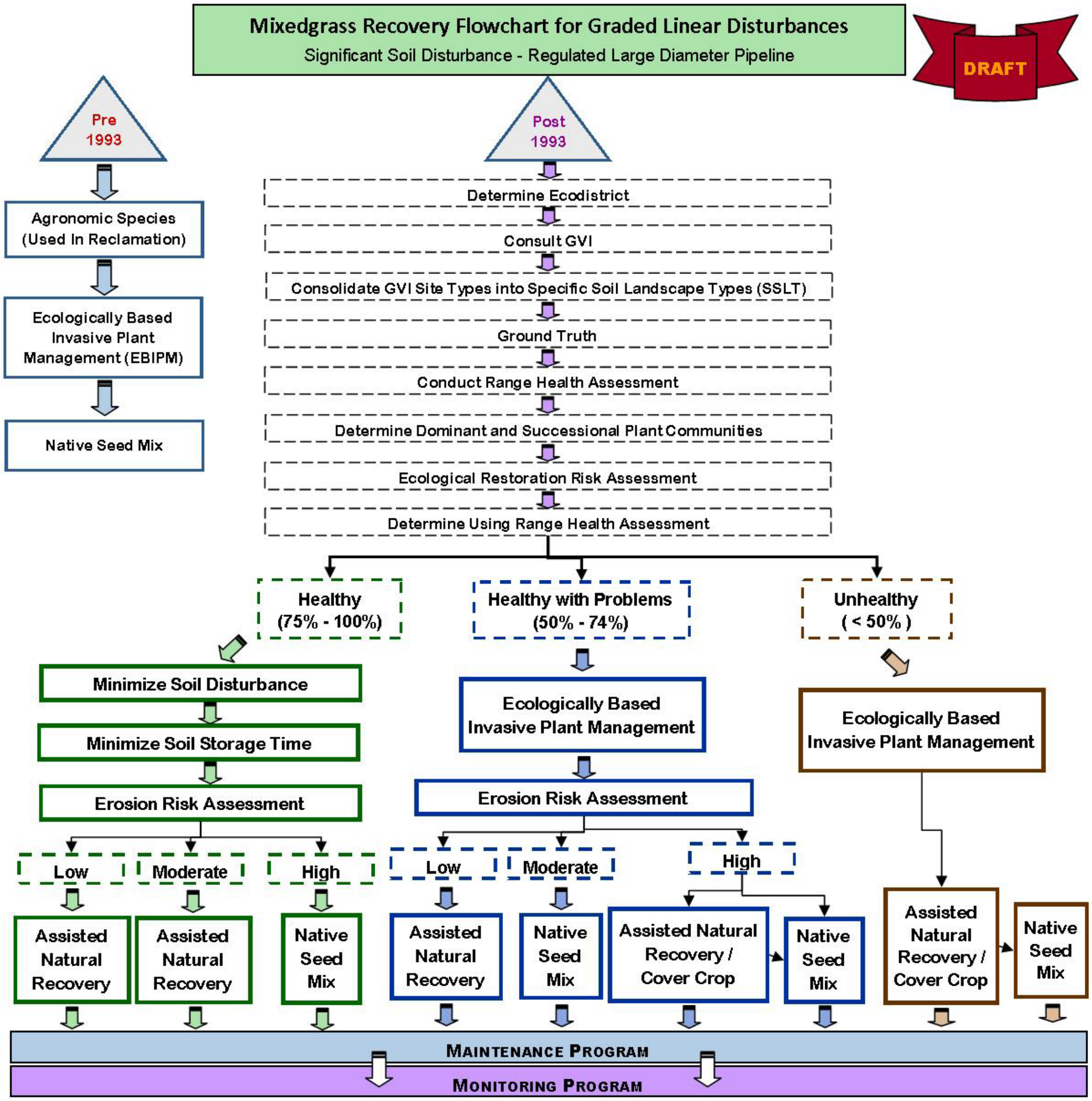
The accompanying flow charts (Figures 12 and 13) for linear and non-linear disturbances provide a pathway for decision making when considering natural recovery, assisted natural recovery and native seed mixes.

Figure 12 - Mixedgrass Recovery Flow Chart for Non-linear Disturbances



Note: Reduced refers to small soil disturbances with a large edge to disturbance ratio. Significant refers to soil disturbances with small edge to disturbance ratio.

Figure 13 - Mixedgrass Recovery Flow Chart for Linear Disturbances



Note: This chart applies to large areas of soil disturbance such as large diameter pipelines, strip mines, and graded access roads. Large diameter pipelines in this context are pipelines where topsoil salvage and grading is required on portions of the right of way due to topographic constraints or for safety requirements. These pipelines are regulated under the Environmental Protection Act and/or by the National Energy Board. They are generally greater than 20 inches in outside diameter.

5.2.2 Assisted Natural Recovery

Assisted natural recovery uses short term additions of materials to a disturbed site to modify site conditions such that they are more favourable for the re-establishment of vegetation from the resources naturally present on the site and in the surrounding area.

Cover Crops

Seeding soil disturbances with annual or short lived perennial species to stabilize erosion prone soils can facilitate the process of revegetation by natural recovery. In the Mixedgrass a combination of fall rye and flax at a light seeding rate (1/2 bushel per acre of each species) was used on a small diameter pipeline in the Cypress Upland (Appendix B Case Studies) and on other industrial disturbances since the late 1990s. Other short lived perennial native cultivars such as Canada wild rye (*Elymus Canadensis*) and slender wheatgrass (*Agropyron trachycaulum*) have been used as well. Applying the seed at low seeding rates is essential (3 to 5 kgs per hectare depending of type of application) and a carrier (polished short grain rice or chick starter has been used) will be required to adequately disperse the seed. It is important to obtain Certificates of Seed Analysis before purchasing the seed and to ensure there is no Prohibited Noxious, Noxious weeds or undesirable invasive agronomic species such as crested wheat grass or sweet clover present in the seed. Retain the Certificates of Seed Analysis on file as they may be required during an environmental audit. Grazing management must be considered when using a cover crop. The combination of fall rye and flax is relatively unpalatable to livestock in pastures with healthy range health condition. Local knowledge and communication with the landowner/grazing lease holder is very important when considering the implementation of this strategy.

Wild Harvested Hay Mulch

Another method of assisted natural recovery involves mowing the native grasses and forbs adjacent to the area to be restored, chopping and spreading the mowed “native mulch” over the bare soil and leaving the site to recover with no additional added seed. To be successful the dominant grass species have to be in the mature seed set stage. Timing is essential to success. In the Mixedgrass NSR, the dominant species may be needle-and-thread, western porcupine grass or plains rough fescue, depending on the area. Note that plains rough fescue does not seed every year so availability for seed harvest is not guaranteed.

The advantage of this method is the potential to increase the amount and diversity of the seed source available to the disturbed soils. As well, the mulch conserves moisture and protects the surface of the soil from erosion. Also the procedure is very site specific as the plant material used is obtained from locally adapted seed within the same ecological range site as the disturbance.

The areas to be harvested must be free of invasive plants. For example, species such as crested wheat grass are prolific seed setters, and only a few plants in the harvest area could result in dominance by this invasive plant (see the Section “Guidelines for Wild Harvest Native Plant Materials” for details). Weather plays a role in successful native hay harvesting. Wind may affect successful cover of the disturbance. The chopped hay mulch is normally sprayed onto the disturbance and with wind, chaff and light-weight seeds could be carried away. The harvest area must be dry as wet grasses cannot be cut properly.

Native hay harvester developed by Ron Johnson (Medicine Hat, AB) and Marshal Gillespie (Finnegan, AB)

Choosing this strategy requires the same pathway for decision making as natural recovery. Rangelands show varying degrees of natural soil stability depending on climate, site, topography and plant cover. Assisted natural recovery may be appropriate where soil disturbance has occurred and there is potential for additional soil erosion based on soil properties and the action of wind and water. Examples include soil disturbances in Choppy Sand Hills or Thin Breaks ecological range sites. The addition of the seeded species does delay the process of natural recovery. However, where erosion is a concern it does provide an option to native seed mixes if suitable native seed is not available.

5.2.3 Use of Native Seed Mixes

Long term monitoring case studies conducted to prepare this manual (Kestrel Research Inc. and Gramineae Services Ltd. 2011; Lancaster, Neville and Hickman 2012) have illustrated the need for change in the way seed mixes are designed for native prairie. The native seed industry needs to evolve if the expected outcome is restoration. In the Mixedgrass, several of the native grass cultivars used in the past are too competitive to allow infill from the surrounding native plant community to occur. A reliable supply of native seed of the dominant species in the Mixedgrass plant communities such as needle-and-thread grass, western porcupine grass and plains rough fescue is essential. This will be achieved by changing the way native seed mixes are designed and develop a reliable supply of the required key native species.

Invasive non-native plant management is a component that must be considered for restoration planning in the fragmented native prairie of the Mixedgrass.

Industry has indicated a need for a standardized method of designing native seed mixes for large industrial disturbances not suited to natural recovery or assisted natural recovery in the Mixedgrass. These disturbances include:

- decommissioned wellsites with significant soil disturbance due to contaminated soils, decommissioned full build out oil or gas well sites, reclaimed access roads, large diameter stripped and graded pipelines, burrow pits and mines;
- large areas of disturbance with erosion and site stability concerns;
- areas of disturbance that require soil stabilization during the production phase (interim reclamation);

- large disturbances in rangeland where the surrounding native plant communities have low scores for plant community integrity and ecological status;
- disturbed sites where the surrounding native plant community does not have sufficient plant material resources to colonize the disturbance; and
- disturbances where seeding is required as part of an Ecologically Based Invasive Plant Management plan (Rangelands SRM 2012).

The native seed industry and supply chain has also requested direction to facilitate growth within the industry in order to meet anticipated demand. Seed mix design methods used in this publication encompass the species list, plant communities and ecological range sites currently described in the Mixedgrass Range Plant Community Guide (Adams et al. 2013). The goal of the guidelines provided for seed mix design is to revegetate disturbances with species that will establish a mid- to late-seral plant community.

The current Range Plant Community Guide for the Mixedgrass (Adams et al. 2013) contains 38 native grassland plant community descriptions, seven modified native plant communities and six native shrubland plant communities. Given the diversity of ecological range sites and successional plant community types that can be encountered within a relatively small area on the prairie landscape, it is necessary to establish which ecological range sites have species in common based on the Agricultural Region of Alberta Soil Information Database (AGRASID) soil and landscape correlation. These groupings of ecological range sites with common dominant native grass species are referred to as **target recovering plant communities** (Appendix C). They are clearly not mature reference native plant communities but rather composed of the dominant native grass species that are drivers in the successional process. The goal of using native seed mixes is to establish the pathway(s) to restore the pre-disturbance plant community. Example native seed mixes are provided for each target recovering plant community. When seeded at the recommended low seeding rates, (8 kilograms per hectare for drill seeding and 15 kilograms per hectare for broadcast seeding), these dominant grass species will provide the vegetative cover to stabilize disturbed soils and facilitate the recovery of the plant community (including the native forb component) over time. Appendix C includes the specifics of the target recovering plant communities and examples of the expected outcome.

Nursery Propagated Native Plant Materials

Nursery propagated native plant materials are used to promote the establishment of tree, shrub, forb, grasses, sedges and rushes on disturbed sites. They are used to establish species that are key components of ecological range sites that are difficult to establish by other strategies, to enhance diversity and infill and to create key habitat features for wildlife and /or rare plants. This strategy requires the engagement of suitably qualified and experienced practitioners and nurserymen to assess the site requirements, prepare the site design, and then collect, propagate, install and maintain the plant material. Plant material harvested for propagation should be sourced from the Mixedgrass NSR, the same ecodistrict and an equivalent ecological range site as the disturbed area to be restored. The plant material must be removed from the nursery and hardened off prior to installation to prevent transplant shock and die-back. A monitoring and adaptive management program is required to maximize the success rate of this recovery strategy. Prairie conditions are harsh for young tender plants.

5.3 Special Consideration for Lentic and Lotic Sites

In most cases, government policy and regulations will strictly limit industrial activities which disturb lotic or lentic wetlands. When disturbance does occur, maintaining the health and function of all classes of water bodies is extremely important in the semi-arid landscapes of the Mixedgrass. Alberta's Wetland Policy provides specific direction regarding development activity near all classes of wetlands. The policy can be found on the web at: http://www.wetlandpolicy.ca/

There are off-set requirements for industrial disturbance near most classes of wetlands and water bodies and it is important that they are adhered to when planning industrial development. Details are provided in the Enhanced Approval Process found online at:
www.srd.alberta.ca/FormsOnlineServices/EnhancedApprovalProcess/Default.aspx

Riparian Plant Communities of Southern Alberta; Detailed Site and Soils Characterization and Interpretation (McNeil, 2008) is an important resource, providing practical information for development and mitigation planning near Lentic and Lotic sites.

When decommissioning existing industrial infrastructure located in or near lentic or lotic sites, it is important to ensure remediation of all contamination issues (both soil and water) according to the current reclamation criteria (Alberta Environment 2011).

When industrial activity within a wetland occurs, as with upland native prairie vegetation communities, avoiding or minimizing disturbance to soil structure, soil layers and surface vegetation is likely to provide the most effective mitigation for wetland communities. Exposed moist wetland soils are vulnerable to colonization by invasive plants.

During reclamation, replacing stripped subsoils and topsoil so that the original wetland contours are recreated is important to restore the hydrological regime of the wetland. This will permit natural circulation of water and redistribution of seed in the basin.

Natural recovery is usually the best restoration strategy for lentic (still water) prairie wetlands. Zonation patterns of wetland vegetation communities occur in response to dynamic seasonal moisture conditions. Prairie wetlands contain large sources of buried viable seed capable of responding to changing environmental conditions including disturbance (summarized in Keddy 2000). Seed is redistributed within wetlands during high water events.

Barriers to restoration of prairie lentic wetlands include:

- Exotic weed invasion, particularly in vulnerable shallow low prairie and wet meadow wetland zones;
- Drought;
- Flooding of seed or seedlings in the wet prairie and sedge meadow zones, which serve as seed sources and can affect recruitment of plants;
- Sedimentation, which can result in eutrophication of the wetland or burial of seed;
- Long-term storage of piled topsoils resulting in seed and propagule mortality.

Response to disturbance can be slower in saline wetlands; where seed densities are much lower (summarized in Keddy 2000). The majority of re-colonization of disturbance occurs through spread of neighbouring rhizomatous species.

For riparian (lotic) wetlands, more intensive reclamation strategies such as the use of erosion control fabric and geotextiles, hydomulching, nursery raised shrub and forb transplants and seedlings and soil bioengineering procedures such as live fachines or live staking may be required to control water erosion and promote restoration.

6 IMPLEMENTNG THE STRATEGY

The findings of the pre-disturbance site assessment and the size and type of disturbance will determine the most appropriate revegetation strategy for the site. Site preparation, timing and using the right equipment are three key elements to successful revegetation whether relying on natural recovery or planting a native seed mix. It is important to recognize that site preparation, soil handling and timing of activities need to be clearly defined for contractors. If native seed is required, begin the process of acquiring the seed well in advance of the time it is required. Large projects requiring large volumes of seed may require "forward contracting" native seed supply companies several years in advance to secure the appropriate native seed in the volumes required.

If native seed is required, begin the process of acquiring the seed well in advance, potentially one or more growing seasons in advance

6.1 Salvaging Native Plant Material Resources

Assessing the pre-disturbance quality and quantity of the topsoil resource is a valuable component of restoration planning. The native seed bank, important for the recovery of native species diversity, is retained in the top 3 to 5 centimetres of soil. To conserve this valuable resource it is important to:

- reduce the amount of area disturbed;
- minimize the soil handling within the area disturbed;
- consider a two lift stripping procedure for areas with deep topsoil resources;
- minimize the timeframe between topsoil stripping and replacement; and
- avoid pulverizing and mixing the soils.

6.2 Site Preparation and Micro-Contouring

The native prairie is not flat. Micro-contouring facilitates seedling survival in the Mixedgrass. Retain the sod as intact as possible during stripping and replacement. Do not harrow to break down the sod and pulverize the soil. Clumps of sod contain live plant material and the native seed bank that can re-establish, providing an important source of infill species and diversity within the recovering plant community. A roughened surface retains more moisture, provides shade and shelter for seedling growth and reduces erosion potential. This is particularly important for natural recovery sites.

6.3 Recommended Timing of Restoration Activities

The Express project illustrated that natural recovery is most successful on sites where the soils were stripped in the late summer and replaced as quickly as possible in the fall of the same year before freeze up. This timeframe also avoids the sensitive breeding and rearing period for wildlife, (early spring to mid-summer) when timing constraints and/or conditions for industrial activity in native prairie may apply. Natural recovery was not as successful when topsoils were stored over winter and replaced in the summer of the following year.

Late fall after the first hard frost or early spring as soon as the soils can be worked is the best time for seeding cool season grasses such as the native wheat grasses, needle-and-thread, western porcupine grass, and plains rough fescue. Warm season grasses should be seeded ideally mid to late June. They need the soil to remain consistently warm for germination and emergence. Seeding is not recommended during the heat of the summer months when moisture is at a deficit.

6.4 Selecting Equipment to Suit the Strategy

Native seed mixes usually contain a combination of large and small seeds which can lead to uneven seed dispersal and bridging in the seeding equipment. One solution to this problem is to have the small seeds blended and bagged separately from the large seeds. Most drill seeders used in reclamation such as the Great Plains, Truax or John Deere are specially designed with two seed boxes to accommodate large and small seeds. Another option is to drill seed the large seeded species and broadcast, harrow and pack the small seeds. This method also facilitates more accurate seeding depth and reduces the competition for moisture between large and small seeded species.

Some seed such as wild harvested needle-and-thread can also contain considerable amounts of inert material from the cleaning and de-awning process. The amount of inert material should be recorded on the Certificate of Seed Analysis. Seed containing unusually high amounts of inert material should be re-cleaned. Prairie Habitats Inc. has more than 20 years of experience in seeding wild harvested seed. Their website illustrates a complete line of wild harvesting and seeding equipment specially designed for restoration projects. http://www.prairiehabitats.com/

6.4.1 Guidelines for the Procurement of Native Seed

For projects that require native seed in the Mixedgrass NSR the following guidelines are recommended:

- For large disturbances such as large diameter pipelines, wind energy projects, mines, burrow pits or large plant sites it is important to plan at least two years in advance in order to ensure an adequate supply of the key species required for the project.
- Order plant material sourced from within the Mixedgrass.
- Ensure the seed lots of each species proposed are tested for purity and germination at an accredited laboratory prior to purchase from the vendor. Testing should be conducted within 12 months of the proposed planting date. Purity testing of large seed species such as the native wheatgrasses, needle-and-thread or western porcupine grass requires a minimum 50 gram sample size, small seed species such as June grass require a minimum sample size of 10 grams.
- It may be necessary to contract a wild harvest of key species such as needle-and-thread grass, western porcupine grass or plains rough fescue to ensure an adequate supply for the project. Reputable and experienced companies are listed on the Foothills Restoration Forum and the Alberta Native Plant Council websites. Specify the ecological range sites from which the material should be harvested (i.e. Blowouts vs Loamy vs Sands and/or Choppy Sandhills). Obtain, review, approve and retain on file Certificates of Seed Analysis for each species harvested.
- When ordering native plant cultivars, order varieties produced specifically for the Mixedgrass by reputable research institutions such as the Alberta Research Council now referred to as Alberta Innovates. Consider forward contracting to ensure an adequate supply of appropriate species.
- Specify source identified seed grown within the Mixedgrass or the Mixedgrass Ecoregion of Saskatchewan. Purchase only from seed suppliers that can provide the necessary quality assurance. Obtain, review, approve and retain on file Certificates of Seed Analysis for each species.
- When ordering seed as well as the common name, include the scientific nomenclature and cultivar/variety or ecovar if applicable.

- There is zero tolerance of seed lots containing Restricted Noxious Weeds, Noxious Weeds such as downy brome (*Bromus tectorum*), Japanese brome (*Bromus japonicus*), and invasive agronomic species such as crested wheatgrass (*Agropyron cristatum*), awnless brome (*Bromus inermus*), or Kentucky bluegrass (*Poa pratensis*) in the Mixedgrass. Seed lots containing quack grass (*Agropyron repens*) or foxtail barley (*Hordeum jubatum*) should also be rejected.
- Be aware that some private landowners and specifically certified organic producers will have specific requirements and specifications for seed mixes and weed control.
- Examples of Certificate of Seed Analysis and an explanation of interpretation is found in Appendix D.3

6.4.2 Guidelines for Wild Harvested Native Plant Material

In order to obtain the plant material for the key dominant species required for restoration projects in the Mixedgrass, the material will have to be obtained through a process known as "wild harvesting". Wild harvesting should only be considered on sites that are in healthy range condition, free of Prohibited Noxious and Noxious weeds and invasive non-native agronomic species such as crested wheatgrass, awnless brome, Kentucky bluegrass and sweet clover.

Methods of obtaining the necessary material include:

1. Use of specially designed equipment that harvests only the seed from the stems of select species such as needle-and-thread, western porcupine grass, June grass, blue grama grass, or plains rough fescue. The target species must be in the mature seed set stage. Care must be taken to ensure the collected seed is allowed to dry and cure following the harvest. The seed is then either spread directly on the area to be restored or sent away to be cleaned and marketed as a single species.
2. Wild harvested seed collection for field propagation and production. This could include field propagation of species such as needle-and-thread similar to the DU Ecovar program or the Alberta Innovates (formerly Alberta Research Council) source identified program for ultimate commercial sale.
3. Seed collection of specific native grasses and forbs for nursery propagation of live plant material. The purpose is to install islands of live plant material that will create a seed source within the disturbed area.
4. A non-selective method is wild harvested hay. Specialized equipment is required. This method collects all species in seed at the time of cutting, and possibly early or prior-year seeds if ground litter is collected. Normally the hay is chopped and applied as mulch to the disturbance the same day it is harvested. The hay mulch is lightly crimped or harrowed and left on the surface.

The products of wild harvesting provide valued goods and services to the landowner or land manager. There may be a cost associated with obtaining wild harvest native plant materials. Negotiations to obtain permission should be conducted well in advance of the timeframe for the harvest.

Guidelines for Wild Harvesting Native Seed

The following guidelines have been established for wild harvesting on Public Lands. It is recommended that these guidelines be implemented when harvesting on private lands. Consult other jurisdictions such as First Nations Band Councils to determine if other guidelines are in place and/or if permits are required.

1. You will be required to obtain written consent from the grazing lease holder for the area that you are planning to carry out your seed harvest.
2. Only healthy range sites will be selected for seed harvest that are free of Prohibited Noxious, Noxious and invasive non-native species such as crested wheatgrass, awnless brome and sweet clover.
3. You must notify the ESRD - Range Agrologist responsible for the selected area to obtain approval for the site. A detailed sketch of the proposed location of the harvest must be provided. A Letter of Authority will be issued by the Range Agrologist to authorize the harvest.
4. Seed harvesting will be done using an alternating strip approach such that only half of the area is harvested.
5. Seed harvesting will not occur on the same site for a period of 7-10 years following the harvest (depending on climate and range health conditions).

Guidelines for Harvesting Native Hay Mulch

Follow the guidelines for Collecting Wild Harvested Seed for site access permissions and site selection. Additional guidelines pertain to native hay cutting.

1. Native harvesters vary from small mowers that cut and collect native hay to larger modified combines. If a mower/collector is used, timing is essential, as dominant grasses must have seeded. Some modified harvesters include a vacuum, which collects surface litter including seeds from earlier in the season or the previous year, in which case timing is less essential.
2. Native grassland should be cut in strips, leaving uncut strips to act as a seed rain source for the cut areas.
3. The amount of native grassland required for harvesting varies with subregions. In drier Mixedgrass NSR areas, where needle-and-thread and blue grama dominate, the harvest area should be approximately 3 times the disturbance area. This includes sufficient area for un-cut strips. In moister rough fescue-dominant areas, roughly 2.5 times the disturbance area may suffice.
4. If the area is grazed, it is recommended grazing be suspended until after harvesting. Ideally, grazing should continue the following year, after the cut areas have had a chance to recover.
5. Native hay mulch harvesting will not occur on the same site for a period of 7-10 years following the harvest (depending on climate and range health conditions).

Wild harvested hay may be cut with a variety of equipment (photos in the Wild Harvested Hay Mulch section).

Finally, wild harvested native plant material is a precious resource. Before you harvest make sure there is a specific need and/or market for the material. Never take more than is required to meet the need and ensure careful handling and storage of the plant material.

7 MAINTAINING THE PATHWAY

Most restoration projects will require a monitoring and adaptive management program for the first five growing seasons. Notice that funds will need to be secured for this program early in the planning phase. The program should incorporate all of the relevant pre-disturbance site assessment information, details of the restoration plan, and documentation of specific issues encountered during the implementation of the plan. This information forms the basis of the program and facilitates the preparation of a work plan and budget.

Most restoration projects will require a monitoring and adaptive management program for the first five growing seasons.

Control of Restricted Noxious and Noxious weeds is required under the Alberta Weed Control Act (Province of Alberta 2010A). Weed and invasive plant management is a specialized area of expertise and requires a Commercial Applicator's licence. Contractors hired should be familiar with the 2010 Reclamation Criteria-Native Grasslands, and the desired long term outcome of native grassland restoration. Control of specific weed species at identified locations is preferred over a wide spectrum or broad application of herbicides. This approach will improve the chances for native forbs to establish and encourage the restoration of the plant community.

On private lands discuss invasive plant management with the landowner. Be aware that certified organic producers will have specific requirements and specifications for weed control.

Quite often there will be a flush of annual weeds and native forb species during the first couple of growing seasons following soil disturbance. This is a normal occurrence and should not cause concern. These species provide the "scab" that promotes the healing process by stabilizing the soil and retaining moisture. Where necessary, mowing annual weeds prior to seed set can reduce the competition for available soil moisture, reduce weed seed set and enhance seedling survival of desired species.

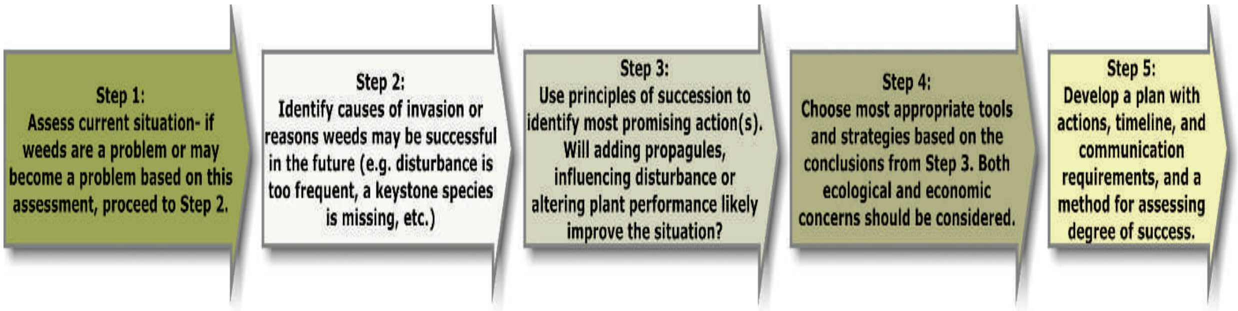
A coordinated, multi-faceted approach to vegetation management is often the most successful and cost effective. Maintaining a database of areas where vegetation management is required and evaluating the success of the control methods implemented are important steps in a successful vegetation management program.

7.1 Ecologically Based Invasive Plant Management (EBIPM)

The December 2012 issue of Rangelands (Volume 34, issue 6) is a special issue dedicated to a weed management system termed Ecologically Based Invasive Plant Management (EBIPM). EBIPM is an approach to rangeland invasive plant management which applies scientific principles and management experiences in a step by step plan (Figure 14).

Figure 14 - The step by step process of EPBIM from Rangelands

(Volume 34, Issue 6) (Svejcar and Boyd 2012)



Prior to applying EBPIM, it is important to understand the history of the area, especially locating and evaluating historical cultivation. Cultivation has been practiced in southern Alberta since the 1880's, with several million cultivated acres in the Mixedgrass NSR being abandoned following the drought and depression of the 1930's. Long term effects of cultivation include soil compaction, reduced native seedbanks, and changes in soil nutrients and fertility, all potential causes of invasive plant succession. Knowing if an area has been cultivated will help identify causes of plant community change and which ecological processes are in need of repair.

Step 1 *Assess the Current Situation*

The Alberta Invasive Plant Council is an important source of information regarding new weeds of concern and methods of control. Their website is located at: http://www.invasiveplants.ab.ca/. The Association of Agricultural Fieldmen located at http://www1.agric.gov.ab.ca can direct you to the Fieldman responsible for your project area. Incorporating their local knowledge of weeds of concern and effective methods of control is very useful in vegetation management planning. Also look south of the border to our neighbours in the United States. The USDA Agricultural Research Service has conducted considerable research in the field of vegetation management. A recent publication entitled *Revegetation Guidelines for the Great Basin: Considering Invasive Weeds* (Sheley and Mangold et al. March 2011) is a valuable source of information relevant to the Mixedgrass NSR of Alberta.

The Noxious Weeds section of the Rangeland Health Assessment, found at http://srd.alberta.ca/LandsForests/GrazingRangeManagement/RangeHealth.aspx, is a useful tool for identifying, not only noxious weeds, but also invasive plants. By applying the Density Distribution guide, you will be able to determine the extent of invasion and start planning the management process.

- Weed Score 2 or 3 – no or light infestation – no control required, or prevention if possible invasion from adjacent areas.
- Weed Score 1 – moderate infestation with some desired plants – control infestation and increase desired species – proceed to Step 2.
- Weed score 0 – heavy infestation without desired species – revegetation or restoration – proceed to Step 2.

Step 2 *Identify Causes of Invasion or Reasons Invasive Plants May Be Successful in the Future*

Treating invasive plants is often really only treating a symptom. Three ecological processes cause changes in plant communities and influence success of desired and invasive plants: site availability, species availability, and species performance.

Site availability is a disturbance that causes a pronounced change in an ecosystem and encourages invasive plants.

- Large-scale disturbances favour establishment of undesirable plants.
- Smaller-scale disturbances spread over time will be less likely to promote growth of invasive plants.
- Legacies of historical cultivation, which can last for decades to centuries, may affect site availability.

Species availability – presence or absence of viable invasive plant propagules brought in by external dispersal or present in the disturbed soil seedbank.

- Disturbances surrounded by native grassland will be less likely to be invaded than those adjacent to areas dominated by invasive plans, e.g. crested wheatgrass.
- Disturbances in areas seeded or infested by invasive species in the past, may have those seeds in the seedbank, some lasting for many years, e.g. Kentucky bluegrass.

Species performance – how well invasive plants grow in disturbed environment conditions.

- Most invasive plants require more fertile or moist soil characteristics than native grasses. For example, awnless brome will thrive close to riparian areas.
- Special attention must be paid to areas that might promote the growth of invasive plants.

Step 3 *Use Principles of Succession to Identify the Most Promising Actions*

When invasive plant performance is controlled through herbicides, biological control, mowing, or other methods, niches are opened in the plant community allowing for native plant succession. Refer to section 4.2 for more information on succession processes. Use Figure 10 to determine the current stage of the invasive plant community.

Step 4 *Choose the Most Appropriate Tools and Strategies Based on the Conclusions from Step 3*

The use of a particular management tool for control of invasive plants often depends on the life cycle of the target invasive plant or plants, as well as the life cycle of the desirable plants within the community.

- Livestock grazing can be one of the most useful tools to keep rangelands in good condition and maintain optimum production. Livestock remove litter, recycle nutrients, stimulate tillering of perennial grasses, and reduce seedbanks of competitive annual plants. Targeted grazing is an effective tool for invasive plant control, especially if managers exploit differences in plant phenologies, for example invasive plants may be more susceptible to grazing when green and when perennial grasses are brown and dormant.
- Applying herbicides is a common strategy to control invasive species, especially for annual weeds, and may require repeated application over a long-term control time.

- Mowing is effective for annual species, if done prior to seed setting. If infestations are low, hand pulling or spot herbicide applications may be effective.

The following invasive plants are found in the Mixedgrass (Table 3). Alberta Agriculture provides information on all registered herbicides for these species http://www.agric.gov.ab.ca/app23/herbsel. The table indicates if grazing is an option.

Table 3– Invasive Plants Found in the Mixedgrass NSR with Grazing Responses

Common Name	Scientific Name	Growth Habit	Grazing Option
Forbs			
absinth	*Artemisia absinthium*	perennial, stems root	Poor – low forage value
clover, alsike	*Trifolium hybridum*	perennial, taproot	Good
clover, sweet	*Melilotus officinalis*	biennial, taproot	Spring grazing
Canada thistle	*Cirsium arvense* (noxious)	perennial, deep rhizomes	Poor – cattle avoidance
dandelion	*Taraxacum officinale*	perennial, taproot	Fair
goats-beard	*Tragopogon dubius*	perennial, taproot	Fair
mayweed, pineapple weed	*Matricaria discoidea*	perennial, rhizomes	Poor – low forage value
leafy spurge	*Euphorbia esula (noxious)*	perennial, deep rhizomes	Poor – toxic to livestock
yellow toadflax	*Linaria vulgaris* (noxious)	perennial, rhizomes	Poor – cattle avoidance
Grasses			
barley, foxtail or wild	*Hordeum jubatum*	perennial, tufted	Poor – cattle avoidance
brome, downy	*Bromus tectorum (noxious)*	annual, tufted	Poor – injurious to cattle
brome, Japanese or chess	*Bromus japonicus (noxious)*	annual, tufted	Poor – injurious to cattle
brome, smooth	*Bromus inermis*	perennial, rhizomes	Good – very palatable
Kentucky bluegrass	*Poa pratensis*	perennial, rhizomes	Good – spring grazing
Russian wild rye	*Elymus junceus*	perennial, tufted, deep root	Good

Step 5 ***Develop a Plan with Actions, Timeline, and Communication Requirements, and a Method for Assessing the Degree of Success***.

An adaptive management cycle using the EBIPM framework is required to successfully manage invasive plants.

- Set measurable goals and objectives with the information obtained in Steps 1 to 4.
- Collect information on the proposed site and treatments on sites with similar climate, soils, and potential plant community to allow treatment alternatives design.
- Develop the adaptive management plan, defining the scale of the treatments, replication of sampling, study plot sizes, proper location of control areas, and protocols for data collection.
- Seek stakeholder input and incorporate stakeholder concerns.
- Adjust the plan to incorporate stakeholder comments. Widespread support for a management plan is key to its success.

- Implement the management plan, including a long-term perspective. The plan should be conducted for several years to be successful.
- Collect and analyse monitoring data, rigorously on a regular basis for several years.
- Draw conclusions and update the plan.

These steps should be repeated with each cycle, ultimately improving management.

7.2 Grazing Management

Native grasslands have evolved in association with grazing animals. Today, fences contain and restrict grazing animals and this factor must be considered in restoration planning. Consider the following guidelines:

- Early consultation with the landowner or lease holder is important. Grazing management plans implemented to enhance recovery of industrial disturbances should incorporate local knowledge, be designed in consensus with the rancher and be well documented regarding the responsibilities of both parties, including who is responsible for removing fencing.
- Use the Range Health Assessment protocol and consultation with land manager to determine when temporary fencing might be appropriate. Restoration sites located in fields with unhealthy range health scores will require temporary fencing.
- Interim reclamation sites where topsoil resources have been stripped and stored may require fencing until vegetation is re-established. Once established the fencing should be removed.
- Industrial soil disturbances located in pastures rated as "healthy with problems" may require temporary fencing depending on which factors are affecting the range health scores. Also the timing and duration of grazing will need to be factored into the decision.
- The size and type of disturbance also determines the requirement for fencing. For example, reclaimed wellsites with more than 25% disturbance may require fencing. This will allow seeded areas at least one growing season for seed to germinate and establish a root system before grazing is allowed. If possible allow the newly established plants a second year to set seed (usually by mid-summer) prior to removing the fence. This recommendation will result in livestock trampling a portion of the seed into the upper soil surface to further enhance infilling.
- Fencing can also restrict the movement and distribution of livestock and wildlife within the pasture surrounding the industrial development. Ensuring access to water is a primary concern. The physical presence of the fence may take quite a while for the animals to get used to particularly when used on large diameter pipeline rights of way. Additional disturbance to the soils adjacent to the fencing has been observed as the animals try and find a way around the fencing. Salt and minerals can be used to lure animals away from the fencing and alter dispersal patterns.
- Ensure the temporary fencing is monitored and maintained. Maintenance is not the landowner's responsibility. Budget for maintenance.
- Ensure temporary fencing is removed when the plant community has reached the target and litter is at optimum rates for the Mixedgrass (figure 7, page 36 of the Range Health Assessment Field Workbook); (Adams et al. 2009). Fencing can have a negative effect on recovery if left in place too long. An excessive build-up of litter on the soil alters moisture conditions which can negatively influence the process of plant community succession. Make certain there are adequate funds allocated for fence removal.

7.3 Monitoring Recovery

Reclaimed sites that are not monitored or managed can quickly deteriorate resulting in costly measures required to mitigate problems. Establishing a standardized method of monitoring industrial restoration projects and evaluating restoration success is required to allow us to communicate progress to stakeholders with increased confidence. Standardized methods will also assist in defining areas where improvement in the methods and strategies used are required. Monitoring should be approached with an adaptive management plan, incorporating goals for expected recovery with recurring monitoring. The following adaptive management plan guide is adapted from what Sheley et al. (2009) described in the December 2012 issue of Rangelands.

7.3.1 Set Measurable Goals and Objectives

- The goal for restoration of native rangelands is to re-establish mature native plant communities on a disturbance that are suited to the ecological range site and equivalent in composition, structure and successional stage to the surrounding native grassland. The process of recovery evolves over time through initial establishment through several successional stages as ecosystem processes re-develop and species composition and structure matures (Kestrel Research Inc. and Gramineae Services Ltd. 2011).
- The 2010 Reclamation Criteria for Wellsites and Associated Facilities for Native Grassland (Alberta Environment 2011) provide both established methods that can be used as a baseline for monitoring and targets for defining successful recovery.
- Collect information for the reclamation site such as climate, soils, and the potential plant community to help establish recovery targets and timeframes.
    - Refer to the Mixedgrass Natural Subregion Range Plant Community Guide (Adams et al. 2013) to determine what the potential plant communities might be. http://srd.alberta.ca/LandsForests/GrazingRangeManagement/RangePlantCommunityGuidesStockingRates.aspx
    - Alberta climate information is available at AgroClimatic Information Service (ACIS), providing historical Alberta Climate Maps and Alberta Weather Station Data and Graphs. You should be able to find weather stations in the vicinity of your sites. Tracking precipitation and temperature for the duration of monitoring will provide important information about potential and actual recovery success. http://agriculture.alberta.ca/acis/
- The timeframe for recovery will vary depending on the size of the disturbance, recovery strategy used and site specific conditions of the ecological range site where disturbance has occurred (climate, presence of invasive species, grazing pressure and range health). For example, if the surrounding area has a low range health score, the proposed site has a sensitive species such as rough fescue, or it is located in a moist/loamy range site, recovery may be slow. Patience is required to allow natural successional processes to take place.

7.3.2 Establish a Monitoring and Adaptive Management Plan

Establishing Permanent Monitoring Sites

- Key to the reclamation criteria is establishing permanent monitoring sites that compare the recovering disturbed site with adjacent undisturbed control sites. Information collected over time from these sites can be used to adjust treatments, as required.
- Define replication of sampling, study plot sizes, proper location of control areas, and protocols for data collection.

- Establish the survey locations on lease and access and corresponding control points early in the establishment phase to assist the process of reclamation certification. Establish permanent photo reference points to capture the progress of restoration over time.
- Establish survey locations on pipelines to monitor the progress of restoration over time. Ensure that monitoring will include the diversity of different recovery strategies used for soil disturbances.
- Establish the frequency of monitoring events to allow timely and effective adaptive management and to track the process of succession towards the Target Recovering Plant Community over time.

Seek Stakeholder Input and Incorporate Stakeholder Concerns

- Stakeholders may include provincial land managers, ranchers, and NGO representatives.
- Adjust the plan to incorporate stakeholder comments. Widespread support for a management plan is key to its success.
- Education of stakeholders may be required, especially to establish reasonable expectations regarding the expected timeframe of recovery.
- Communication with land managers and ranchers is paramount. Techniques such as timing of development activity, fencing and grazing rotation can be utilized to facilitate reclamation.

Collect and Analyse Monitoring Data

Assessing Recovery

The timeframe for recovery will vary depending on the size and age of the disturbance, the recovery strategy used and the site specific conditions of the ecological range site where disturbance has occurred (climate, presence of invasive species, grazing pressure and range health). Patience is required to allow natural successional processes to take place.

- The timeframe for recovery of key indicator species is variable and dependent on a number of interrelated factors. If plains rough fescue, a late seral species, is part of the target plant community, be aware that it is slow growing and susceptible to competition from faster growing species. It may require three to five years for seedlings to become established. Western porcupine grass may not appear until the early to mid-seral successional stage (Kestrel Research Inc. and Gramineae Services Ltd. 2011), but once germinated, it establishes quickly.
- It is not possible to estimate an accurate timeframe at this time. Drier areas of the Mixedgrass, dominated by needle-and-thread and blue grama, may recover similarly to the Dry Mixedgrass NSR. Observations made on Express pipeline indicate that in the Dry Mixedgrass a minimum of 3 years is required to establish a pioneer community on both seeded and unseeded sites. Recovery to a mid-seral plant community was as little as 3 and up to 14 years (Kestrel Research Inc. and Gramineae Services Ltd. 2011).
- Moister areas, such as those dominated by plains rough fescue, may recover more slowly. Assessments of pipelines in the Cypress Hills, Lancaster et al. (2012) concluded recovery to a late seral plant community required 10 to 12 years for relatively narrow, short term disturbances.

General Monitoring Guidelines

- The 2010 Reclamation Criteria for Wellsites and Associated Facilities for Native Grassland (Alberta Environment 2011) describe how to partition the disturbance for assessment, based on the disturbance size.

- Site visits should be targeted to efficiently gather the information needed to support an adaptive management plan. For example the number of site visits during the first two growing seasons may depend on the invasive non-native plant risk factor.
- Completing Rangeland Health Assessments at the established off site controls and onsite monitoring sites, using the standardized methods developed by ESRD, can determine if the disturbed site is on a positive successional pathway.

Monitoring in Years 1-3

- In the first years when seedlings are tiny, determining percent foliar cover of each species is not that important. Instead assess species composition and how it changes over time.
- Delineate a ¼ m^2 and count the young plants. Do this 10 times over the assessment area and average the count. Compare the plants to your seed mix. Low counts may require re-seeding (Hecker and Neufeld 2006). However, bare ground is normal in the first three years, allowing infill of native species from surrounding undisturbed areas.
- Perform Range Health Assessments within the first three growing seasons to identify possible problems on the disturbance that require remedial reclamation such as weed or non-native species issues (see EBIPM Section), soils or erosion issues.

Adaptive Management in Years 1-3

- Fencing to prevent grazing may be used in the first one to three years to allow plant germination and establishment (see section 7.2 Grazing Management).
- A flush of annual weeds and native forb species during the first couple of growing seasons following soil disturbance is normal. These species provide microclimate niches for small grasses, such as June grass, which may be sheltered by annual weeds until they become established. Spraying these so-called weedy species and re-seeding the site may promote aggressive colonizers and reduce the potential for native species infill. If infestations of annual weeds are heavy, mowing before seed set can be used to reduce competition while retaining the erosion mitigation they provide.
- Noxious weeds must be removed, by hand-picking or herbicide application (see EBIPM Section).
- The longer the problems are allowed to go unattended the more difficult and costly it will be to achieve successful restoration.

Monitoring after Year 3

- Later as vegetation becomes established (years three and later) estimating the foliar cover that each species contributes to the plant community, and estimating the amount of bare soil becomes important as the recovering plant community matures.
- Delineate a ¼ m^2 area in a representative part of the restoration and estimate how much ground is being covered by the vegetative canopy. Identify which species were seeded, to judge the success of the seed mix. For accurate results, sample ten replicate frames for an average (Hecker and Neufeld 2006). For sites with high species diversity, building a species area curve will determine how many frames are sufficient to document the number of species on a site.
- Check vertical structure and plant layers, e.g. are there short, mid, and tall plants, bunch type plants and mat-like plants, and compare this to the expected plant community. This procedure is part of the range health assessment, which should be done at each monitoring site, both on the disturbance and the reference area.

Adaptive Management after Year 3

- Litter may start to build up, especially if the area has been fenced. If necessary, mow or rake the litter and haul away grass thatch to simulate grazing and open up bare ground for grass seedlings to emerge and infill to occur.
- If most species are well established, remove fences and allow controlled grazing.
- Noxious weeds must be removed, by hand-picking or herbicide application (see EBIPM Section).

Draw Conclusions and Update the Plan

- The above monitoring and adaptive management steps should be repeated with each monitoring cycle, ultimately improving management.
- Document the monitoring and maintenance program. Share successes and failures with colleagues through organizations such as the Canada Land Reclamation Association and the Foothills Restoration Forum.

The 2010 Reclamation Criteria – Native Grasslands shifts the focus from reclamation to restoration. As wellsites and associated facilities are assessed with the criteria our knowledge of the most successful recovery strategies on a site specific basis will increase.

8 THE IMPORTANCE OF LONG-TERM MONITORING

If we are to conserve what remains of our native prairie for future generations, then we must continue to improve our recovery practices in native prairie landscapes. In the past, equivalent land capability focused on salvaging soil. Today, equivalent land capability includes restoration of native plant communities in native rangeland. Our focus must shift from reclamation to restoration.

Time is an important factor in the process of recovery from industrial disturbance in native grasslands. Extended timeframe monitoring using standardized methods of evaluation provides the opportunity to reflect on construction and reclamation procedures used in the past and make informed choices that will improve future restoration potential. Time is required to meet our restoration goals.

The results of the Express monitoring project 14 years after construction indicate that significant changes in the composition of recovering plant communities may occur after the first five years of reclamation both in positive and negative directions. There is very little information available on the long term efficacy of various native grassland reclamation and recovery techniques in the Natural Subregions of Alberta. Additional data is required to fully understand native plant community successional pathways following industrial disturbance in the long term. Long term monitoring is needed to contribute to our understanding of whether restoration of native vegetation communities is possible, and if so, in what situations and over what timeframe. It is necessary to continue to develop best management practices and appropriate revegetation strategies for industrial disturbances in native prairie to promote industry stewardship on increasingly pressured prairie landscapes.

9 FUTURE RESEARCH REQUIRED

Stakeholder workshops were held during the preparation of this manual. Participants included experienced representatives involved in industrial development and reclamation of native prairie, the Mixedgrass ranching community, the native seed industry, conservation organizations and Government of Alberta regulatory authorities. Summaries of the workshops are included as Appendix E. One of the key issues discussed was the need for future research to improve restoration potential and expected outcomes for industrial disturbances in Mixedgrass prairie. Research priorities proposed by the stakeholders include:

- What role does soil compaction play in the recovery of unstripped minimal disturbance sites? Sites where soil compaction has taken place should be monitored and research questions defined. Research should be funded and given priority. The Mixedgrass NSR is prone to Chinooks and poses increased risk for rutting and compaction of soils during winter construction and development activities. Mixedgrass loamy soils are more at risk than soils in the Dry Mixedgrass.
- What are the long term ecological impacts of invasive species on linear and non-linear disturbances.
- What practices are available to remediate the invasive impacts of invasive agronomic species.
- More monitoring and research is required to define appropriate seeding rates for sites that require seeding.
- The best methods to manage downy brome including: herbicidal products, alternatives to chemical treatment and the timing of chemical application or alternative treatments are required.
- The effects of soil disturbance on mycorrhizal populations and whether inoculating disturbance will improve restoration potential should be researched.
- Does uneven distribution of replaced topsoils on a disturbance promote more species diversity?
- If grazing is used as a tool to promote restoration how can the stocking rate, timing and duration for grazing be determined on a site and issue specific basis?
- What is the effect of soil disturbance on soil microbes?
- What are the methods to stimulate seed production in healthy areas surrounding disturbance?
- Regarding wild harvested hay, guidelines to ensure recovery of harvested areas, percentage filling in, and potential for centrally located designated areas to supply native hay. Further study on the success of the technique is required.
- What is the role of early colonizers in perennial establishment?
- Research is required regarding the role of forbs in plant community succession. Suggestion to include more information on the use of forbs in plantings, perhaps as a follow up to seeding?
- Further research and monitoring regarding the importance of the two-lift stripping procedure to native plant community restoration is required.
- The planting of wild harvested native grasses without processing first. An example would be marsh reed grass (*Calamagrostis Canadensis)*. It is a very light seed and is very difficult to clean.
- Effectiveness of using nursery propagated native plant material, (rooted seedlings) to start hard to establish species (e.g., shrubs, forbs) or, to establish native species on difficult sites (steep terrain, exposed areas, xeric sites).
- Awns play an important role in establishing seed naturally. Processing to remove the awn can damage up to 50% of the seed, increasing the cost. We need to understand the function of the awn. Consider methods of applying seed mulch? Example, needle-and-thread grass (*Stipa Comata)*, problem with awn, seeds fluffy, how to apply rather than clean it, seed mulch?

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Appendix A Glossary of Terms

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Appendix B Case Studies

B.1 Case Study of Express Pipeline

B.1.1 Why is Express Important?

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

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

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

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

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

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

B.1.2 Express Results –Mixedgrass Seed Mixes

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

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

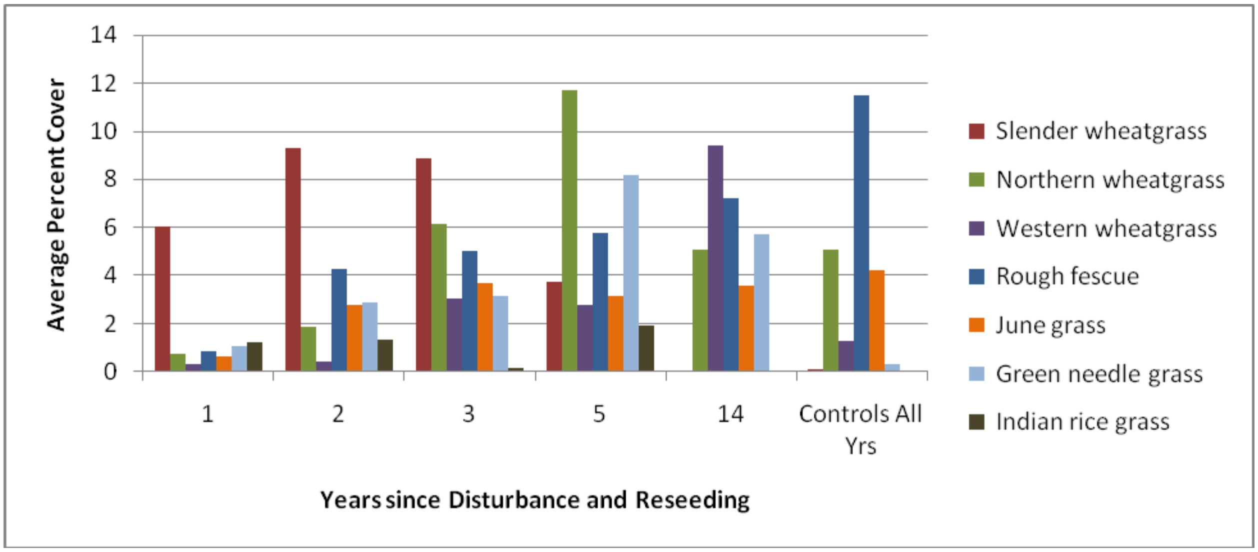
Wild-harvested Seed

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

Cultivars

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

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

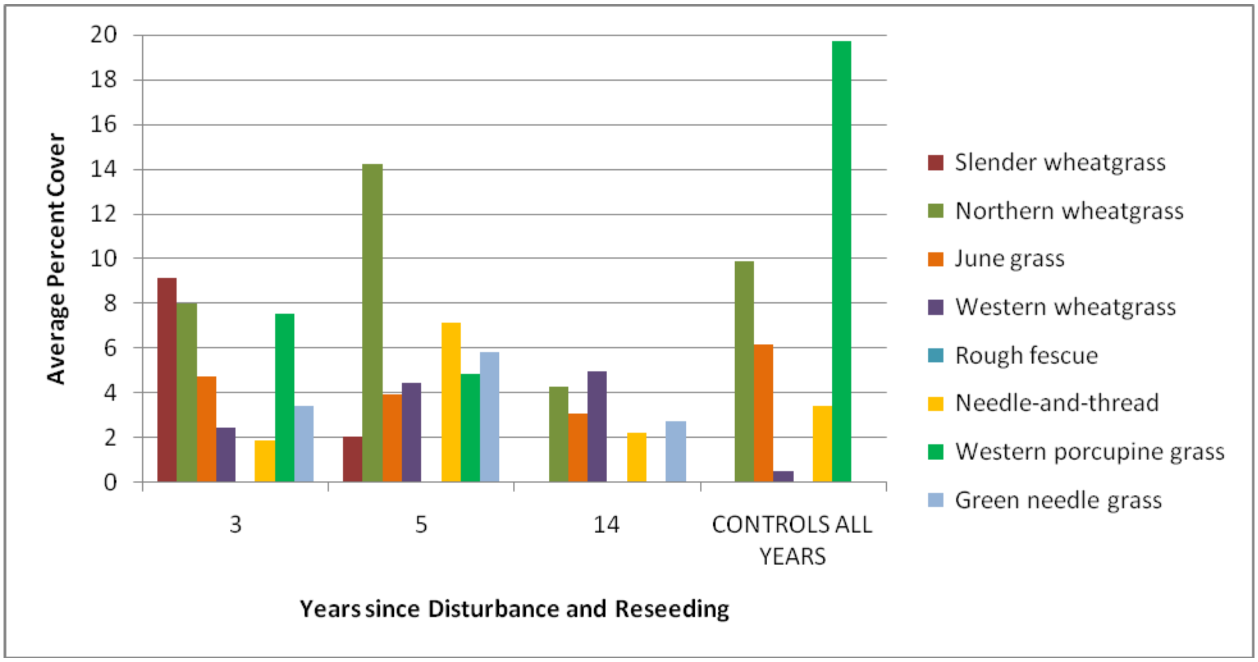


Average % Cover of Seeded Species for all Sites Seeded to Mix 2: Sites #s 4, 21, 22, 23, 25

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

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

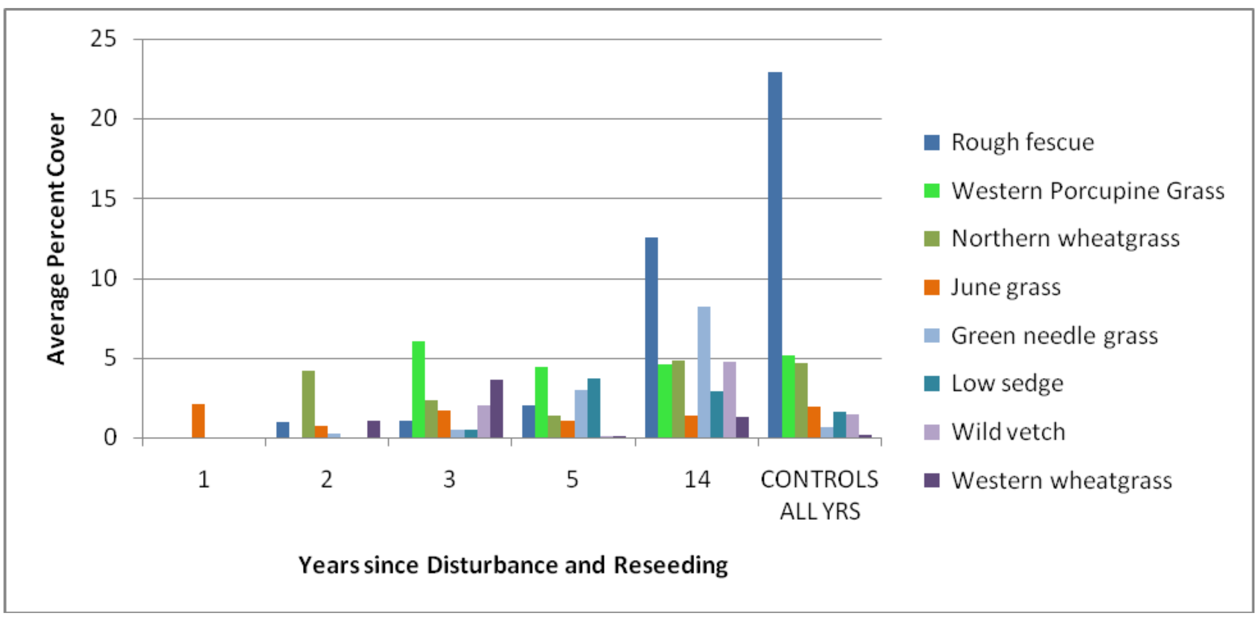
Figure B2 - Species Cover over Time for Seed Trial: Seed Mix 2* + Rough Fescue + Needle-and-thread 5:6:6



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

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

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



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

B.1.3 Express Results – Mixedgrass Natural Recovery

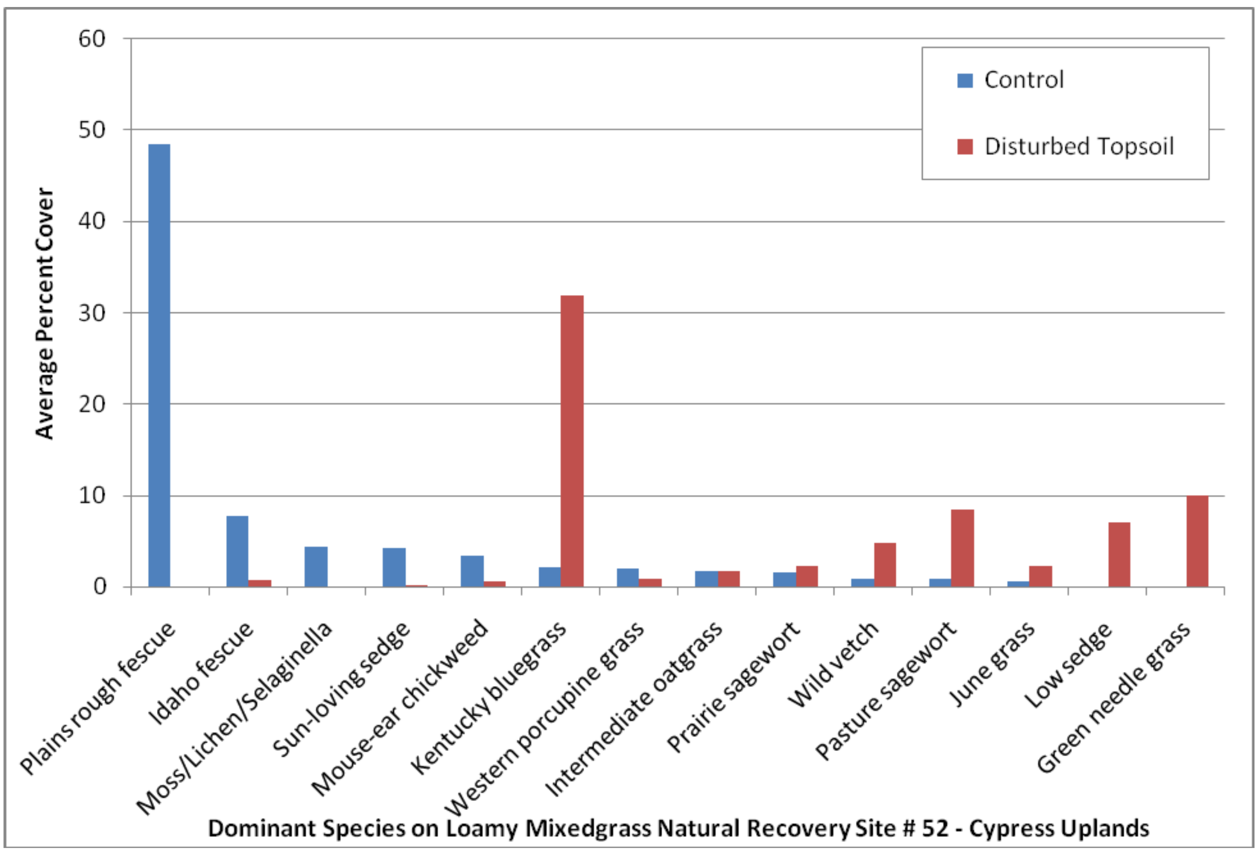
Natural recovery trials were established on Loamy soils in the Mixedgrass. Two sites were selected on relatively level terrain where site stability due to slopes was not an issue and soil exposure to wind erosion was minimized. Cultivars are absent from the reclaiming plant communities, which results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

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

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

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

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



B.1.4 Assessing Plant Community Succession on Disturbances

Methods for Analysis of Succession

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

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

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

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

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

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

B.1.5 Express Results – Mixedgrass Plant Community Succession

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

Mixedgrass – Limy Ecological Range Sites

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

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

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

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

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

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

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

Mixedgrass – Loamy Ecological Range Sites

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

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

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

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

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

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

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

B.1.6 Challenges for Succession on Mixedgrass Sites after Disturbance

Seeded Soils

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

Unseeded Soils

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

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

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

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

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

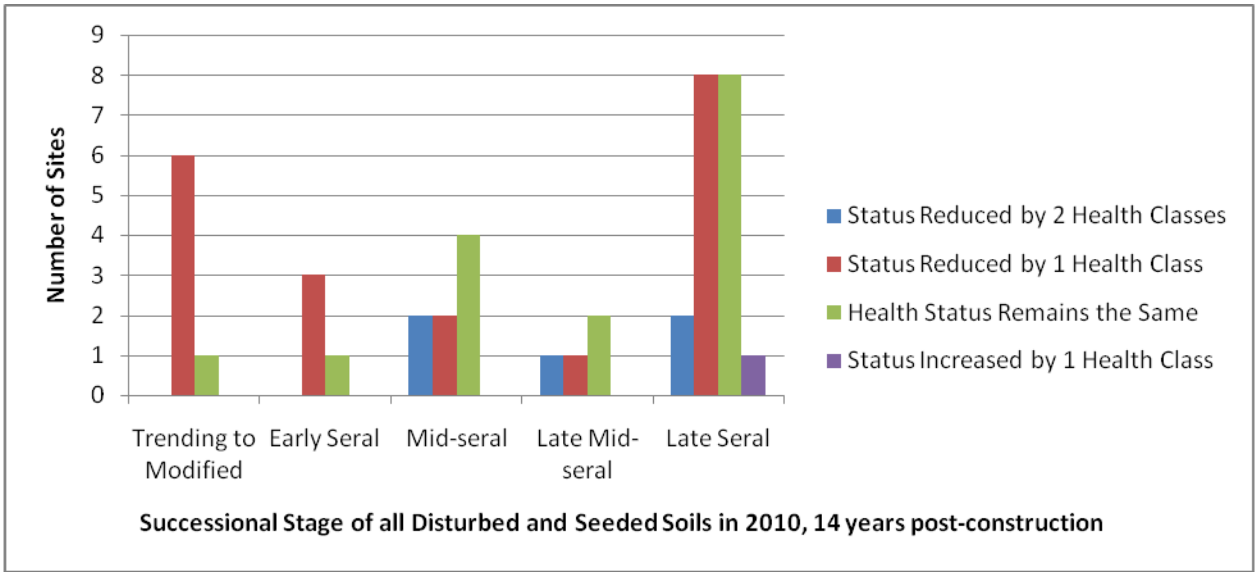
B.1.8 Express Results – Range Health

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

Ecological Status

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

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



Plant Community Structure

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

Invasive Species

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

Interacting Variables

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

B.1.9 Express Results – Diversity After Disturbance

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

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

B.1.10 Express Management Observations and Recommendations

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

Restoration Planning

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

Seed Mixes

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

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

Natural Recovery

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

Communication of Restoration Commitments and Strategies from Construction to Operations

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

Assessing Restoration Progress

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

B.2 Cypress Uplands and Majorville Uplands Case Studies

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

B.2.1 Case Study Project Settings

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

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

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

B.2.2 Minimal Disturbance Construction Techniques for Small Diameter Pipelines

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

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

Construction procedures that differed between the projects are:

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

B.2.3 Revegetation Strategies

Three revegetation strategies were used on the projects:

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

B.2.4 Long term Monitoring

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

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

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

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

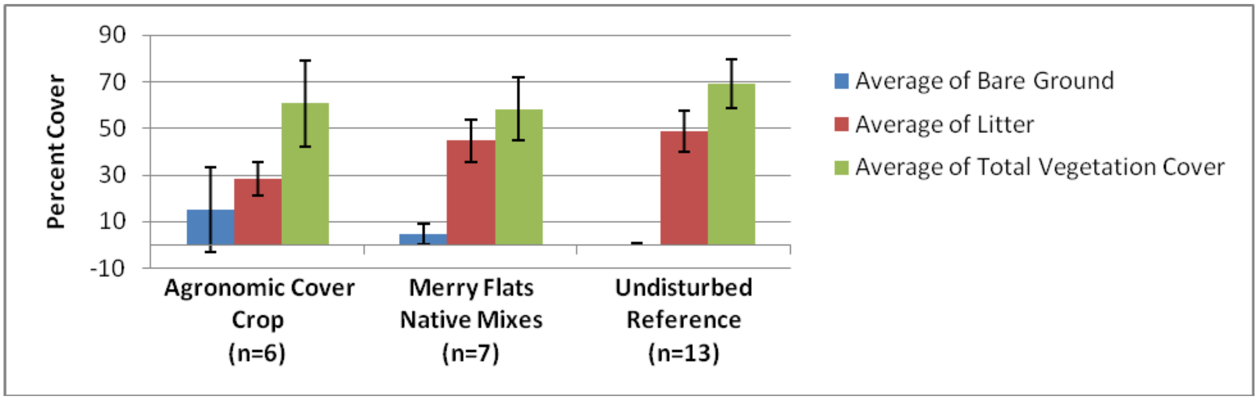
Cypress Uplands: Shallow to Gravel Ecological Range Sites

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

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

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

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



Majorville Uplands Natural Recovery: Loamy and Limey Ecological Range Sites

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

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

B.2.6 Restoring Range Health

Cypress Uplands: Shallow to Gravel Ecological Range Sites

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

Majorville Uplands Natural Recovery: Loamy and Limey Ecological Range Sites

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

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

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

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

Cypress Uplands: Shallow to Gravel Ecological Range Sites

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

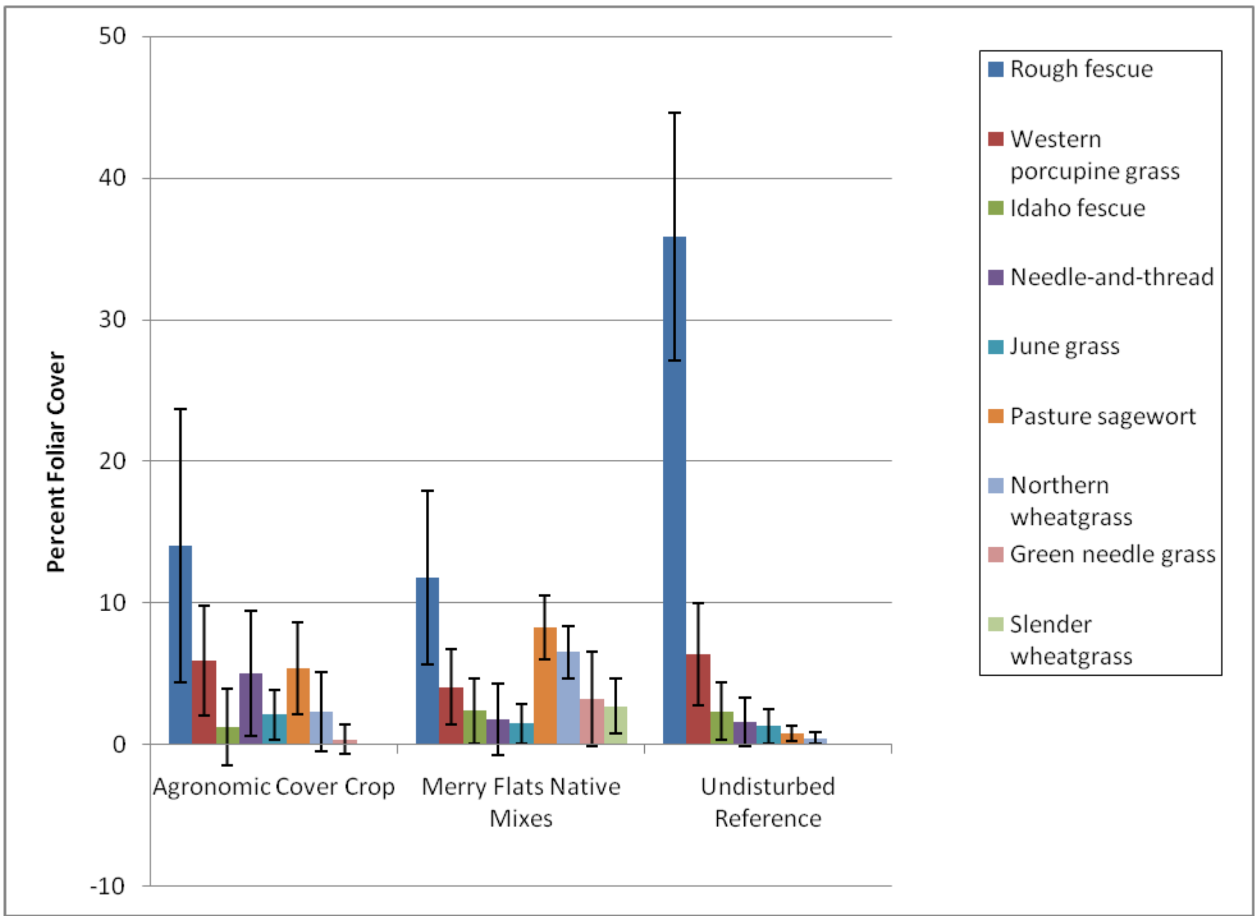
The primary differences between the composition and cover of native seed mix sites versus the undisturbed plant community or the assisted natural recovery sites is the presence of northern wheatgrass, slender wheatgrass and green needle grass cultivars at significantly higher cover than natural cover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

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

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

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

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



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

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

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

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

Table B5 - Succession of Reclaiming Plant Communities

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

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

B.2.8 Restoring Plant Communities: Natural Recovery

Majorville Uplands: Loamy and Limey Ecological Range Sites

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

B.2.9 Data Gaps and Further Research Required

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

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

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

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

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

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

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

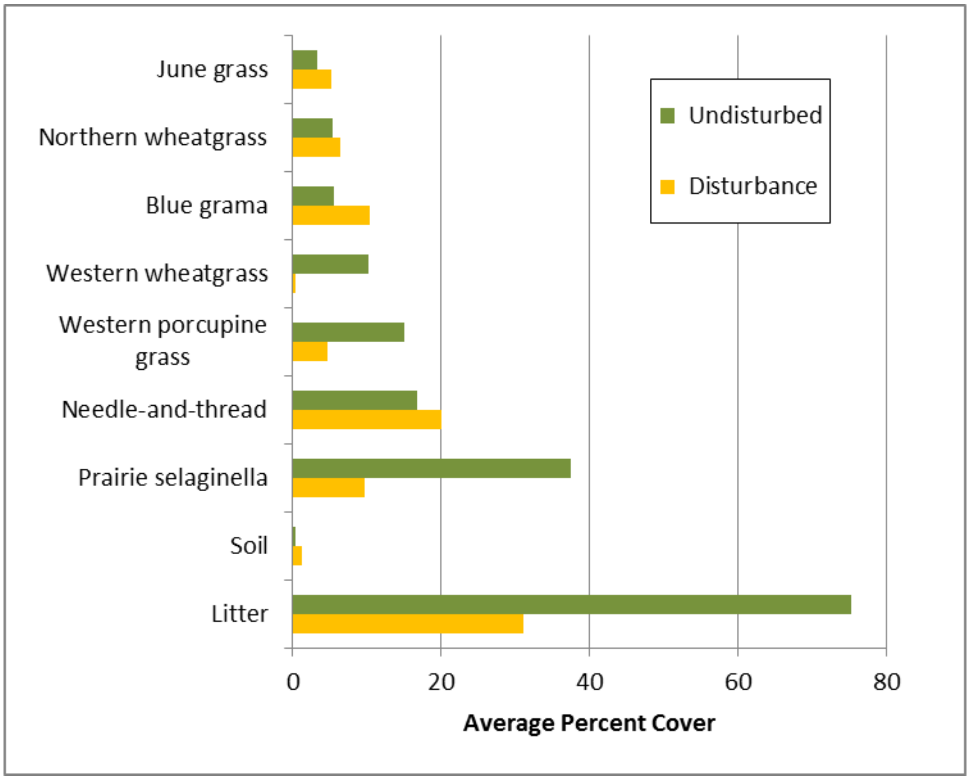
- Cover of tall grasses, forbs and groundcover is reduced but recovering;
- Total numbers of species are approaching off-site numbers;
- The number of native forb species is greater than 50% of number on undisturbed grassland;
- Litter values on undisturbed areas are double those found on the RoW;
-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

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

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

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

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



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

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

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

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

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

Appendix C Target Recovering Plant Communities

Introduction

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

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

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

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

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

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

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

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

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

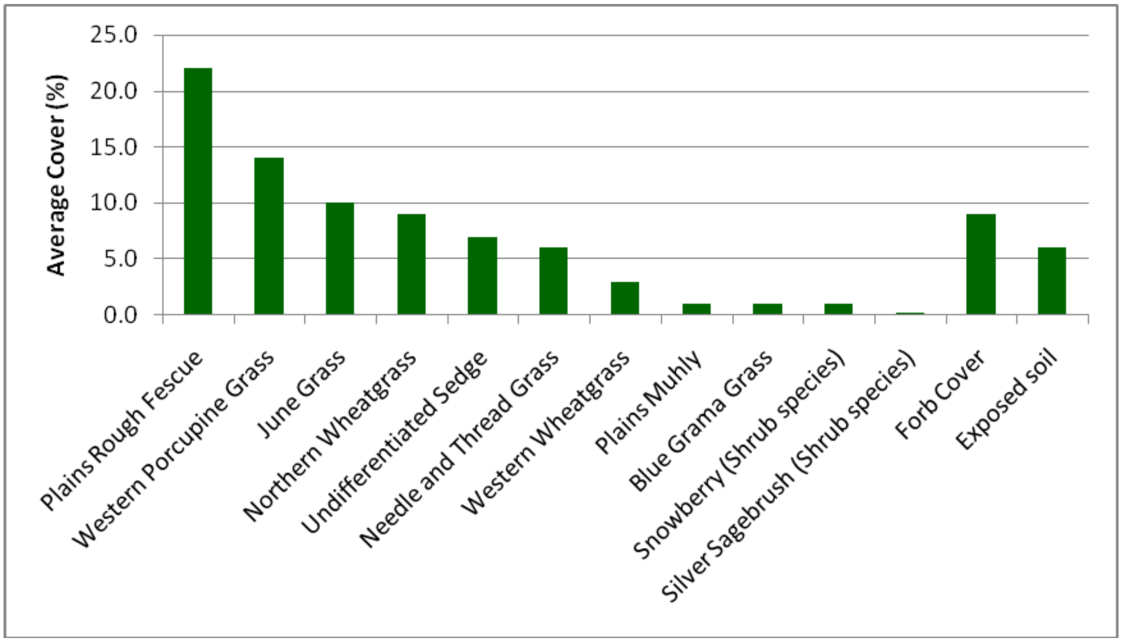
This cluster generally applies to the mid to upper slope positions in the Cypress Upland Ecodistrict. Native grasslands are largely intact under the stewardship of large ranching operations. In this area Plains rough fescue is a key indicator species common to loamy, shallow to gravel, gravel and thin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

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

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

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

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



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

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

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

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

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

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

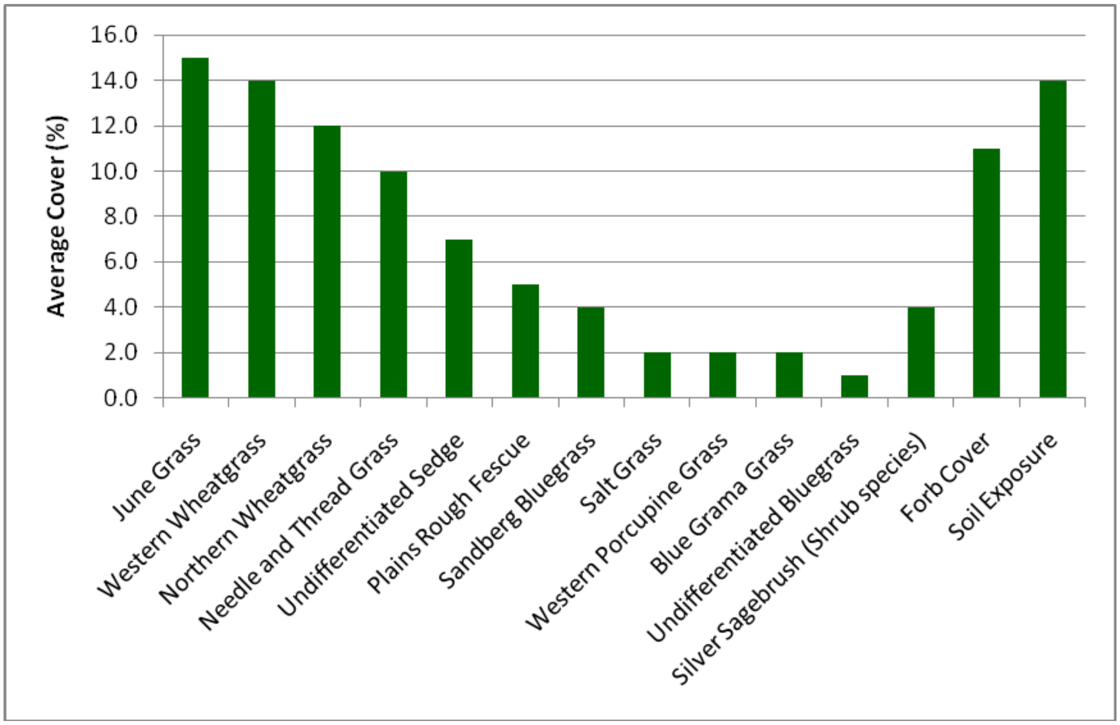
This cluster represents mid- to late seral plant communities found at lower elevations in the Cypress Upland on lower slope, terrace and level landform elements. The lower slopes tend to be more fragmented by cultivation. Drought tolerant species such as June grass, northern and western wheatgrass and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

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

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

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

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



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

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

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

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

C.1.3 Cypress Upland: Saline Lowlands Ecological Range Sites

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

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

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

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

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

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

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

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

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

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

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

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

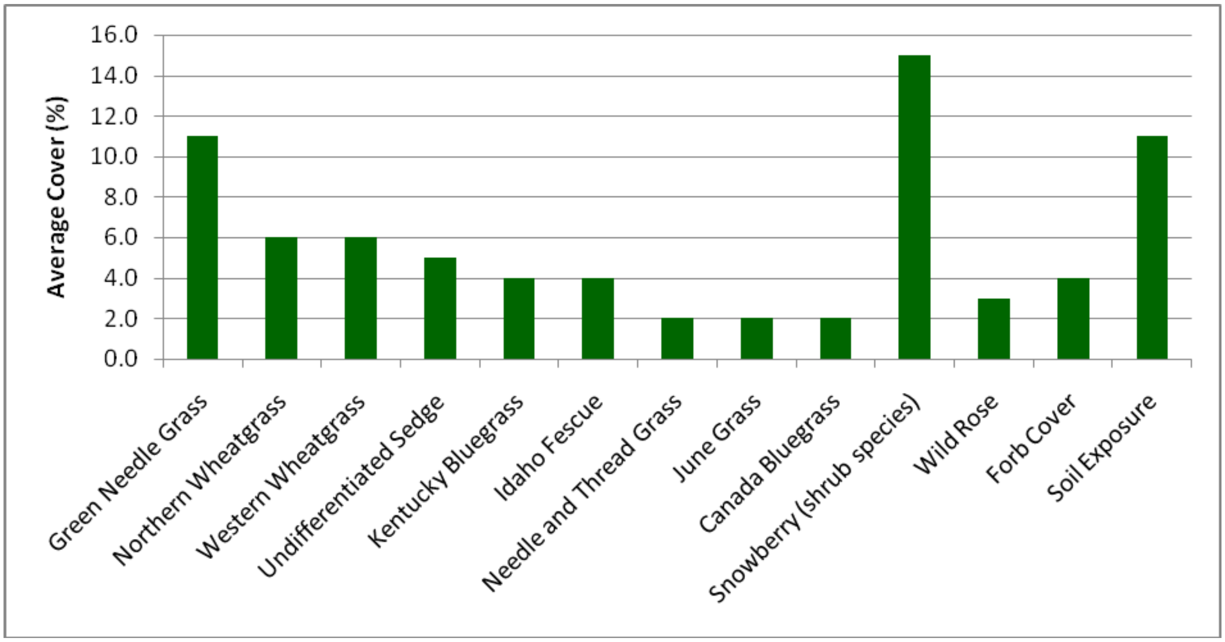
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11 (Adams et al. 2013). The plant communities included in this cluster include: MGB2, MGC7, and MGC2.

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

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

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

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



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

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

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

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

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

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

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

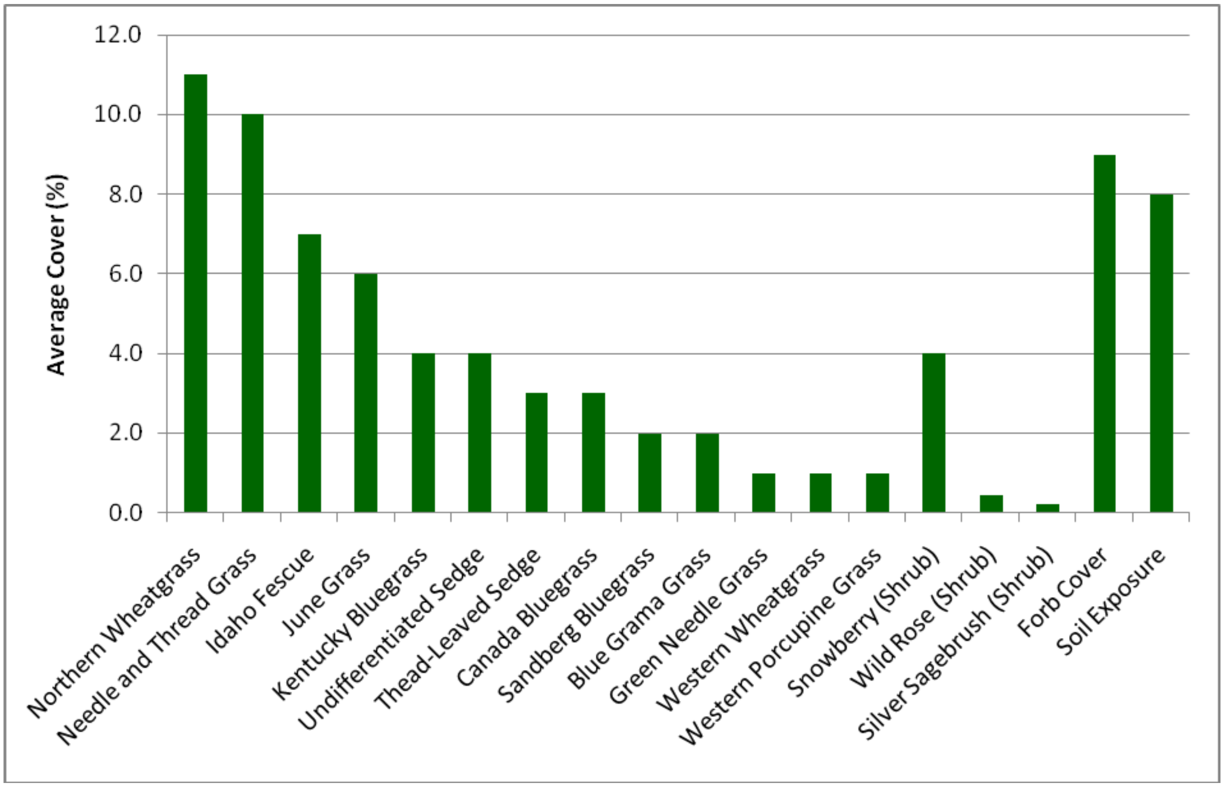
Table C9 - Target Recovering Plant Community for Sweetgrass and Milk River Upland: Loamy and Thin Breaks Range Sites

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

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

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

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



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

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

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

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

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

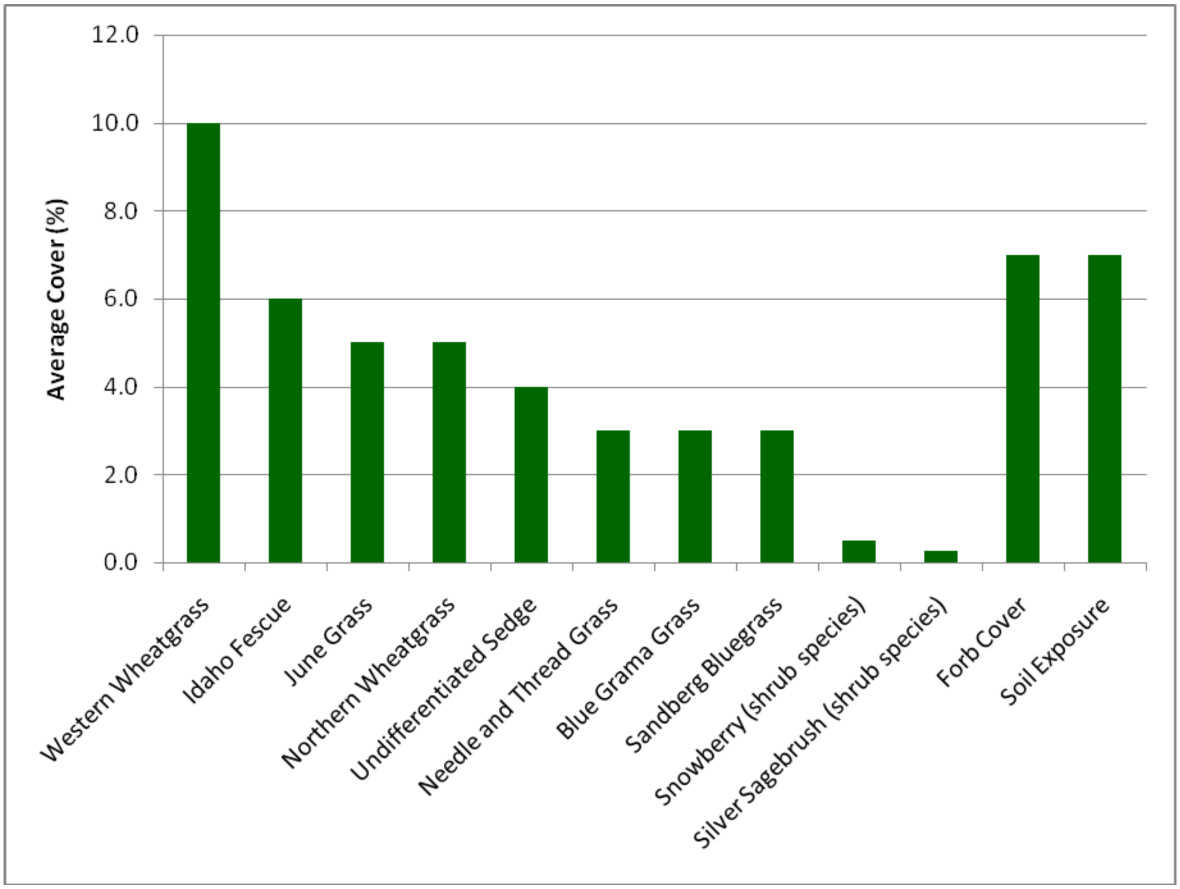
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11 (Adams et al. 2013). The plant communities included in this cluster include: MGA33, MGA34, and MGA35.

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

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

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

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



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

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

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

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

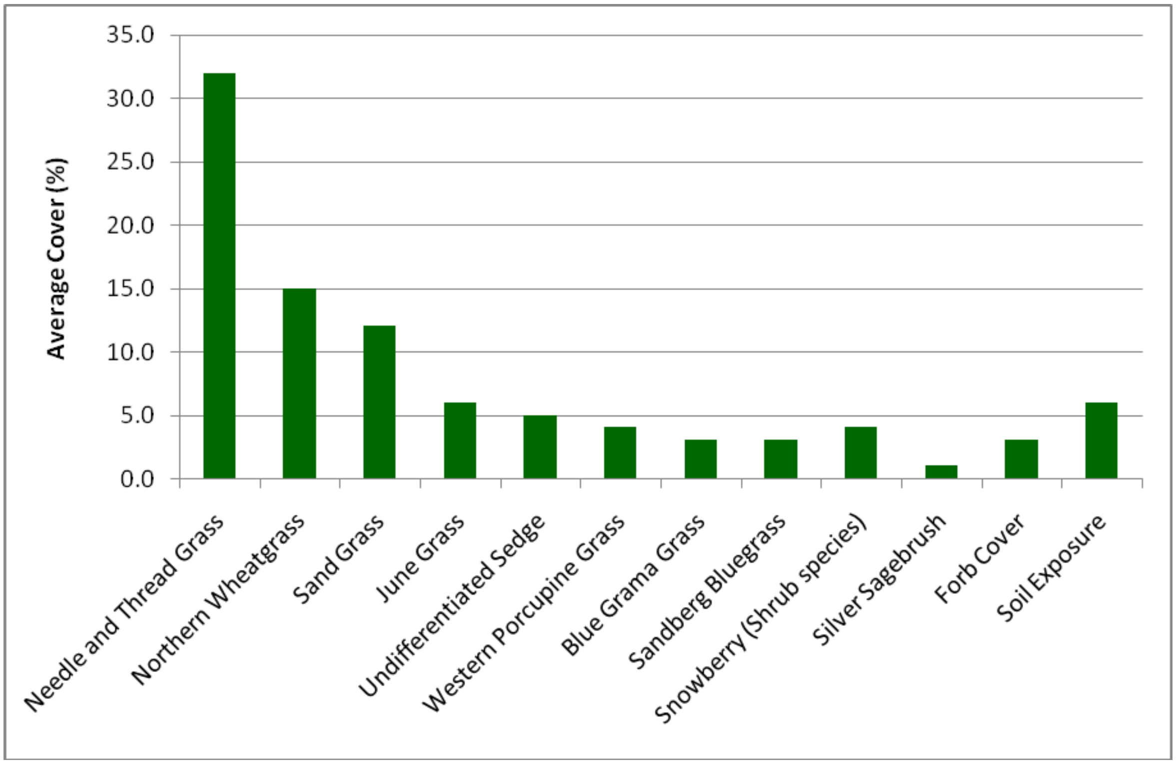
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11 (Adams et al. 2013). The plant communities included in this cluster include: MGA16 and MGB4.

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

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

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

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



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

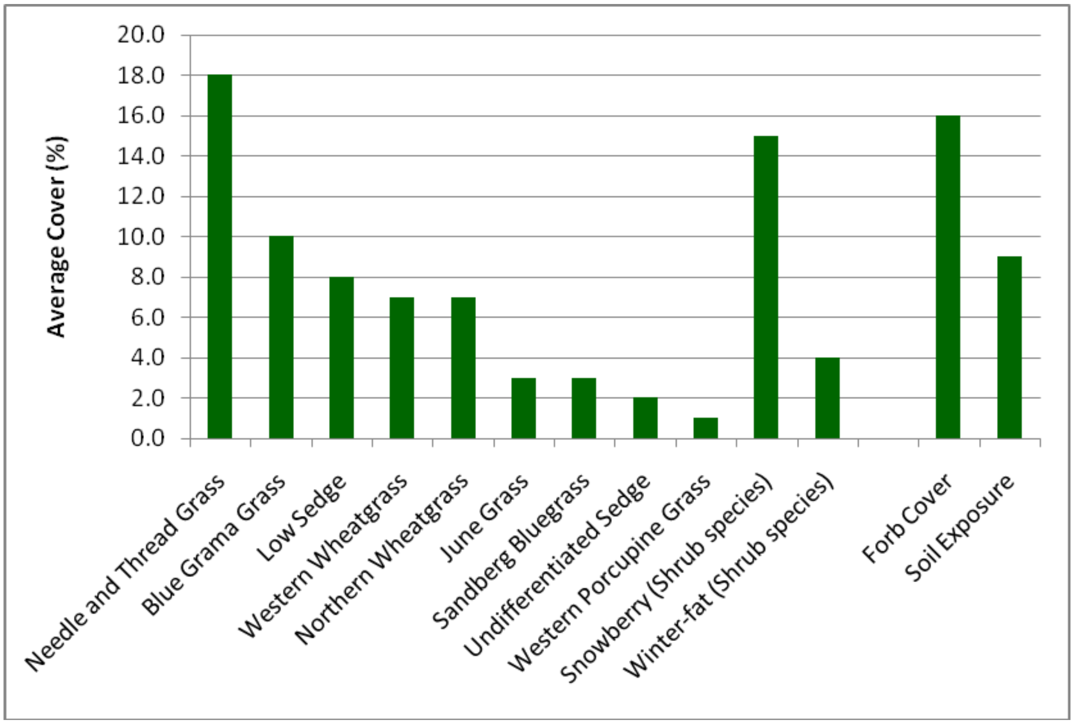
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11 (Adams et al. 2013). The plant communities included in this cluster include: MGA21, MGA22, MGC4, MGC5, MGC6.

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

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

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

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



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

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

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

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

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

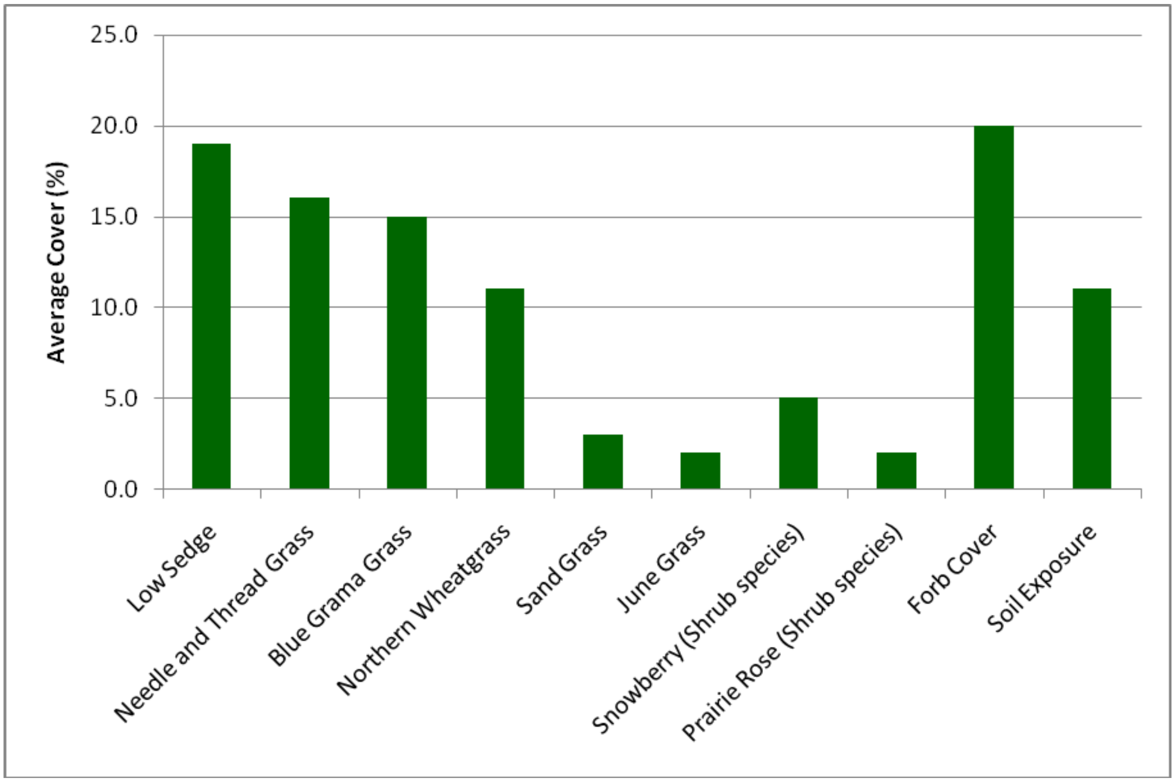
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11 (Adams et al. 2013). The plant communities included in this cluster include: MGA25, MGA24, MGA26, MGA27, MGA28.

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

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

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

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



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

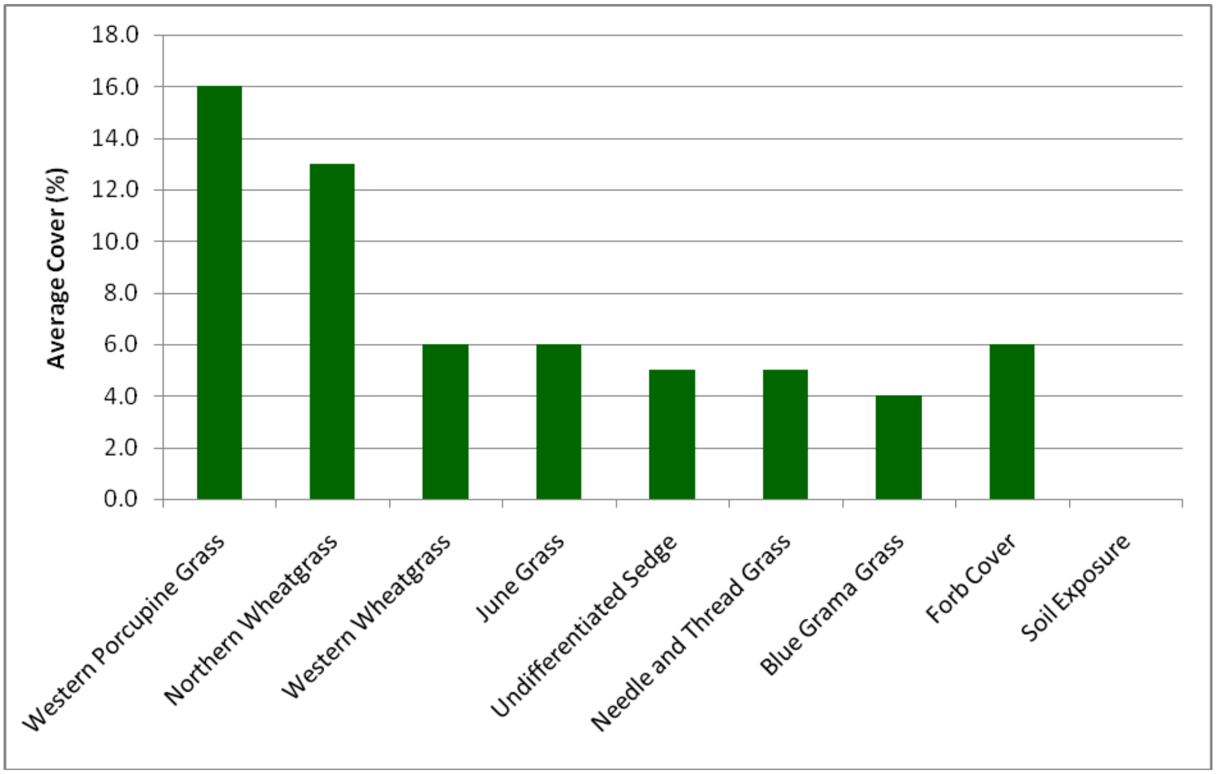
C.4.1 Majorville Upland Ecodistrict: Loamy Ecological Range Sites

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

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

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

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



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

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

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

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

C.5 Final Step

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

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

Appendix D Seeding Pathways

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

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

and/or

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

Seeding Rate Conversion Charts For Using Native Species In Reclamation Projects

Alberta
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Andrew M. Hammermeister
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Public Lands Management Branch
Agriculture, Food and Rural Development
200, J.G. O'Donoghue Bldg.
7000 - 113 St.
Edmonton, AB T6H 5T6

Seeding Rate Conversion Charts For Using Native Species In Reclamation Projects

Introduction

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

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

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

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

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

Calculating Seeding Rates

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 3.
General seeding rate guidelines.

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

Formula 1.

Converting seeding rate of a species from % weight basis to PLS/m².

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

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

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

This is an estimate of the weight of the seed.

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

Conversion factor which adjusts for the % value by dividing by 100 and converting the kg/ha to g/m².

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

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

Formula 2.

Converting seeding rate of a species from PLS/m² to % weight basis (i.e. reverse of Formula 1).

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

Formula 3.

Metric to Imperial conversions:

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

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

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

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

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

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

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

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

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

*Note: these PLS/m^2 are converted from kg/ha. For a lb/ac conversion, multiply the PLS/m^2 by 0.891.

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

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Table 8. Converting PLS/m^2 to kg/ha. (Based on seed weights shown in Table 2.)

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

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

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Appendix

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

Adapted from USDA, NRCS Form ND-CPA-9

Pure Live Seed Needs **Bulk Seed Needs**

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

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

Interpreting your Report of Seed Analysis:

Important notes:

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

Purity tests

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

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

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

Pure Living Seed

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

Germination Test

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

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

Tetrazolium chloride (TZ) Test:

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

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

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

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

20/20 Seed Labs Inc.

Report Of Seed Analysis

CFIA Accreditation No.1068

This designates that a sample of Wheatgrass, northern

Lot# 123-4567

Date: Apr 18, 2012

Lab No. AB1120401008

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

Nisku, AB, CA
T9E 7N5

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

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

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

% PURE SEED *

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

PURITY *

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

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

Germination *

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

ACCREDITED REMARKS

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

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

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20/20 Seed Labs Inc.

Detailed Testing Result Summary

CFIA Accreditation No.1068

This designates

that a sample of Wheatgrass, northern

Lot# 123-4567

Date: Apr 18, 2012

Lab No. AB1120401008

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

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

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

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20/20 Seed Labs Inc.

Report Of Seed Analysis

CFIA Accreditation No.1068

Date: Apr 18, 2012

Lab No. AB1120401009

This designates that a sample of Wheatgrass, northern

Lot# 123-4567

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

Nisku, AB, CA
T9E 7N5

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

signed by:
SENIOR MEMBER OF
Commercial Seed Analysts Association of Canada Inc.
139
Carey Matthiessen

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

% PURE SEED *

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

PURITY *

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

NOXIOUS WEED SEEDS		OTHER WEED SEEDS		OTHER CROP SEEDS
Prohibited Noxious		Green needlegrass	21.5	Slender wheatgrass
Total Prohibited	0.0	Narrow-leaved hawk's beard	11.0	Alfalfa
Primary Noxious		Downy brome	37.5	Smooth bromegrass
Cleavers bedstraw	0.5	Japanese brome	6.5	
Canada thistle	0.5			
Total Primary	1.0			
Secondary Noxious				
Night-flowering catchfly	2.5			
Total Secondary	2.5			

Primary Plus Secondary	3.5	**Total Weed Seeds of All Kinds**	80.0	**Total Other Crop Seeds**	More than 3% by weight
Brassica spp.	0.0			**Sclerotia Bodies**	n/a
				Sweet Clover	0.0
				Ergot Bodies	Less than 1% by weight

Germination *

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

ACCREDITED REMARKS

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

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

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20/20 Seed Labs Inc.

Detailed Testing Result Summary

CFIA Accreditation No.1068

This designates

Date: Apr 18, 2012

that a sample of Wheatgrass, northern

Lot# 123-4567

Lab No. AB1120401009

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

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

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

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20/20 Seed Labs Inc.

Report Of Seed Analysis

CFIA Accreditation No.1068

This designates

Date: Apr 18, 2012

that a sample of Needle And Thread

Lot# 345-6789

Lab No. AB1120401050

was received from:

Scarecrow Enterprises
#201, 509 11 Avenue

Nisku, AB, CA
T9E 7N5

and was tested at:

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

signed by:

SENIOR MEMBER OF

COMMERCIAL SEED ANALYSTS ASSOCIATION CANADA INC

139
Carey Matthiessen

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

% PURE SEED *

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

PURITY *

WEED SEEDS: No. PER 25 GRAMS

TOTAL GRAMS ANALYZED FOR PURITY: 150

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

Germination *

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

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

ACCREDITED REMARKS

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

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

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20/20 Seed Labs Inc.

Detailed Testing Result Summary

CFIA Accreditation No.1068

This designates

Date: Apr 18, 2012

that a sample of Needle And Thread

Lot# 345-6789

Lab No. AB1120401050

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

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

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

Appendix E Mixedgrass Rancher and Industry Workshop Summaries

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

Expectations of Recovery

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

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

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

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

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

Non-Native Species Invasion

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

Experience with non-native species invasion suggests that:

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

Grazing Management

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

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

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

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

Additional Recommendations

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

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

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

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

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

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

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

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

Best Practices for Recovery in Mixedgrass Prairie

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

Natural Recovery

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

Assisted Natural Recovery

Cover Crop

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

Wild Harvested Hay

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

Seeding with Native Seed Mixes

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

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

Plug Planting

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

Invasive Non-Native Species Management

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

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

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

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

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

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

What are the stumbling blocks preventing improved restoration potential?

Expectations of the timeframe for recovery

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

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

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

Lack of suitable species for seed mixes

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

Suggestions:

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

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

Grazing management

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

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

Lack of follow up after initial reclamation treatment

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

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

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

Knowledge Gaps and Potential Research Questions

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

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

Mixedgrass Research / Monitoring Projects Underway

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

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

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

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

Comments on the Map/Target Plant Communities for Mixedgrass

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

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

Appendix F Species Names – Common and Scientific

F.1 Species Names Ordered by Common Name

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

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

F.2 Species Names Ordered by Scientific Name

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

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