Recovery Strategies for Industrial Development in Native Prairie

for the

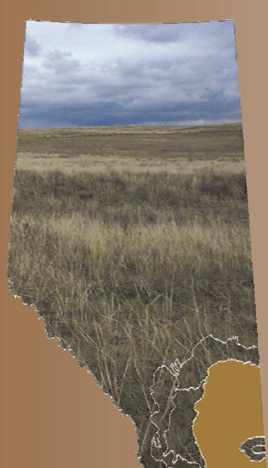
Dry Mixedgrass

Natural Subregion of Alberta

Dry Mixedgrass Natural Subregion

Natural Recovery—Hemaruka Dunes

Reduced Disturbance Drilling with Rig in Place



First Approximation

February 2013

Recovery Strategies for Industrial Development in Native Prairie

The Dry Mixedgrass Natural Subregion of Alberta

February 2013

First Approximation

Prepared for:

Range Resource Management Program
Lands Division
Alberta Environment and Sustainable Resource Development

Alberta Environment and Sustainable Resource Development

Prepared by:

Gramineae Services Ltd.

In Partnership With:

Special Areas Board

Foothills Restoration Forum

ERCB

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A project such as this cannot be completed in isolation. The partnerships established during the evolution of this project captured and incorporated the knowledge of Albertans who share a common goal of minimizing the impact of industrial disturbance in native prairie landscapes.

The project has been developed in two phases:

- an initial information gathering and field verification component; jointly funded by Kinder Morgan Canada Inc., TransCanada Pipelines, ConocoPhillips Canada and Alberta Sustainable Resource Development, Rangeland Management Branch, and;
- a series of peer review workshops with reclamation practitioners, reclamation contractors and environmental planners from industry, landowners, lease holders, rangeland agrologists, land use managers and not-for-profit organizations with an interest in prairie restoration. Funding for the second phase of the project has been provided by Alberta Environment and Sustainable Resource Development (ESRD) Range Resource Management Program.

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Barry Adams and Marilyn Neville

February 2013

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 Dry 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.

Partners with new tools build the pathway to restoration

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 enable 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. The purpose is to provide the tactical 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 infrastructure 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.

Remount Area, Dry Mixedgrass Natural Subregion

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 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 Dry Mixedgrass Natural Subregion.

This document is the first in a series of new guideline documents that will eventually address all natural subregions within the Grassland Natural Region. Projects are underway through the partnership established with the 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. A literature search for research projects and related information on restoration of grassland plant communities has been initiated for this project and is ongoing for future projects. A bibliography, links, and abstracts will be compiled by Natural Subregion and posted in the information portal on the Foothills Restoration Forum website at: http://www.foothillsrestorationforum.ca/

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 Dry Mixedgrass Natural Subregion is unique in the challenges it offers to industrial development. The semi-arid climate supports native plant communities uniquely adapted to drought and often adverse soil growing conditions. Minimizing the soil disturbance and natural recovery are the most effective strategies for restoring native plant communities in the Dry Mixedgrass. Alternate strategies for large disturbances not suited to natural recovery and severely degraded sites are defined and discussed in the context of the restoration tools and recent publications.

Scarlet Mallow

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Abbreviations

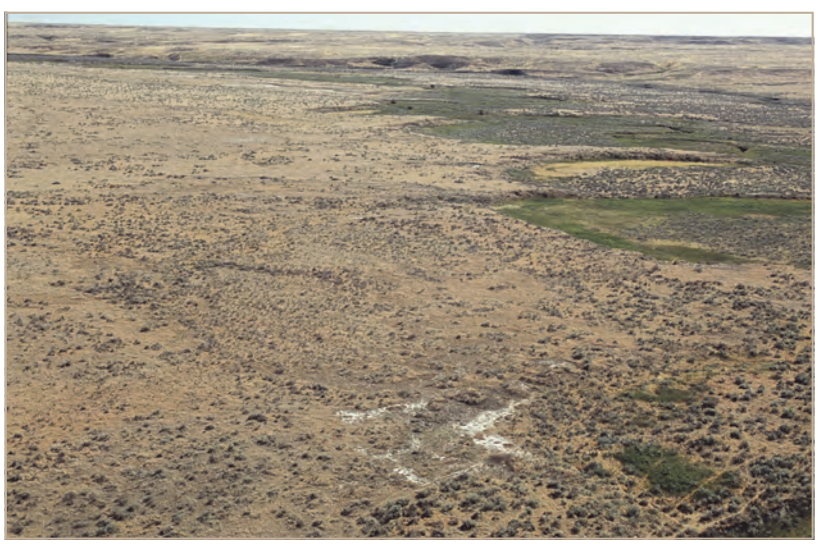
ACIMS....Alberta Conservation Information Management System
AENV....Alberta Environment
AGRASID....Agricultural Region of Alberta Soil Information Database
AI....Alberta Innovates (Formerly Alberta Research Council)
CFB....Canadian Forces Base
cm....centimetre
DMG....Dry Mixedgrass
EAP....Enhanced Approval Process
EPP....Environmental Protection Plan
ERCB....Energy Resources Conservation Board
ERS....Ecological Range Site
ESRD....Alberta Environment and Sustainable Resource Development
ESRRA....Ecological Site Restoration Risk Analysis
Express....Express Pipeline
FRF....Foothills Restoration Forum
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
NSR....Natural Subregion
PLS....Pure Live Seed
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 in Focus to Restoration

Why is ecological restoration important for our native grassland ecosystems? We have lost much of our original native grasslands 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.

Restoring ecological health, function and operability

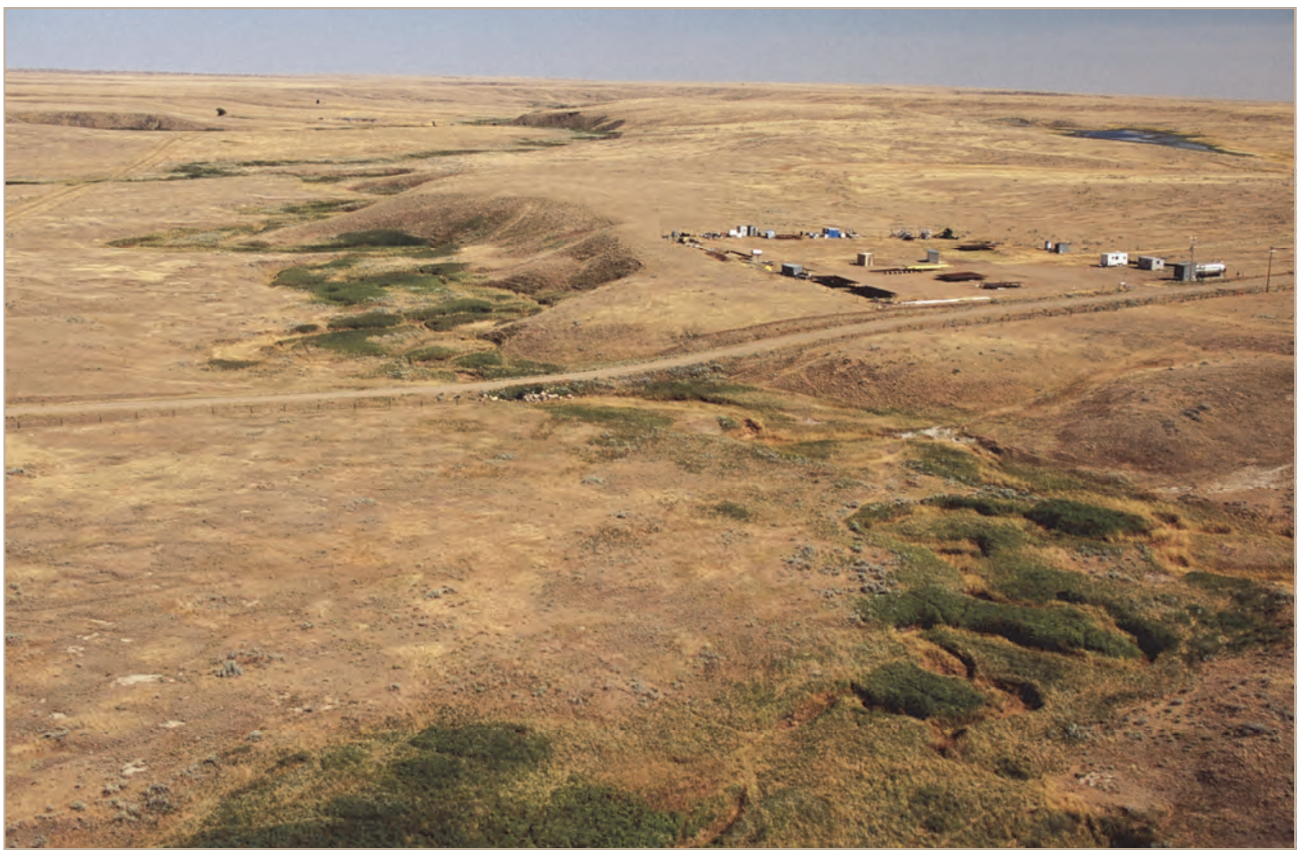
Ecological restoration is defined as "*the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed*" (Society for Ecological Restoration 2004). There is an increasing public awareness of the remaining native grassland ecosystems and the ecological goods and services 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 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.



Sage Flats, Sage Creek Grazing Reserve

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.



Sage Creek Grazing Reserve, Reduced Disturbance Avoids Riparian Zone with Setback ; Located Next to Existing Disturbance

2 OVERVIEW OF DRY MIXEDGRASS NATURAL SUBREGION

The Dry Mixedgrass has the warmest summers, longest growing season and lowest precipitation of any Natural Subregion of Alberta

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* (Achuff 1994). 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 Dry Mixedgrass Natural Subregion.

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

The Dry Mixedgrass Natural Subregion (Dry Mixedgrass) occupies a large area of the southeastern corner of Alberta (Figure 1). It is an expanse of level to gently undulating semi-arid prairie, broken in places by coulees, valleys, badlands and dune fields. The native grasslands and associated land forms support a rich biodiversity of species, including habitat for multiple Species at Risk and their gene pool.

The Dry Mixedgrass has the warmest summers, longest growing season and lowest precipitation of any Natural Subregion of Alberta. Drying winds, low summer precipitation, high summer temperatures and intense sunshine contribute to significant soil moisture deficits. Agricultural crop production is largely dependent on irrigation. Hard lessons were learned by the early settlers who broke the prairie soils and tried to dryland farm. Reclamation and revegetation of industrial disturbances is also difficult when the protective prairie vegetation is destroyed and the soils disturbed. However, the semi-arid growing conditions of the Dry Mixedgrass provide a less favorable growing environment for many invasive non-native species permitting better restoration outcomes than in more moist climates. So, in the Dry Mixedgrass, aridity can be viewed as assisting restoration outcomes.

In the Dry Mixedgrass many species of native plants are deep-rooted, short-lived or physiologically adapted to drought. Brown Chernozemic soils are dominant, but Brown Solonetzic soils have developed where saline and sodic conditions prevail. Sand plains and sand dunes have a high proportion of weakly developed Rego Chernozemic and Regosolic soils (Natural Regions Committee 2006). Understanding of the complex physiography and the interrelationship with the climate, soils and native plant communities of the Dry Mixedgrass is essential to minimizing the impact of industrial development. A more detailed description of the Dry Mixedgrass is provided in the Dry Mixedgrass Range Plant Community Guide (Adams et al. 2005). The most current approximation can be found on the ESRD website at: http://www.srd.alberta.ca

Milk River Canyon

Sage Grouse Habitat

Types of Industrial Activity

There are numerous types of industrial activities operating in the native grassland ecosystems of the Dry Mixedgrass. Currently, the Dry Mixedgrass has the highest density of producing natural gas wells, oil wells and the associated infrastructure in the province. There are also several large diameter pipeline corridors crossing extensive tracts of native grassland. Coal is strip mined to create electricity and gravel is extracted to construct and maintain transportation corridors. Agriculture was historically the dominant land use, and 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 Dry Mixedgrass are significant and the long term impact of surface soil disturbance on the ecological integrity of these grasslands is not well understood.

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/

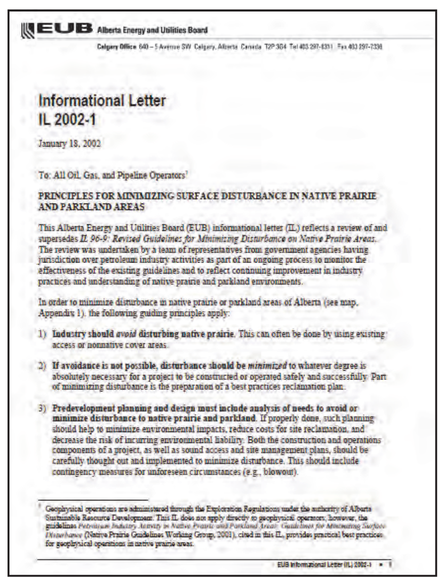
IL 92-12 (ERCB IL92-12) (Rescinded and replaced by ERCB IL2002-1)

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.



EUB Alberta Energy and Utilities Board

Calgary Office 640 – 5 Avenue SW Calgary, Alberta Canada T2P 3G4 Tel 403 297-8311 Fax 403 297-7336

Informational Letter
IL 2002-1

January 18, 2002

To: All Oil, Gas, and Pipeline Operators[1]

PRINCIPLES FOR MINIMIZING SURFACE DISTURBANCE IN NATIVE PRAIRIE AND PARKLAND AREAS

This Alberta Energy and Utilities Board (EUB) informational letter (IL) reflects a review of and supersedes *IL 96-9: Revised Guidelines for Minimizing Disturbance on Native Prairie Areas.* The review was undertaken by a team of representatives from government agencies having jurisdiction over petroleum industry activities as part of an ongoing process to monitor the effectiveness of the existing guidelines and to reflect continuing improvement in industry practices and understanding of native prairie and parkland environments.

In order to minimize disturbance in native prairie or parkland areas of Alberta (see map, Appendix 1), the following guiding principles apply:

1) **Industry should *avoid* disturbing native prairie.** This can often be done by using existing access or nonnative cover areas.

2) **If avoidance is not possible, disturbance should be *minimized*** to whatever degree is absolutely necessary for a project to be constructed or operated safely and successfully. Part of minimizing disturbance is the preparation of a best practices reclamation plan.

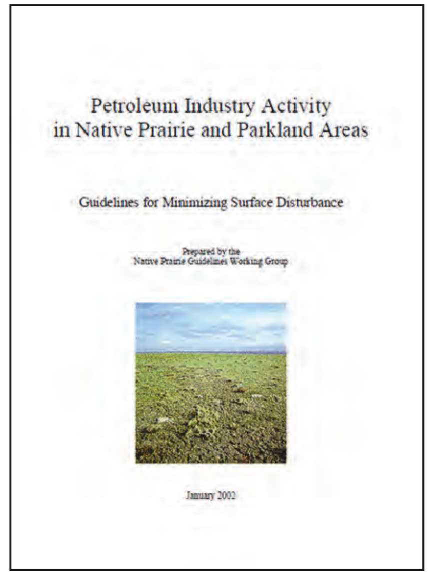
3) **Predevelopment planning and design must include analysis of needs to avoid or minimize disturbance to native prairie and parkland.** If properly done, such planning should help to minimize environmental impacts, reduce costs for site reclamation, and decrease the risk of incurring environmental liability. Both the construction and operations components of a project, as well as sound access and site management plans, should be carefully thought out and implemented to minimize disturbance. This should include contingency measures for unforeseen circumstances (e.g., blowout).

[1] Geophysical operations are administered through the Exploration Regulations under the authority of Alberta Sustainable Resource Development. This IL does not apply directly to geophysical operators; however, the guidelines *Petroleum Industry Activity in Native Prairie and Parkland Areas: Guidelines for Minimizing Surface Disturbance* (Native Prairie Guidelines Working Group, 2001), cited in this IL, provides practical best practices for geophysical operations in native prairie areas.

EUB Informational Letter (IL) 2002-1 • 1

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:

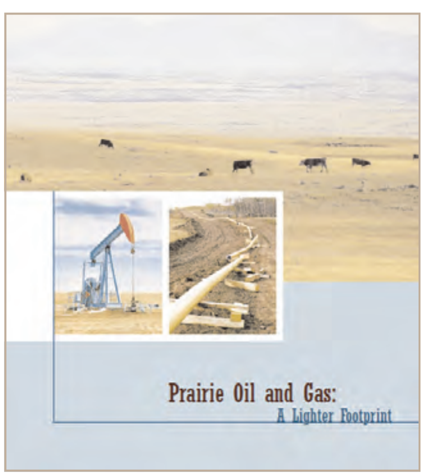


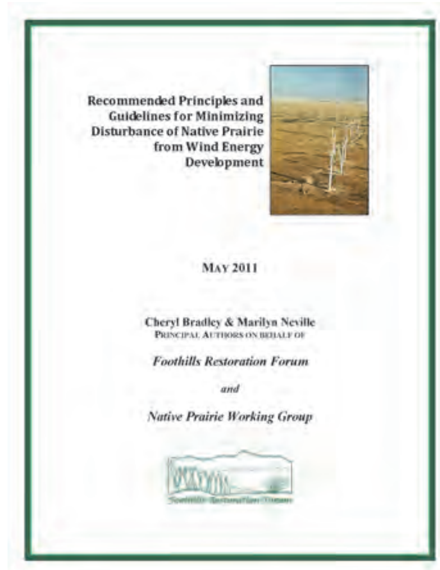
- Avoidance of native prairie and parkland landscapes if at all possible;
- The use of previously disturbed areas such as existing access roads and prairie trails; and
- Indicates the requirement for special planning measures, field based environmental assessments, minimal disturbance construction techniques 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 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





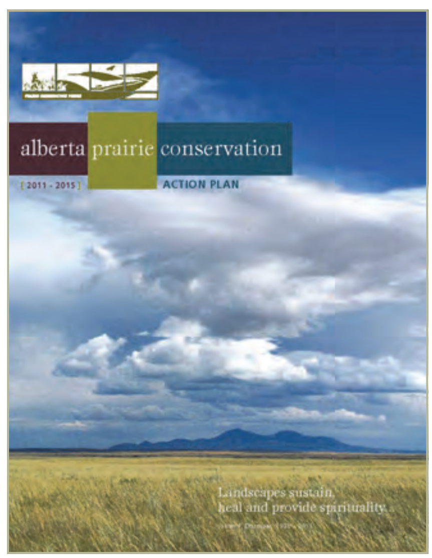
Recommended Principles and Guidelines for Wind Energy Development in Native Prairie (Foothills Restoration Forum Technical Advisory Committee 2011)

This document proposes recommended 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

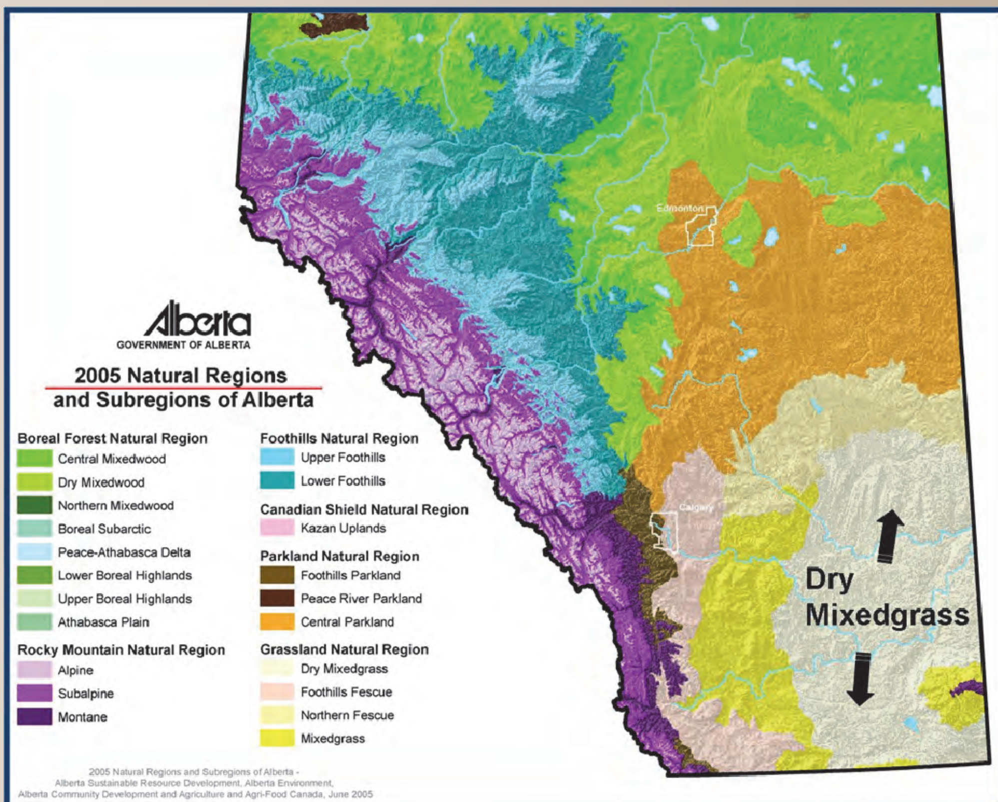
The vision embedded in the 2011 to 2015 Action Plan is to ensure the biological diversity of Alberta's prairie and parkland ecosystems is secure through the thoughtful and committed stewardship of all Albertans. To achieve the vision, three important long term outcomes are the focus of the PCF Action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

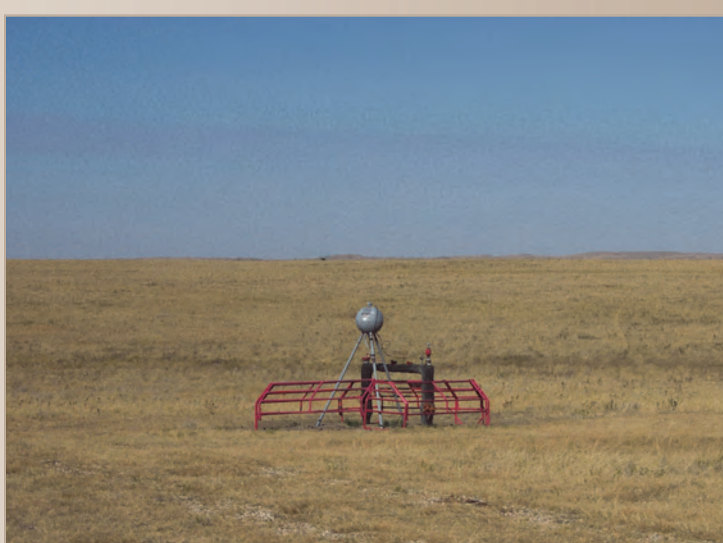
- ➪ Maintain large prairie and parkland landscapes;
- ➪ Conserve connecting corridors for biodiversity; and
- ➪ Protect isolated native habitats.



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 Website at: http://www.albertapcf.org/

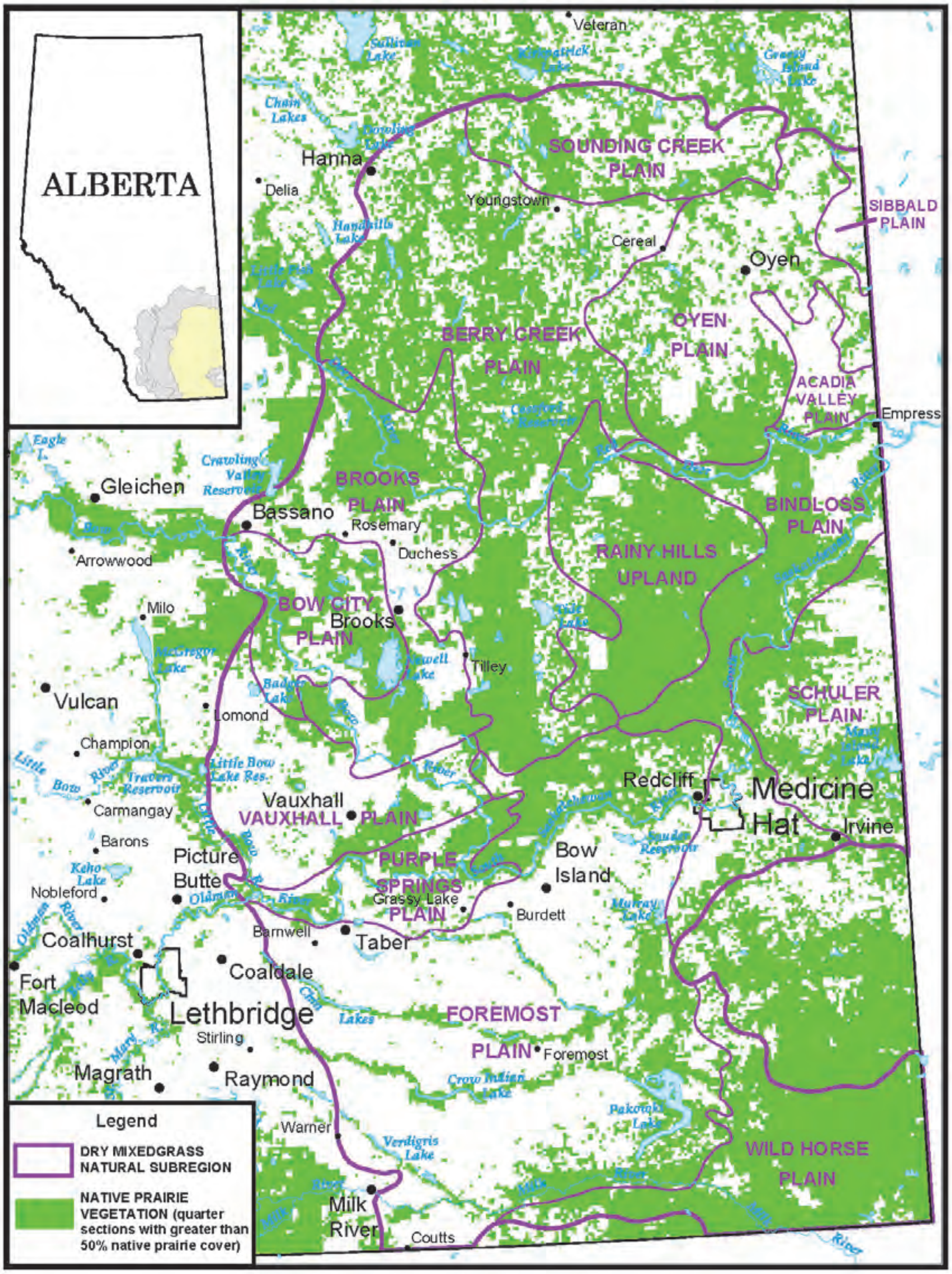
Figure 1 - Natural Subregions of Alberta





Reduced Disturbance Wellsite

Figure 2-Ecodistricts in the Dry Mixedgrass Natural Subregion



* From Dry Mixedgrass Range Plant Community Guide (Adams et al. 2005)

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.

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 layer or features. 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 (ESRD) or obtaining website information from:

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

Range Plant Community Guides

The Dry Mixedgrass Range Plant Community Guide is an essential reference for conducting range health assessments in the Dry 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. 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/DryMixedgrassSubregionAssessmentGuidelines.pdf

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:////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.

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. 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

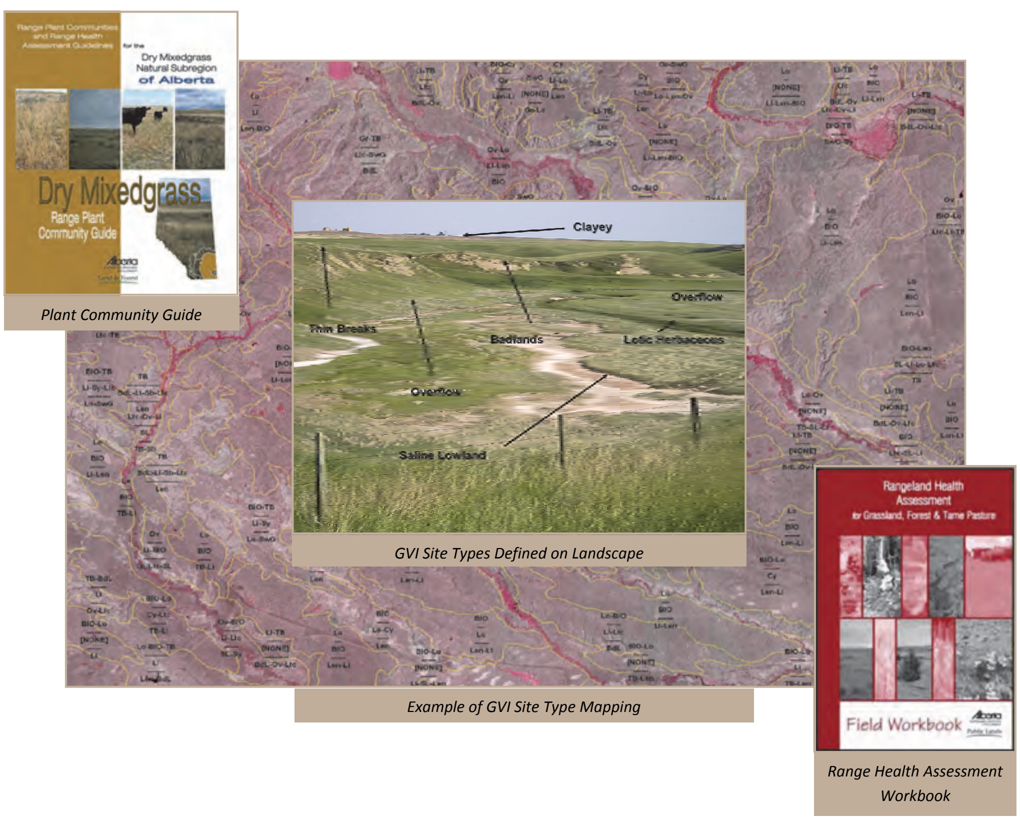
The range health assessment questions detailed in the field workbook are indirect measures of the following indicators:

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

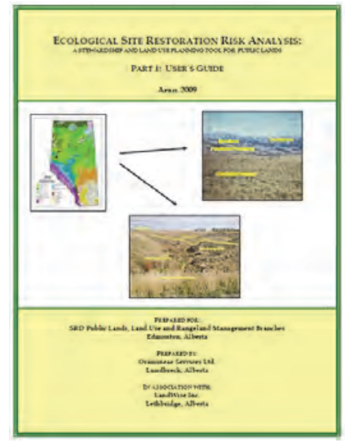
An evaluation of each indicator using the methods and scoring system detailed in the field workbook indicates whether these important ecological functions are being performed.

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 3 - Standardized Grassland Assessment Tools



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://ww.foothillsrestorationforum.ca/

Restoration Risk will affect your potential Restoration Outcome

In the Dry 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 Dry Mixedgrass available moisture is the limiting factor. There may be sufficient moisture in the spring to facilitate germination, however seedling mortality can occur due to a lack of sufficient moisture during the critical emergence stage.

2. The resistance the site can afford to non-native species invasion. Non-native species of concern include Prohibited Noxious and Noxious Weeds listed under the Alberta Weed Control Act and aggressive agronomic species such as crested wheatgrass and sweet clover. Aggressive non-native grass species such as downy brome and Japanese brome are of particular concern in the Dry Mixedgrass due to their adaptation to semi arid conditions and disturbed soils. It has been observed that within the Grassland Natural Region the potential for non-native species 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 species invasion than the more drought-prone climatic conditions and Brown soils of the Dry 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 Dry Mixedgrass, Overflow range sites are more prone to non-native species 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 an ecological 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. Close proximity to transportation corridors or tame pasture seeded to invasive non-native agronomic species such as crested wheatgrass or sweet clover, or sites invaded by weeds and non-native invasive species, can limit restoration potential. The grazing intensity both long term and present must be factored into the restoration potential.

These factors which indicate site sensitivity to development and restoration potential should be used to determine:

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

Figure 4- Drier is Better

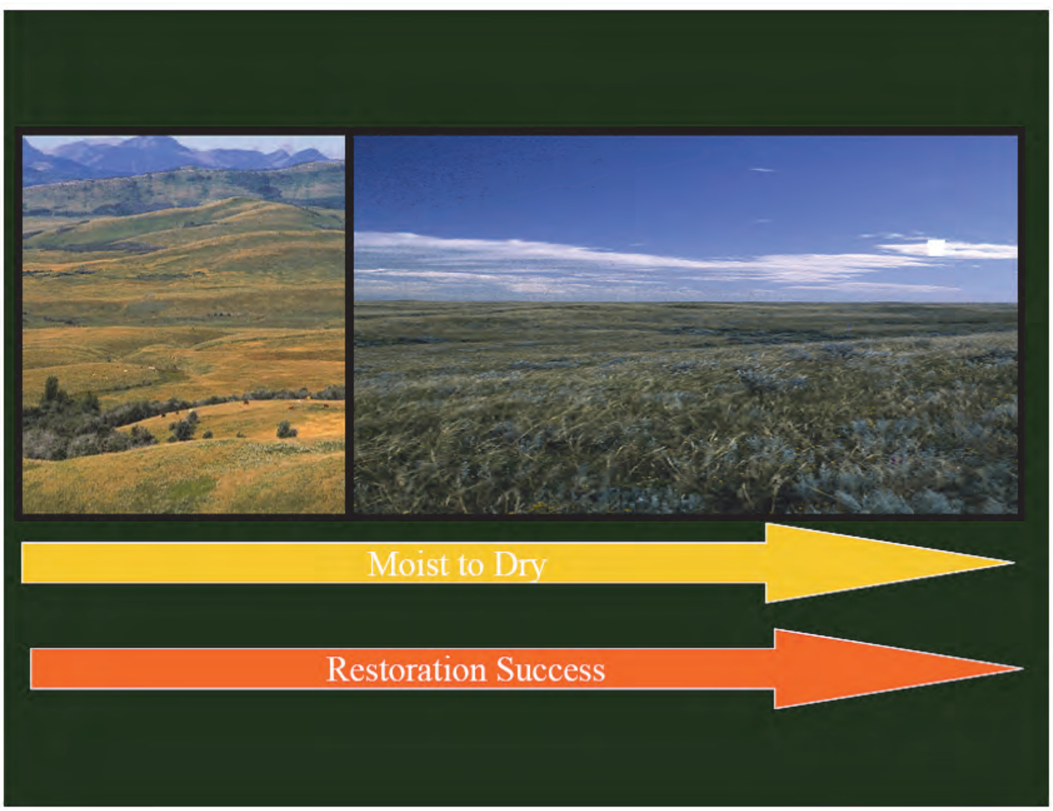


Image Courtesy of Barry Adams, ESRD Rangeland Management Branch

4 PROMOTING NATIVE PLANT COMMUNITY SUCCESSION

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 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.

Influence of Man Made Disturbance

Early Disturbance of Native Prairie

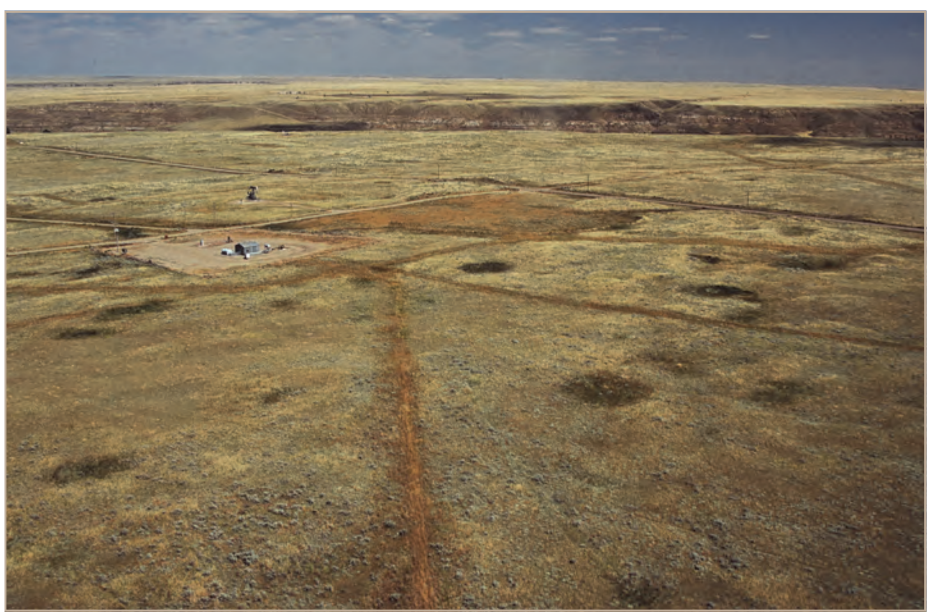
The history of reclamation in the grasslands of Alberta can be divided into four periods:

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.



Fragmentation of native plant communities; shadow effect from invasive crested wheatgrass

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.

Pipeline with full RoW soil disturbance seeded to crested wheatgrass

1993 to the Present

During this period, the importance of the native grassland plant communities' role in ecological function has been recognized and 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. 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. Some cultivars delay the process of succession because they display a competitive advantage over the wild species and are very persistent in the stand.

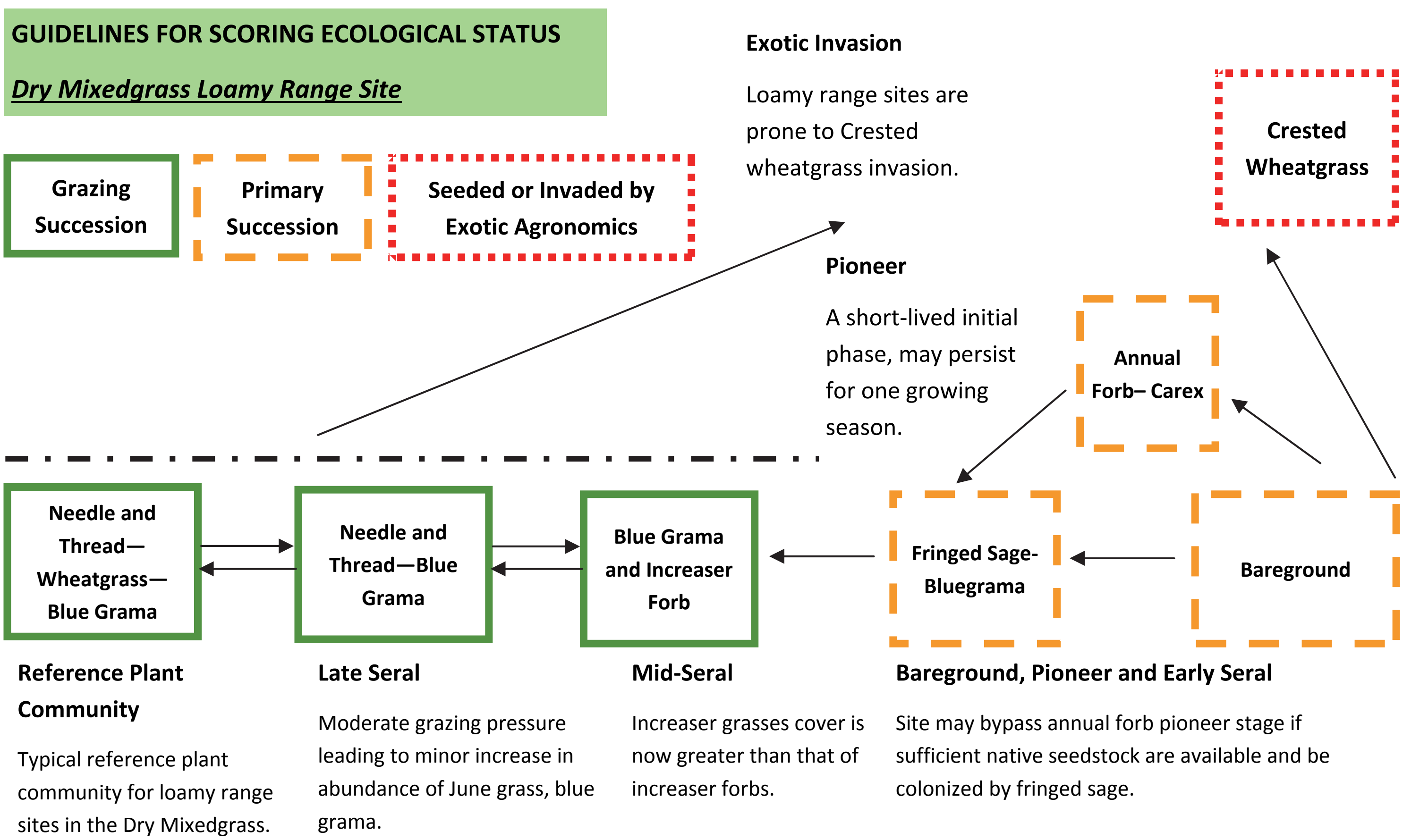
Understanding the Process of Succession

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.
- **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 smooth brome, timothy or Kentucky bluegrass) with a composition of greater than 70% non-native species.

Figure 5 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 5 – Guidelines for Scoring Ecological Status



Alberta Sustainable Resource Development—Lands Division, Rangeland Management Branch July 7, 2008

It is important to note that the pioneer, early and mid-seral stages in Figure 5 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.

Industrial Disturbance and the Process of Plant Community Succession

Appendix B is a case study entitled "*Long Term Recovery of Native Prairie from Industrial Disturbance, Express Pipeline Revegetation Monitoring Project 2010*". The purpose of this study was to provide industry and the Government of Alberta with much needed data on the long term revegetation success of reclamation techniques used on native prairie. The case study presents data, discussion and recommendations relevant to the Dry Mixedgrass, only part of a larger study. The complete report and an abridged edition 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 the 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, Russian thistle and the goosefoots 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 is not often understood 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.

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 species that are known to replace native species and establish permanent dominance in grassland communities include crested wheatgrass, smooth brome and sheep fescue in the Dry Mixedgrass NSR.

5 PREPARING THE PATHWAY

Planning to Reduce Disturbance

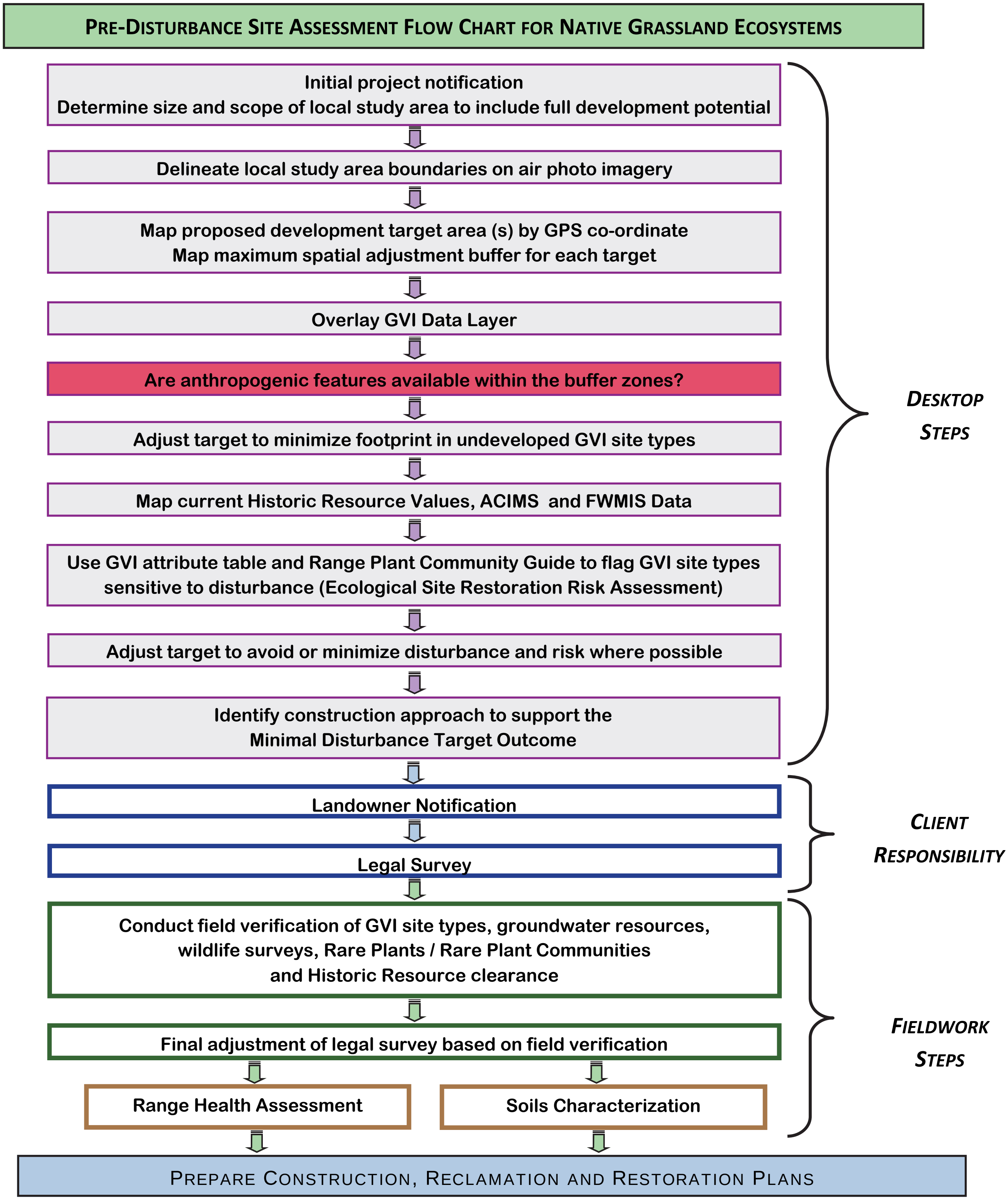
Pre-disturbance planning is the first step in identifying the footprint of industrial development in native grassland ecosystems. It provides the opportunity to avoid disturbance to native grasslands by locating development on cultivation and previously disturbed lands dominated by non-native vegetative 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 Guidelines Working Group 2002) and have been implemented widely and successfully by the industry. Other industries are encouraged to develop industry specific guidelines.

Pre-Disturbance Site Assessment

Pre-disturbance site assessment is the decision-making process that enables productive and cost effective development planning. In the Dry 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.

Dry Mixedgrass Natural Subregion

Figure 6 - Pre-Disturbance Site Assessment Flowchart for Native Grassland Ecosystems



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 imagery available. This is the area surrounding the proposed target(s) that will be directly affected by development activity. The area should be sufficiently 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. 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 with the landscape sensitivities with the proposed location and activity to 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.

Map proposed development target area by GPS coordinate. 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

Map current documented ACIMS, FWMIS data, and Historic Resource Values. Highlight areas with potential habitat for Species at Risk. Implement desktop survey of groundwater resources.

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.

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 defined outcome expectation of restoration that aligns with the 2010 Grassland Reclamation Criteria.

Communicates a progressive message to analyze, adapt and improve practices

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 Dry Mixedgrass a general timeframe for field work is May 15 to September 15. Document plant community type 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 non-native species 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 restoration.

Monitor to ensure contractual compliance.

Reduced Disturbance; Best Practices

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

Notify and Consult with Landowners and/or Grazing 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.

Manyberries Area; Pipeline Seeded with Native Plant Cultivars

- Healthy native grasslands are an important asset to the ranching industry.
- 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 developer needs to understand this and work with the rancher to reduce the impact.
- 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, to 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.
- Maintain that vital communication link through the operations phase. Use respect!

Reduced Disturbance Access Road, Natural Recovery, Manyberries Area

Reclaimed Reduced Disturbance Wellsite, Natural Recovery, Pink Flag Indicates Well Centre

Ensure Compliance with Regional Land Use Policy

The Dry 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") is reclaimed. 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;

- Canadian Forces Base Suffield through the Range Standing Orders and specifically chapter 7 of the Oil and Gas Activity Protocols;

- 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 First Nations Reserves. Exploration and development planning and activities are federally regulated and must be compliant with the Canadian Environmental Assessment Act.

Proposed Wellsite in Purple Springs Grazing Reserve

Selecting the Recovery Strategy

Selecting the most appropriate recovery strategy for the size and type of disturbance is key to restoration success in the Dry 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.

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. 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 7 provides guidance for selecting the appropriate strategy for non-linear disturbances with reduced soil disturbance (less than 25% of the lease area). Generally this refers to shallow gas wells and applicable access trails where much of the development activity takes place on unstripped soils.

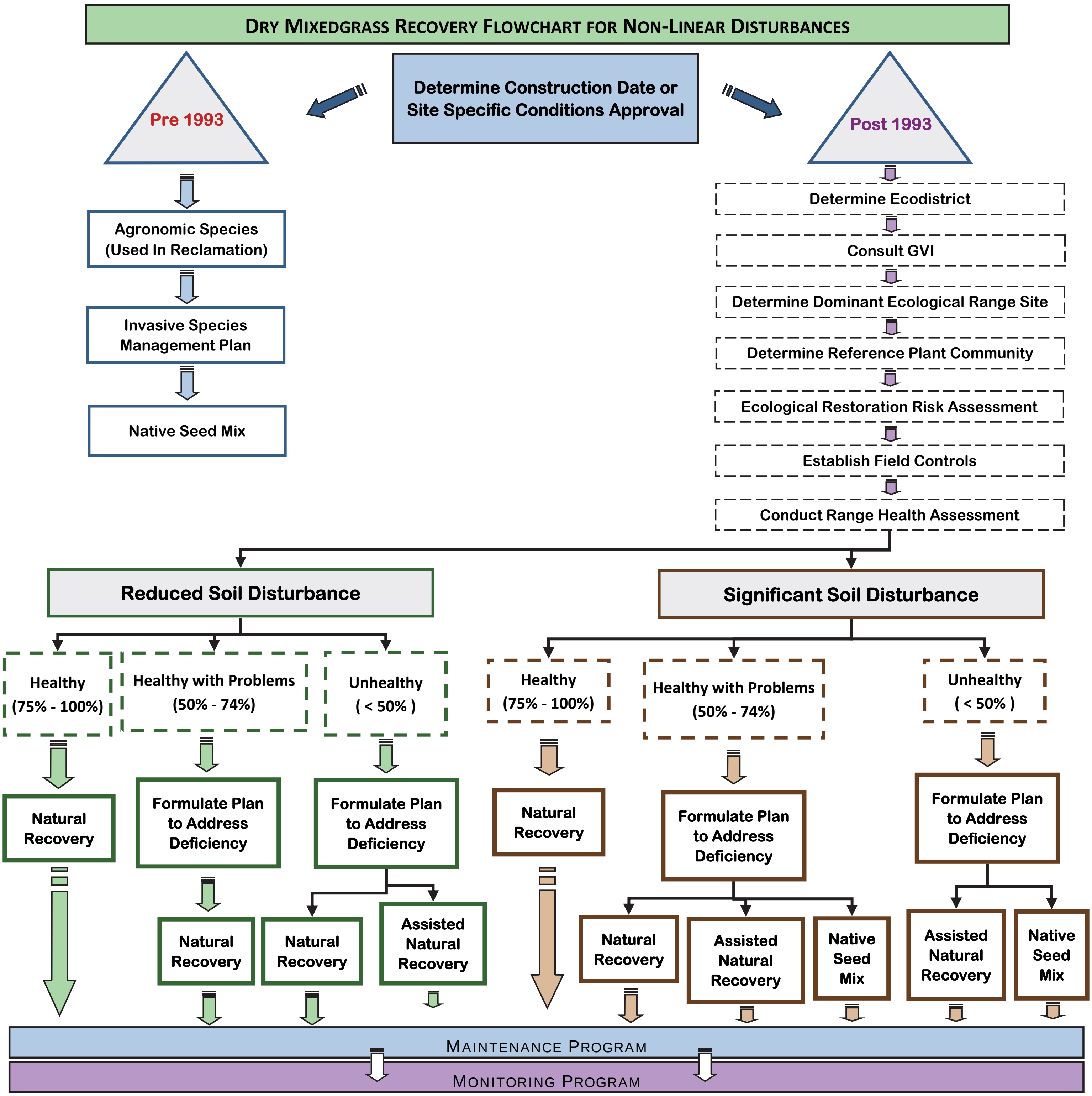
Sites with soil disturbance on more than 25% of the lease area refers to oil wells, oil production batteries, decommissioned sour gas wells, contaminated wellsites where soil remediation has taken place or topsoil has been imported, decommissioned compressor or pumping stations and reclaimed access roads. Other industrial sites such as mines, burrow pits, and turbine sites on wind farms would fall into this category.

Figure 8 provides guidance for linear disturbances.

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.

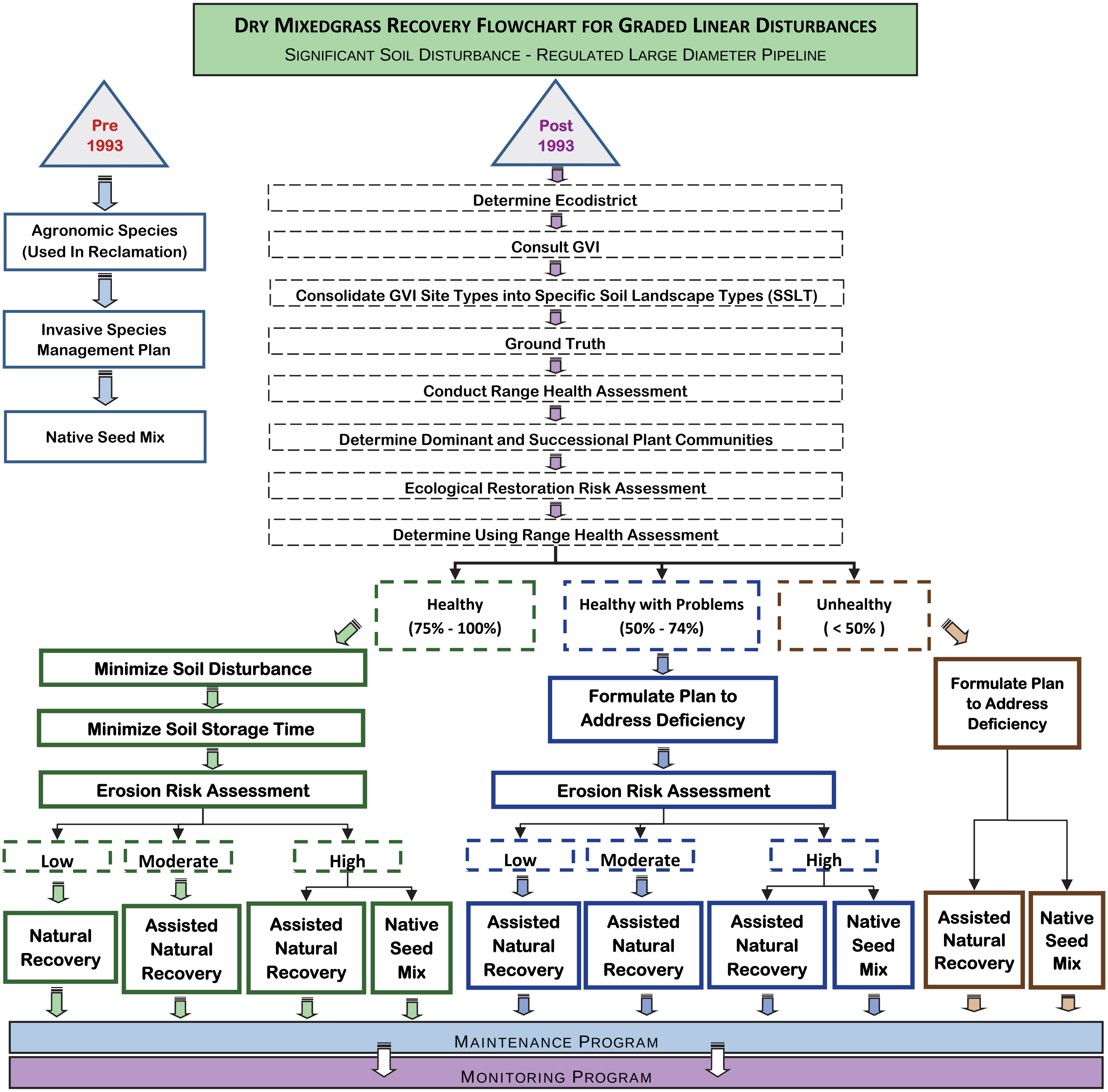
Recovery strategies include: natural recovery, assisted natural recovery and the use of native seed mixes.

Figure 7 - Recovery Flow Chart for Non-Linear Disturbances



Note: Reduced Soil Disturbance e.g. Shallow Gas Wells and access; Significant Soil Disturbance eg. Oil Wells and associated facilities, other industrial disturbances.

Figure 8 - Recovery Flow Chart for Linear Disturbances



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.

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 center, and pipeline construction where the only soil disturbance is over the trenchline**.** The pre-disturbance native vegetation recovers from the procedure providing 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 impact is short term, and development is conducted under dry or frozen ground conditions

Natural recovery is a recovery strategy that 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 determine the ecological status of the native grassland surrounding the disturbance. Does the native plant community have the resources to re-establish on the disturbed soils? Are there species present with the sufficient vigour and reproductive capability to colonize the site? Many species in the Dry Mixedgrass are uniquely adapted to site conditions. Are the key indicator species present?

Also important is whether non-native invasive species are present in the on-site community, or in the surrounding area near the site. In the Dry MIxedgrass, invasive species such as downy brome, Japanese brome, crested wheat grass, leafy spurge and the knapweed species are known to invade bare ground and are very difficult to eradicate.

The accompanying flow charts (Figures 7 and 8) for linear and non-linear disturbances provide a pathway for decision making when considering 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 Dry Mixedgrass) and within the same the year.

Observations made during the Express Pipeline long term monitoring project (Appendix B Case Study) indicate re-disturbance of stored topsoil during the spring and summer months when the seed bank and propogules have germinated during storage sets the recovery process back significantly. Patience is required. The timeframe for the recovery from bare ground to a healthy, functioning native plant community is long term.

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 ongoing 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.

On natural recovery sites, cultivars are absent from the recovering plant communities, which results in better potential to match off RoW communities in terms of composition and the structural characteristics of the local plants. (Appendix B Case Study). Native forb species play an important role in the process of native plant community succession and ecosystem function. Key indicator species such as Needle-and-thread grass (*Stipa comata*) colonize the site. The risk of introducing invasive non-native species is reduced and the gene pool of the surrounding native plant community is not compromised. The recovering disturbance gradually blends into the surrounding landscape with time.

Reclaimed Wellsite, Manyberries Area

The shrub component of Dry Mixedgrass plant communities provides important habitat for wildlife and Species at Risk such as Sage Grouse. A recent Master's Degree Thesis entitled "*Reclamation Outcomes on Energy Disturbances in Silver Sagebrush Communities*" prepared by Laura Hickman (2010), assessed pipeline and wellsite footprints relative to control sample units in Sage Grouse habitat south of Medicine Hat.

The purpose of the study was to: "*examine past and present reclamation practices and their outcomes in silver sagebrush communities in south-eastern Alberta and to recommend beneficial management for achieving successful reclamation and restoration of disturbance footprints*". A key finding of the study indicated that silver sagebrush re-established more effectively on overflow and blowout ecological range sites where natural recovery was implemented as the revegetation strategy following pipeline construction when compared to similar ecological range sites on the same pipeline project that were seeded to a native grass cultivar seed mix (Hickman 2010).

Natural Recovery Wellsite; Disturbance Confined to Well Centre

Assisted Natural Recovery

One method of assisted natural recovery is defined as seeding soil disturbances with annual or short lived perennial species to stabilize erosion prone soils to facilitate the process of revegetation by natural recovery. In the Dry Mixedgrass a combination of fall rye and flax at a light seeding rate (1/2 bushel per acre of each species) has been successfully used 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. It is important to obtain Certificates of Seed Analysis before purchasing the seed and to ensure there are 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. Ensure the source of seed has not been genetically modified.

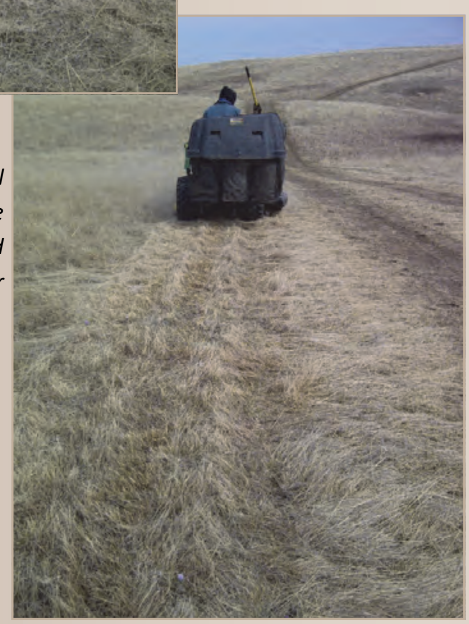
Assisted Natural Recovery, Pipeline Seeded to Fall Rye & Flax; Koomati Area

Another method of assisted natural recovery involves the mowing of the native grasses and forbs adjacent to the area to be restored and spreading the mowed “native mulch” over the bare soil and then leaving the site to recover with no additional added seed. To be successful the dominant grass species such as needle-and-thread have to be in at the mature seed set stage. Timing is essential to success. 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 within the same ecological range site as the disturbance with minimal risk of weed introduction.

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 soil erosion beyond what could be expected to occur naturally. 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.

Wild Hay Harvester; mows and collects Native Hay

Wild Harvested Hay Spread on Pipeline RoW



Minimal Disturbance to Ground Cover

Use of Native Seed Mixes

The Express pipeline case study illustrated the need for change in the way we design seed mixes for native prairie. We need to move the native seed industry forward if the expected outcome is restoration. In the Dry Mixedgrass, several of the native grass cultivars we have used in the past are too competitive to allow infill from the surrounding native plant community to occur. Also we did not have access to a reliable supply of native seed of the dominant species in the plant communities such as needle-and-thread grass and western porcupine grass. We need to change the way we design native seed mixes and develop a reliable supply of key indicator species if we are going to use native seed.

The appropriate use of native seed mixes as a recovery strategy for industrial disturbances in the Dry Mixedgrass is restricted to areas with large surface soil disturbances not suited to natural recovery or assisted natural recovery.

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 Dry Mixedgrass. These disturbances include:

Invasive Species

Large Disturbances

- 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; and
- large disturbances in rangeland where the surrounding native plant communities have low scores for plant community integrity and ecological status.

The native seed industry and supply chain has also requested direction to facilitate growth within the industry in order to meet anticipated demand. The method used in this publication is similar to the method used to design standardized seed mixes for Canadian Forces Base Suffield, and encompass the species list, plant communities and ecological range sites currently contained in the Dry Mixedgrass Range Plant Community Guide (Adams et al. 2009). The goal of the guidelines provided for seed mix design is to revegetate the disturbance with species that will establish a mid- to late-seral plant community.

Erosion and/or Stability Concerns

The current Range Plant Community Guide for the Dry Mixedgrass (Adams et al. 2009) contains 48 native grassland plant community descriptions and five 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) (Brierley et al. 2001) soil and landscape correlation.

These groupings of ecological range sites with common dominant native grass species are referred to as **target recovering plant communities**. They are clearly not native plant communities but rather composed of the dominant native grass species that are drivers in the successional process. The goal 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 in Appendix C. When seeded at the recommended low seeding rates, (8 kilograms per hectare for drill seeding and 11 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.

Pipeline Seeded with Wild Harvest Needle-and-Thread Grass

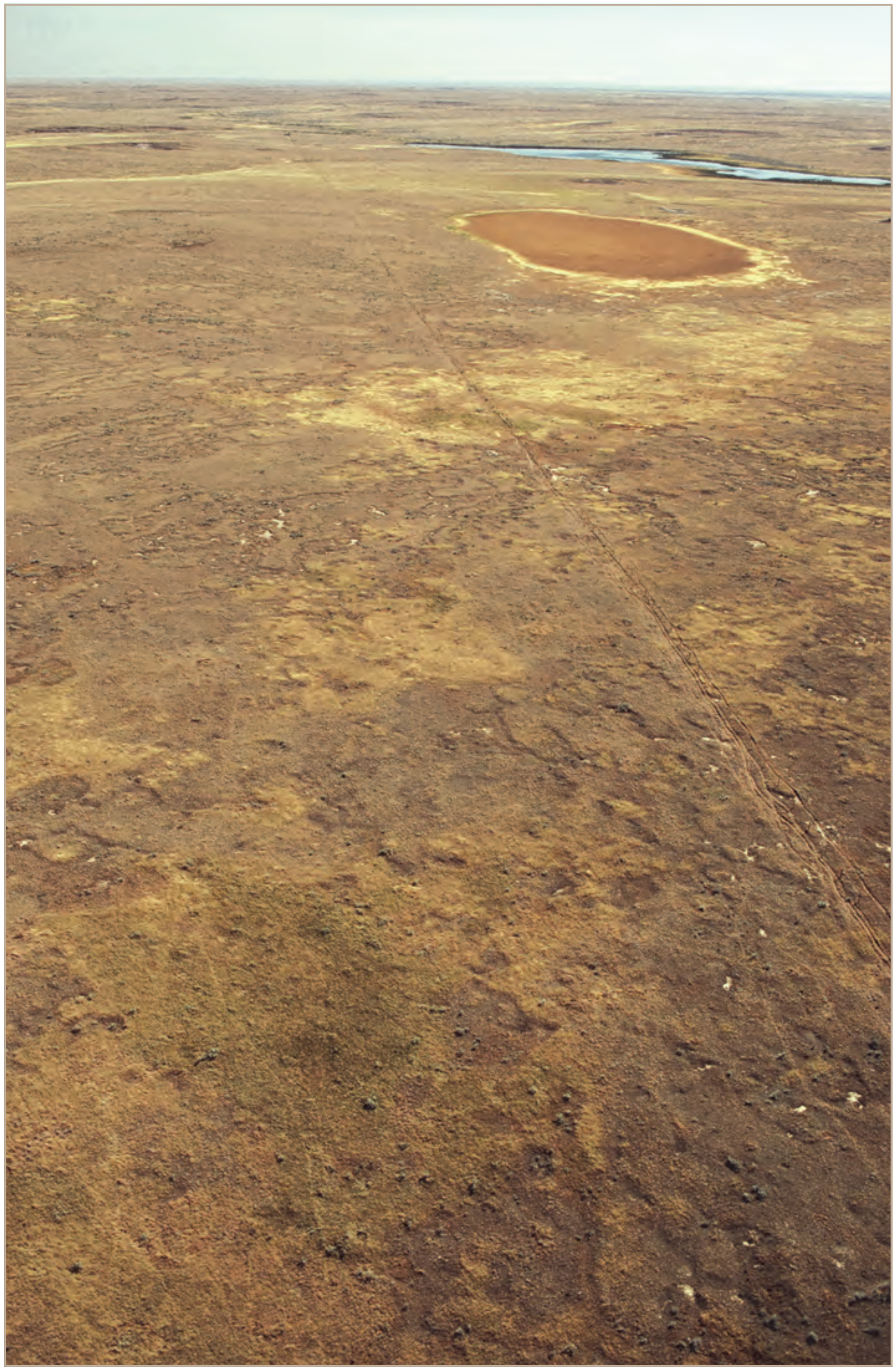
Special Consideration for Lentic and Lotic Sites

In the Dry Mixedgrass, maintaining the health and function of all classes of water bodies is extremely important in a semi-arid landscape. 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 all 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: http://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 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 and to restore local drainage patterns.



Pipeline Avoids Lentic Seasonal; Cripple Creek Area

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.

Salvaging Native Plant Material Resources

The topsoil resource in the Dry Mixedgrass NSR is thin compared to the other Grassland Natural Subregions. Average topsoil depths are in the 10 to 20cm range depending on the soil unit. 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 important resource it is important to:

- reduce the amount of area disturbed;
- minimize the soil handling within the area disturbed;
- minimize the timeframe between topsoil stripping and replacement; and
- avoid pulverizing and mixing the soils.

Sod Salvage

Site Preparation and Micro-Contouring

The native prairie is not flat. Micro-contouring facilitates seedling survival in the Dry 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 for seedling growth and reduces erosion potential. This is particularly important for natural recovery sites (Petherbridge 2000).

Selaginella in Sod Replacement on Ditchline

A Roughened Surface Retains Moisture

Recommended Timing of Restoration Activities

The timing of restoration activities affects restoration outcomes

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 for cool season grasses such as the native wheat grasses, needle-and-thread and western porcupine grass. Warm season grasses such as Blue grama should be seeded separately. They need the soil to remain consistently warm for germination and emergence, ideally mid to late June. Seeding is not recommended during the heat of the summer months when moisture is at a deficit.

Selecting Equipment to Suit the Strategy

If Native seeding is determined to be the appropriate method, it is important to understand that 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 Report 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/

Guidelines for the Procurement of Native Seed

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

- For large projects 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 Dry Mixedgrass NSR.

- 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 wheat grasses, needle-and-thread or western porcupine grass requires a minimum of 50 gram sample size, small seed species such as June grass or blue grama 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, western porcupine or blue grama grass 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 Dry Mixedgrass NSR 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 Dry Mixedgrass NSR 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 include the scientific nomenclature as well as the common name.

- 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*) in the Dry 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 Report of Seed Analysis and an explanation of interpretation is found in Appendix D.3.

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 Dry Mixedgrass NSR, 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, smooth brome and sweet clover.

Methods of obtaining the necessary material include:

1. The first method involves specially designed equipment that harvests only the seed from the culms of select species such as needle-and-thread, western porcupine grass, june grass or blue grama grass. 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 propogation of species such as needle-and-thread similar to the Ducks Unlimited 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 propogation of live plant material. The purpose is to install islands of live plant material that will create a seed source within the disturbed area.

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.

Wild Harvest of Native Grass 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 the Special Areas Board or Canadian Forces Base Suffield to determine if other guidelines are in place and/or if permits are required.

1. You will be required to obtain written support from the grazing lease holder or landowner 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, smooth brome and sweet clover.

3. You must notify the Public Lands 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 Temporary Field 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).

One source of wild harvesting equipment is available through Prairie Habitats Inc. and illustrated on their website at http://www.prairiehabitats.com/

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.

Wild Harvest Equipment

Alternating Rows

Separating Seeds

Drying Seeds

Bagged and Ready for Storage

7 MAINTAINING THE PATHWAY

Most restoration projects will require a monitoring and maintenance 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.

Colonizers, Weeds and Invasive Species Management

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 and enhance seedling survival of desired species. Control of Restricted Noxious and Noxious weeds is required under the Alberta Weed Control Act (Province of Alberta 2010a). Weed and invasive species 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 (Alberta Environment 2011), 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 weed and invasive species management with the landowner. Be aware that certified organic producers will have specific requirements and specifications for weed control.

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.

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 to the south. 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 et al. 2008) is a valuable source of information relevant to the Dry Mixedgrass NSR of Alberta.

Grazing Management

Native grasslands have evolved in association with grazing animals. Grazing is an ecological process. However, 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.
- Use 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. 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 of native species.
- Ensure temporary fencing is removed when the plant community has reached the target and litter is at optimum rates for the Dry 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 buildup 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.
- 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.
- Fencing can also restrict the movement of wildlife in the Dry Mixedgrass. Antelope are particularly sensitive to fencing. Consult with the local ESRD Fish and Wildlife biologist for recommendations for wildlife friendly fencing.
- Ensure the temporary fencing is monitored and maintained. Maintenance is not the landowners responsibility. Budget for maintenance.

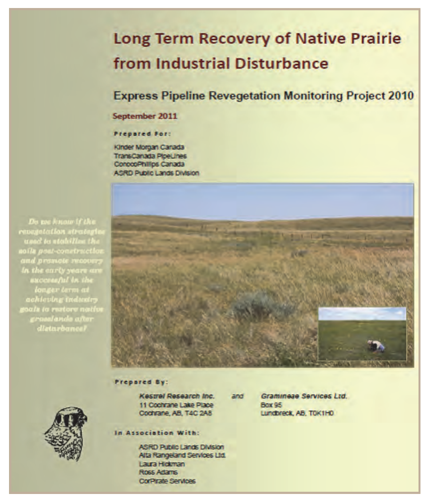
Lodged Native Grass Cultivars Seeded on Remote Sump

Cattle Grazing

Monitoring Progress

Establishing a standardized method of monitoring industrial restoration projects and evaluating restoration success is required to allow us to communicate our progress to stakeholders with increased confidence. Standardized methods will also assist in defining areas where improvement in the methods and strategies used are required. The 2010 Reclamation Criteria for Wellsites and Associated Facilities for Native Grasslands (Alberta Environment 2011) provides established methods that can be used as a baseline for monitoring. Key to the criteria is establishing permanent monitoring sites that compare the recovering disturbed site with adjacent undisturbed control sites. Some additional recommendations include:

- The timeframe for recovery will vary depending on the size 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 healing processes to take place. It is not possible to estimate an accurate timeframe at this time, however 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 up to 14 years.



- It is important to identify within the first three growing seasons possible problems on the disturbance that require remedial reclamation such as weed or non-native species issues, soils or erosion issues. The longer the problems are allowed to go unattended the more difficult and costly it will be to achieve successful restoration.
- Establish permanent photo reference points to capture the progress of restoration over time.
- Establish the observation points on lease and access and corresponding control points early in the establishment phase to assist the process of reclamation certification.
- Establish observation points on pipelines to monitor the progress of restoration over time.
- Track the process of succession towards the Target Recovering Plant Community over time. In the first years when seedlings are tiny, use a ¼ meter square plot frame to identify the species and record the number of plants per species. Determining percent (%) foliar cover of each species at this point is not that important. What is important is the species composition and how it changes over time.
- Later as vegetation becomes established, (years 3 to 5) estimating the foliar cover each species contributes to the plant community, and estimating the amount of bare soil becomes important as the recovering plant community matures. Completing a Rangeland Health Assessments at the established off site controls and onsite monitoring sites, using the standardized methods developed by the ESRD can determine is the disturbed site is on a positive successional pathway.
- 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.

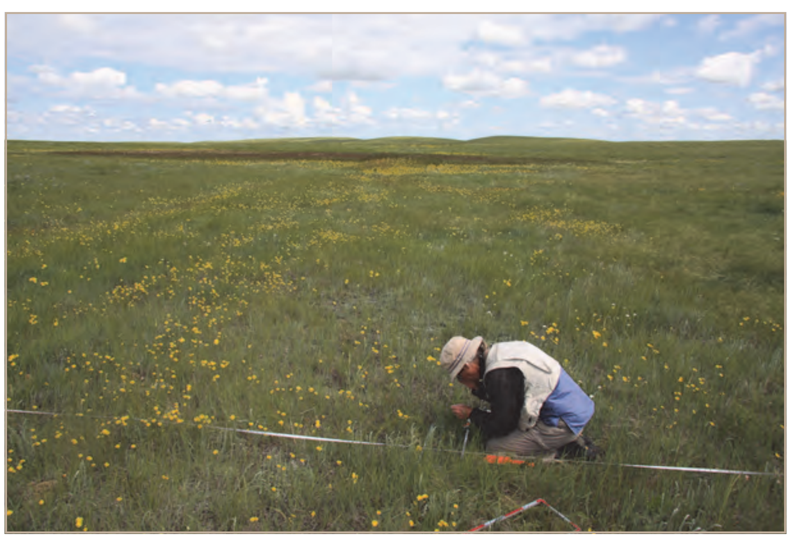
The 2010 Reclamation Criteria – Native Grasslands (Alberta Environment 2010) shifts the focus from reclamation to restoration. As wellsites and associated facilities are assessed with the criteria our knowledge of the most successful recovery strategies on a site specific basis will increase.

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.

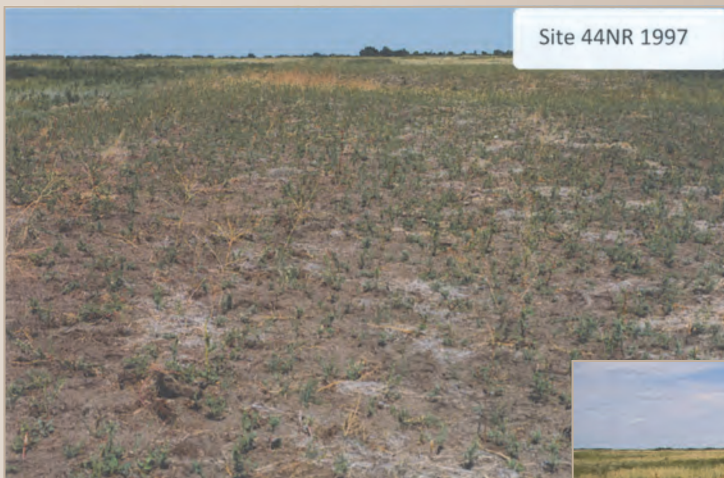
Time is an important factor in the process of recovery from industrial disturbance in native grasslands. Extended timeframe monitoring using standardized methods of evaluation provides the opportunity to reflect on construction and reclamation procedures used in the past and make informed choices that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



Jane Lancaster, Kestrel Research Inc.

Dry Mixedgrass Monitoring, Hemaruka Dunes, Example from Express Pipeline Monitoring



1997 Row

2010 RoW

1997 at 4m on RoW

2010 at 4m on RoW

9 FUTURE RESEARCH REQUIRED

The development of new native grass cultivars for the Dry Mixedgrass Natural Subregion is a research priority. Collection for the foundation seed stock must come from within the Dry Mixedgrass and should be renewed every three to five years. Species required include: Slender, Northern and Western wheatgrass, Green needle grass, June grass and Sand grass. These species are major components of the native seed required for restoration but are not well suited to wild harvest. Further concepts for research projects include:

- Research into grazing regimes that compliment recovery and restoration of native plant communities is required.

- Research is required to understand the role grazing plays in successful restoration outcomes.

- Research into the development of Type 1 and 2 forb and shrub plant material for restoration projects. What are the best methods of propagation (seed or transplants) for long term establishment?

- Research to define the appropriate timing and frequency required to monitor the successional pathways of recovering native plant communities.

- Data collection and analysis to better understand the progress of a positive successional trajectory regarding both cover values and the time required to reach successful reclamation certification.

- Research is required into the mechanisms and timeframe for recovery of the moss and lichen layer following industrial disturbance.

- Research regarding the roll excess litter accumulation plays in altering the moisture regime and native plant community succession following industrial disturbance. What are threshold values and are they easily measured?

- A mechanism is required to pool industry collected vegetation data to support the understanding of successional pathways following industrial disturbance.

- Information sharing will facilitate advancement of reclamation science. Research into information management systems that will facilitate information sharing is required.

Recovery Strategies Feedback

The creative process in the evolution of this manual has been a collaborative effort since the idea was conceived. We welcome comments and feedback as we continue with Revegetation Strategies for all the Natural Subregions and look forward to future research and technology that will yield a need for the Second Approximation of the Revegetation Strategies for the Dry Mixedgrass Natural Subregion of Alberta.

If you have any questions, comments or require further information regarding the manual we can be contacted via the Foothills Restoration Forum website at: http://www.foothillsrestorationforum.ca/

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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, wetands 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 sucessional pathway. Seral stages begin at the pioneer stage of **early seral** , and progress upward in sucession 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 LONG TERM MONITORING: WHAT HAVE WE LEARNED? CASE STUDY OF EXPRESS PIPELINE

B.1 Why is Express Important?

The purpose of the Express Pipeline Long-term Revegetation Monitoring Project (Express) is to provide 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 case study provides a summary of the findings associated with the assessment of reclamation techniques implemented on Express in the Dry Mixedgrass Natural Subregion.

Express Pipeline (Express), 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. Further monitoring could build on the initial five years monitoring results.

B.2 Analysis of Long Term Recovery Using the Cumulative Dataset

To assess whether succession towards pre-disturbance native plant communities is occurring, a time series of observations comprised of detailed vegetation transects from each monitoring site collected one, two, three, five and 14 years post-construction, were analysed. Methods included cluster analysis and non-metric multi-dimensional scaling analysis. The resulting groupings of species (communities) were described using indicator species analysis. Variations in successional pathways and subsequent seral stages for the reclaiming plant communities were observed as a result of the soil handling techniques and various environmental conditions(i.e.,drought, grazing regimes). Parameters were developed to identify the various seral stages of communities recovering from disturbance and applied to each group resulting from the plant community ordination analysis.

In addition, range health assessments were conducted on the disturbances and adjoining controls for comparison.

B.2.1 Results – Dry 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.

Cultivars

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.

The expression and percent cover of seeded species over time on five sites seeded to Sandy Soil Mix 3 are illustrated in Figure B2. The naturally occurring cover of these species on control sites is also shown. Components of the seed mix are presented in Table B2.

- In the Dry Mixedgrass, slender wheatgrass and northern wheatgrass behaved as transition species, establishing in the early years and providing initial cover to stabilize soils, build litter and shelter other seedlings. Both species are diminishing with time to near natural cover levels.

- Western wheatgrass established early but cover has slowly increased over the 14 years. Western wheatgrass persists at greater cover than on the controls.

- Seeded June grass developed a persistent but low cover in the earlier years which has not changed much over time. This species is beneficial for rebuilding diversity, the mid structural layer and is resilient to grazing.

- Green needle grass cover increased steadily over five years in both the Sandy and Solonetzic seed mixes. By year 14, cover levels have declined on Solonetzic sites. However, on Sandy soils, green needle grass cultivars persist at cover levels that are significantly higher than on control sites resulting in higher canopy structure than found on the controls.

- Sand grass (sand reed grass) cultivars developed average cover levels comparable to controls, but their large size creates a persistent increase in canopy structure on the reclaiming RoW relative to the controls.

- Non-native sheep fescue is invasive, increasing in cover on the RoW slowly but steadily on both healthy and unhealthy rangeland. Sheep fescue may contribute to plant community modification over time.

- After 14 years, persistent cultivars that are still expanding or maintaining relative cover beyond control levels are influencing the trajectory of plant community succession.

Figure B1 - Dry Mixedgrass Solonetzic Soil Seed Mix 4 – Species Cover Over Time

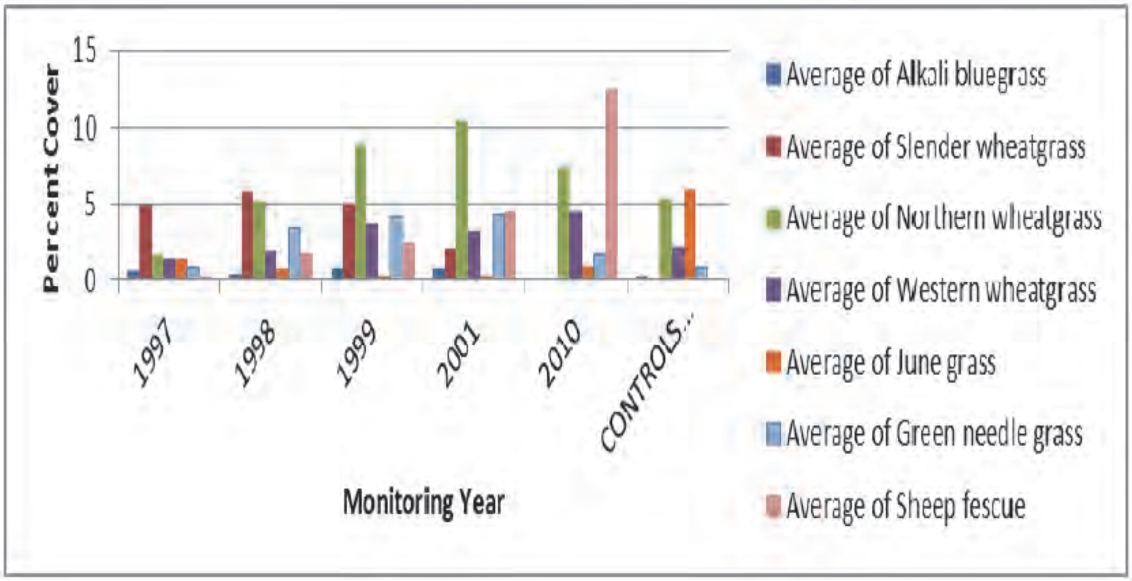


Table B1 - Express Seed Mix 4 Dry Mixedgrass Prairie Solonetzic Soils

Species	seeds/g	PLS	est%	PLS/m2	plt/m2	kg/ha	%/wt	total kg
Western wheatgrass	242	92	25	20	5	0.9	7.8	737
Slender wheatgrass *Revenue*	353	83	25	18	5	0.6	5.4	515
Slender wheatgrass *Adanac*	353	86	25	25	6	0.8	7.1	676
Streambank wheatgrass	344	92	25	61	15	1.9	16.7	1589
Northern wheatgrass	345	92	25	24	6	0.8	6.5	620
Green needle grass *(MB)*	398	88	10	40	4	1.1	9.9	937
Green needle grass *(AB)*	398	81	10	40	4	1.2	10.7	1017
Sheep fescue	1498	88	5	200	10	1.5	13.1	1244
June grass *Prairie Seeds*	3300	80	5	200	10	0.8	6.5	621
Alkali bluegrass	2022	53	5	200	10	1.9	16.1	1530
Totals				**829**	**75**	**12**	**100**	**9486**

Figure B2 - Dry Mixedgrass Sandy Soil Seed Mix 3 - Species Cover Over Time

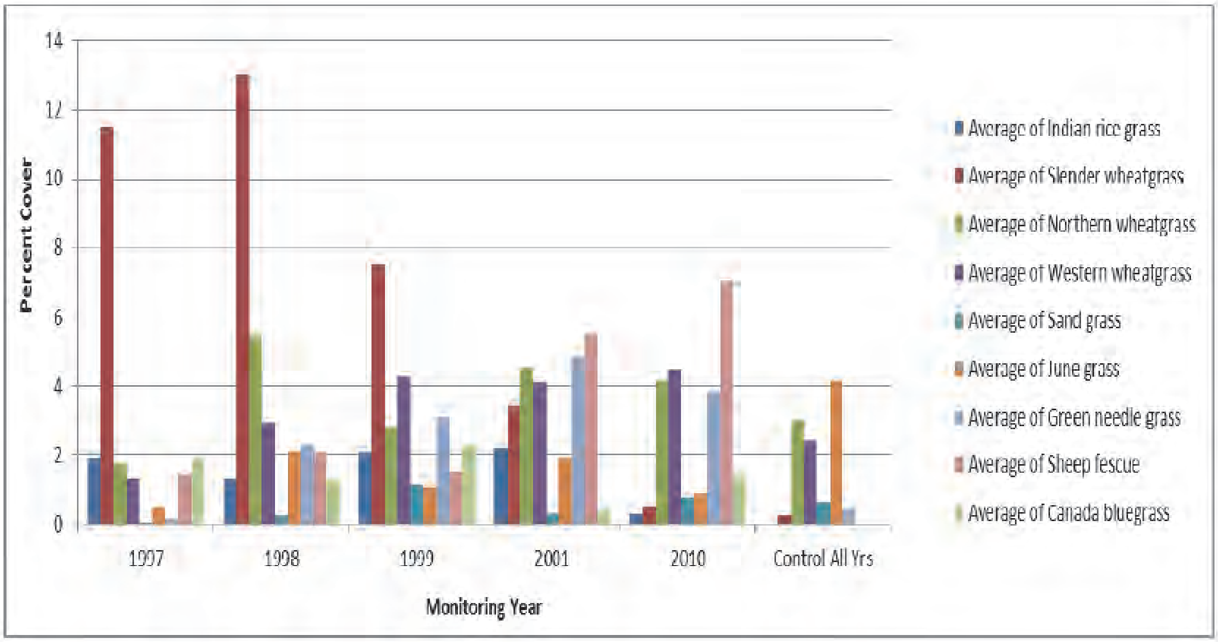


Table B2 - Express Seed Mix 3 Dry Mixedgrass Prairie Sandy Soils

Species	seeds/g	PLS	est%	PLS/m2	plt/m2	kg/ha	%/wt	total kg
Streambank wheatgrass	344	92	25	26	6	0.8	5.4	324
Northern wheatgrass	345	92	25	24	6	0.8	5.1	302
Western wheatgrass	242	92	25	24	6	1.1	7.2	431
Slender wheatgrass *Revenue*	353	83	25	16	4	0.5	3.7	218
Slender wheatgrass *Adanac*	353	85	25	24	6	0.8	5.3	316
Prairie sand reed *ND95*	603	61	10	42	4	1.1	7.6	455
Prairie sand reed *Goshen*	603	82	10	34	3	0.7	4.6	277
Green needle grass *Blight*	398	88	10	40	4	1.1	7.7	457
Indian rice grass	518	86	10	200	20	4.5	30.1	1796
Sheep fescue	1498	88	5	200	10	1.5	10.2	607
Canada bluegrass	5555	80	2	500	10	1.1	7.5	450
June grass *Prairie Seeds*	3300	80	5	221	11	0.8	5.6	335
Totals				**1351**	**91**	**15**	**100**	**5,968**

B.2.2 Results – Natural Recovery

Natural recovery trials were established at three upland locations on the pipeline RoW; two on Solonetzic soils in the Dry Mixedgrass, one on Sandy soils in the Dry Mixedgrass. 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.

Over 14 years, native plant communities re-established on all the natural recovery sites. 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. On all Dry Mixedgrass sites there was significant establishment of needle grasses and wheatgrasses that are dominant in the reference plant community state.

Timing of topsoil replacement is an important factor in the outcome of the natural recovery trials. The best results in terms of reflecting the composition and cover levels of the surrounding undisturbed prairie were on Dry Mixedgrass sites where soils were replaced before the following growing season. The cover of key species for the Dry Mixedgrass, blue grama and needle-and-thread, were greatly reduced on the Rainy Hills sites where topsoils were stored through the winter and re-handled once conditions were dry enough in late spring.

The timing and duration of livestock grazing can also affect the success of natural recovery. It was observed that natural recovery sites located in large fields with healthy range health scores responded to natural recovery more readily than smaller fields that had range health scores in the "healthy with problems" range.

B.2.3 Results – Plant Community Succession

For the analysis of succession, sites were grouped by Natural Subregion (NSR) and Ecological Range Site (ERS) and compared within these similar climate / physiography / soils units. Dry Mixedgrass Loamy and Blowout-Solonetzic ERS groups and the Mixedgrass Limy and Loamy ERS groups are included in the analysis. A number of successional plant communities were differentiated within each group (see Table B3 for definitions of seral stages).

The accompanying figures illustrate the observations that clustered together based on similarities in species composition (an observation is the data from one site in a particular year (e.g. site 6 in 1999)). The plant community was named based on the species that were present most frequently and provided the most cover. The "Group Number" associated with each plant community references a more detailed description of the community found in Appendix C of the full report.

Reclaiming sites are generally progressing from early to late seral communities with successional progress variously influenced by 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.

Table B3 - 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 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
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
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
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, smooth brome and sheep fescue in the Dry Mixedgrass NSR. There has been a debate about whether Kentucky bluegrass should be included in the "trending to modified" 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.*

Dry Mixedgrass – Blowouts/Solonetzic Ecological Range Sites

Figure B3 shows the plant communities that developed over time on both seeded and unseeded Solonetzic range sites in the Dry Mixedgrass. There are four pioneer communities, three dominated by annual weeds and one by seeded slender wheatgrass. Seeded sites remained in a pioneer stage for one to three years, unseeded sites one to four years. Two early seral plant communities were identified on Solonetzic Dry Mixedgrass range sites dominated by the native perennial disturbance forb, pasture sagewort, and the colonizing native perennial grass, needle-and-thread. Most of the reclaiming plant communities remained in an early successional state for two to five years after disturbance. Late seral plant communities are characterized by a dominance of decreaser grasses, the presence of infill species and no more than one structural layer missing. Two late seral communities were identified; one linked to seeded sites and a second found primarily on unseeded sites in later years.

Figure B3 - Plant Community Succession on Disturbed Topsoils on Dry Mixedgrass Solonetzic Ecological Range Sites

		Pioneer			→	Early Seral	→	Mid-seral	Late Mid-seral	Late Seral	→	Trending to Modified	
	Site # *	Slender Wheatgrass-Northern Wheatgrass-Pasture Sagewort	Common Knotweed - Pasture Sagewort - Slender Wheatgrass	Nuttall's Atriplex/ Knotweed sp.-Pasture Sagewort	Summer Cypress-Lamb's quarters-Slender Wheatgrass	Pasture Sagewort-Needle-and-Thread Grass	Pasture Sagewort-Needle-and-Thread Grass - June Grass	Northern Wheatgrass-Pasture Sagewort-Western Wheatgrass	Needle-and-Thread Grass - Pasture Sagewort-Northern Wheatgrass	Western Porcupine Grass - Western Wheatgrass - Pasture Sagewort	Western Wheatgrass -Pasture Sagewort	Sheep Fescue - Northern Wheatgrass –Pasture Sagewort / Moss and Lichens	Sheep Fescue-Pasture Sagewort-Northern Wheatgrass
SEEDED**	6D	1, 2								3, '5			14
	7D		1		2, 3	14					5		
	8D	1, 3				2				14		5	
	28D	1										2, 14	3, '5
	29D	1				2		3, 5					14
	34D					2, 3			1, 5				14
UNSEEDED**	30N		5	1, 2		3					14		
	46N					2, 3, 5, 14							
	47N					2, 3, '5					14		
	48N					3, '5	2, 14						
	49N					2, 3, '5					14		
Unstripped Spoil Storage Area 9S					1			2	3, 5, 14				
Unstripped Spoil Storage Area 27S							1, 2, 3, 5						
Unstripped Travel Lane 32T							3, '5	1, 2					

Site Number Modifiers: D=disturbed topsoil, N=natural recovery site, S=unstripped spoil storage area, T=unstripped travel lane

*** Years since disturbance is recorded for the plant community at each site*

Dry Mixedgrass – Loamy Ecological Range Sites

Figure B4 shows the plant communities that developed over time on seeded and unseeded Loamy range sites in the Dry Mixedgrass. Two pioneer communities, dominated by seeded slender wheatgrass or an unseeded annual forb are prevalent on seeded sites in the first years post-disturbance. All the natural recovery sites on Loamy soils, including unstripped spoil storage areas and disturbed soils, begin their recovery at the early seral stage.

On seeded sites, the cluster analysis indicates two mid-seral plant communities. One community is comprised primarily of seeded species, the other of colonizing grass species from the seed bank, pasture sagewort and seeded green needle grass. These mid-seral communities are prevalent between two and three years after disturbance, but linger in some cases for five to 14 years.

Most unseeded sites progressed directly from early seral to late mid-seral plant communities and did so in five years after disturbance .

Figure B4 - Plant Community Succession on Dry Mixedgrass Loamy Ecological Range Sites

	Pioneer	→	Early Seral	→		Mid-seral	→	Late Mid-seral	→	Late Seral	Trending to Modified
Site # **	**Summer Cypress-Slender Wheatgrass**	**Slender Wheatgrass - Western Wheatgrass - Northern Wheatgrass**	**Low Sedge - Pasture Sagewort**	**Pasture Sagewort - Northern Wheatgrass**	**Narrow-lved Goosefoot - Pasture Sagewort - Northern Wheatgrass**	**Northern Wheatgrass - Green Needle grass - Western Wheatgrass**	**Needle-and-Thread Grass - Green Needle Grass - Pasture Sagewort**	**June Grass - Pasture Sagewort - Northern Wheatgrass**	**Needle-and-Thread grass - Pasture Sagewort**	**Needle-and-Thread grass - Northern Wheatgrass**	**Sheep Fescue - Northern Wheatgrass**
14D											**14**
11D			**1**	**2, 3**			**6**		**5**		
12D		**1**		**6**		**2, 3, 5**					
13D		**1, 3**				**2, 14**					**5**
14D	**1, 2**					**3, 5, 14**					
15D		**1**					**2, 3**			**5**	**14***
35D		**1**					**2, 3**		**14**		**5**
60N					**2**		**3**		**5, 14**		
61N					**2, 3**					**5, 14**	
63N				**1, 3**	**2**				**5**		
14S			**1, 2, 3**						**5, 14**		
31S								**1**		**2, 3, 5**	
36S								**1, 2**	**3, 5**		

** Site Number Modifiers: D=disturbed soil, N=natural recovery site, S=unstripped spoil storage area*
*** Years since disturbance is recorded for the plant community at each site*

Dry Mixedgrass – Sandy Ecological Range Sites

Figure B5 shows the plant communities that developed over time on six unseeded natural recovery sites on disturbed topsoils (sites 40N – 45N) and an unstripped travel lane (site 5T) in Sandy range sites as identified by GVI. The first two years of data collection on four of the six natural recovery sites was not used.

The unstripped travel lane site is a heavily grazed pasture and the plant community (Buckbrush – Sun-Loving Sedge - Pasture Sagewort) remains as a mid-seral plant community dominated by increaser species during all of the monitoring years.

The six natural recovery sites of the Hemaruka Dunes progress from pioneer plant communities in the first year or two to early seral and late seral communities in the third year.

The pioneer community is dominated by an exotic annual weed, lamb's quarters, and rhizomatous native perennials.

The early seral community is dominated by an introduced annual mustard. The native perennial grass western porcupine grass and pasture sagewort are establishing on the RoW. The late seral plant communities are characterized by the dominance of species that characterize the reference plant communities for Sandy ecological range sites, including western porcupine grass, needle-and-thread, and sand grass.

By year five all of the sites have developed to late seral plant communities dominated by needle-and-thread or western porcupine grass. One site (40) is clustering with a mid-seral plant community, but this is likely due to the high cover of buckbrush on this site.

Figure B5 - Plant Community Succession on Unseeded Topsoil on Dry Mixedgrass Sandy Ecological Range Sites

	Pioneer	Early Seral	Mid-seral	Late Seral →		
Site# *	**Prairie Rose - Lamb's Quarters - Prairie Sagewort****	**Tansy Mustard - Western Porcupine Grass - Pasture Sagewort****	**Buckbrush -Sun-Loving Sedge - Pasture Sagewort****	**Western Porcupine Grass - Pasture Sagewort - Sand Grass****	**Needle-and-Thread - Pasture Sagewort - Kentucky Bluegrass****	**Needle-and-Thread - Blunt Sedge - Sand Grass****
40N			**14**	**2, 3, 5**		
41N				**2, 3, 5**	**14**	
42N				**5**		**2, 3, 14**
43N				**5**		**2, 3, 14**
44N	**1**	**3**		**5**	**2, 14**	
45N	**1, 2**	**3**		**5**	**14**	

** Site Number Modifiers: N=natural recovery site*

*** Years since disturbance is recorded for the plant community at each site*

B.2.4 Summary of Succession on Seeded Disturbed Topsoils

Seeded Soils

- Unfortunately the use of sheep fescue in the Dry Mixedgrass seed mixes has resulted in 50% of these sites trending to modified plant communities over 14 years. The communities are still primarily native plant communities but non-native sheep fescue cover is increasing over time and occupying > 5% of the total live cover.

- For seeded sites that remain as early or mid-seral plant communities after 14 years (both in the Mixedgrass and the Dry Mixedgrass), 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

On Dry Mixedgrass soils, 78% of the natural recovery sites support late mid-seral to late seral communities after 14 years.

- *Dry Mixedgrass Solonetzic Soils*: Three of five natural recovery sites support a late seral plant community dominated by western wheatgrass and pasture sagewort. Two remain as early seral communities with pasture sagewort still dominant, due to past grazing intensity and drought conditions.

- *Dry Mixedgrass Loamy Soils:* Of the two sites, one is a late mid-seral Needle-and-Thread – Pasture Sagewort community and the other is a late seral Needle-and-thread – Northern Wheatgrass community.

- *Dry Mixedgrass Sandy Soils:* The six sites all re-established to a late seral Western Porcupine Grass – Pasture Sagewort community by the fifth year. By year 14, five of the sites shifted to two different late seral needle-and-thread communities. One site shifted to a mid-seral stage buckbrush / sun-loving sedge community.

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. Most monitoring sites maintained the same plant community cover over five years. Some sites have maintained the same plant community over the 14 year recovery period.

Table B4 - Seral Stage on Unstripped Spoil and Travel Lane Sites after 14 Years

Unstripped Construction Areas *	Site # **	Seral Stage on Revegetating Unstripped Soils in 2010				
		Pioneer	Early Seral	Mid-seral	Late Mid-seral	Late Seral
DMG - Solonetzic: Spoil	9S	97		98	99, 01	
DMG - Solonetzic: Spoil	27S		97, 98, 99, 01			
DMG - Solonetzic: Travel Lane	32T		99, 01	97, 98		
DMG - Loamy: Spoil	10S		97, 98, 99		01, 10	
DMG - Loamy: Spoil	31S				97	98, 99, 01
DMG - Loamy: Spoil	36S				97, 98, 99, 01	
DMG - Sandy: Travel Lane	5T			97,98,99,01,10		

** DMG = Dry Mixedgrass*

*** Site Number Modifiers: S=unstripped spoil storage area, T=unstripped travel lane*

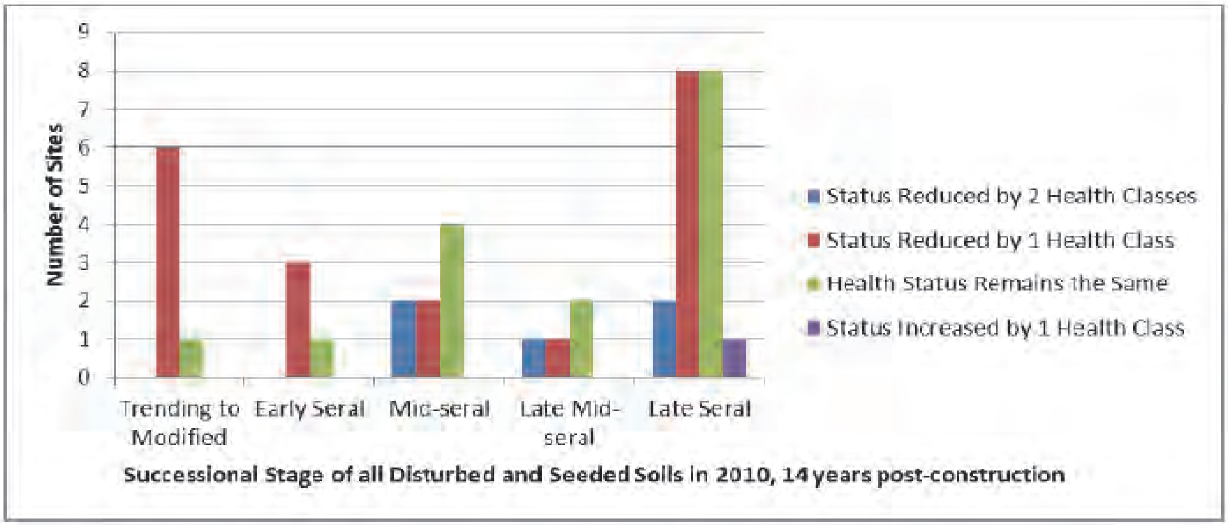
B.2.5 Results – Range Health

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. 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 B6 - Ecological Status and Seral Stage of Reclaiming Sites on Disturbed Soils



Plant Community Structure

Structrual 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. Bare soils, above normal values, were 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 Dry 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 Dry 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.2.6 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 reclaiming soils in the Dry Mixedgrass. The assessment compares 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 are the 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) on natural recovery sites as opposed to the high cover, low diversity seed mix graminoid cover 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.3 Management Recommendations

A number of 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.

- New tools for planning restoration of native prairie after disturbance will identify ecological site characteristics and target plant communities for restoration planning.

- 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 (ERS).

- 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 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 the Dry 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 is lower than the surrounding rangeland.

APPENDIX C TARGET RECOVERING PLANT COMMUNITIES

Introduction

Designing native seed mixes for industrial disturbances not suited to natural recovery in the Dry 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 current Range Plant Community Guide for the Dry Mixedgrass contains 48 native grassland plant community descriptions and five native shrubland plant communities (Adams et al. 2005). 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 (Brierley et al. 2001). These groupings 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 dominant native grass species that are drivers or principle species in the successional process.

The specifics of the target recovering plant communities for each grouping of ecological range sites are presented in this appendix accompanied by recommendations for seed mix design. The recommended native grass species can be seen as facilitating plant community succession and 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 recommended native grass species, 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. It is recommended that qualified professionals with experience in native prairie restoration be consulted for native seed mix design.

C.1 Target Recovering Plant Community for Loamy, Shallow to Gravel and Gravel Range Sites

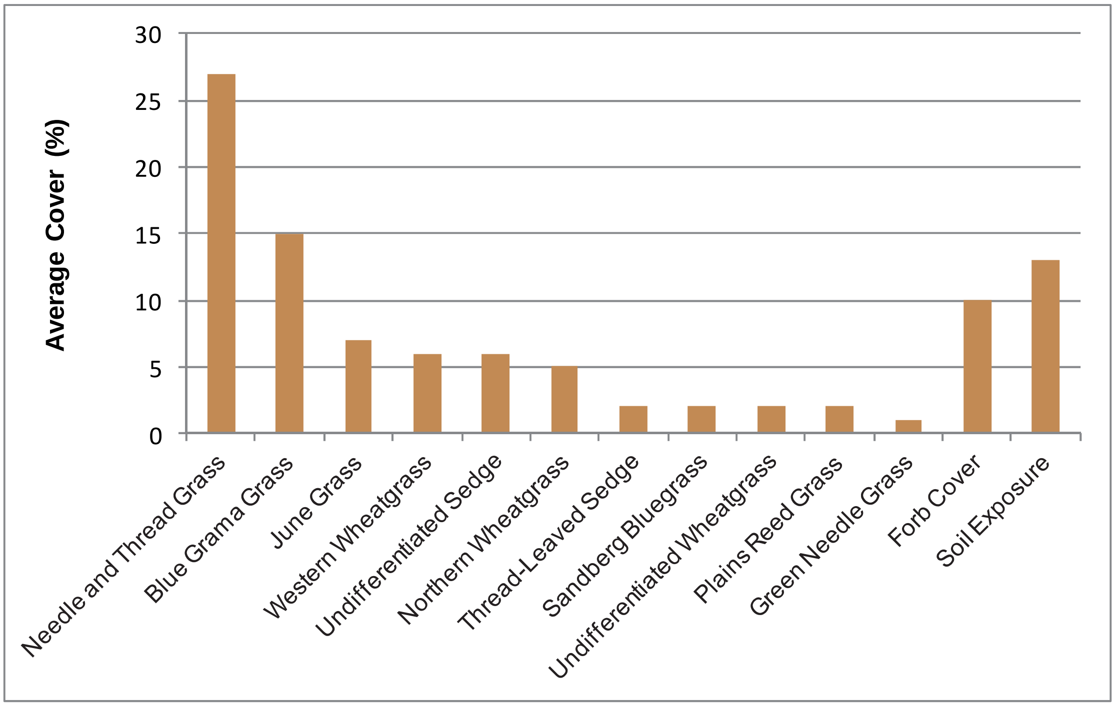
This target recovering plant community is a result of grouping the loamy ecological range sites as described in the Dry Mixedgrass Range Plant Community Guide (Adams et al. 2005). Shallow to gravel and gravel range sites were added to this grouping as they occupy a relatively small portion of the landscape, often associated with loamy sites and with similar dominant species. Refer to the Dry Mixedgrass Range Plant Community Guide, Table 9 for a listing of the Reference Plant Communities and Successional Community Types for loamy, shallow to gravel and gravel range sites.

The grouping includes mid and late seral stage and reference plant communities found on loamy textured topsoils. Common dominant species include Needle-and-thread grass, blue grama grass, June grass and northern wheatgrass. To produce this target recovering plant community the mean per cent cover of each of the graminoid species described for each plant community within the grouping was sorted and the average value used to describe the target recovering plant community. The average mean percent cover of all forb species, moss and lichen, total vegetation and exposed soil is listed as well to provide a detailed description of the recovering community. This grouping 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 Loamy, Shallow to Gravel and Gravel Range Sites

Species	Common Name	Average % Cover	% Constancy
Stipa comata	Needle-and-thread Grass	27	100
Bouteloua gracilis	Blue Grama Grass	15	96
Koeleria macrantha	June Grass	7	96
Agropyron smithii	Western Wheatgrass	6	62
Carex species	Undifferentiated Sedge	6	89
Agropyron dasystachyum	Northern Wheatgrass	5	46
Carex filafolia	Thread-Leaved Sedge	2	6
Poa sandbergii	Sandberg Bluegrass	2	52
Agropyron species	Undifferentiated Wheatgrass	2	6
Calamagrostis montanensis	Plains Reed Grass	2	49
Stipa viridula	Green Needle Grass	1	0.4
Average Total Vegetation Cover		**68**	
Average Forb Cover		**10**	
Average Moss and Lichen Cover		**27**	
Average Soil Exposure		**13**	

Figure C1 - Target Recovering Plant Community for Loamy, Shallow to Gravel and Gravel Range Sites



This information can then be used to design a native seed mix based on the common dominant species in the grouping 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 (PLS) by weight. An example for this grouping could include:

Table C2 - Example Native Seed Mix for Loamy, Shallow to Gravel and Gravel Range Sites

Species	Proportion of Seed Mix % PLS by Weight	
Needle & Thread Grass	*Stipa comata*	40%
Blue Grama Grass	*Bouteloua gracilis*	25%
Slender wheatgrass	*Agropyron trachycaulum*	10%
Northern wheatgrass	*Agropyon dasystachyum*	10%
June Grass	*Koeleria macrantha*	15%

Slender 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 needle and thread and blue grama has been slightly 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.2 Target Recovering Plant Community for Blowout and Clayey Range Sites

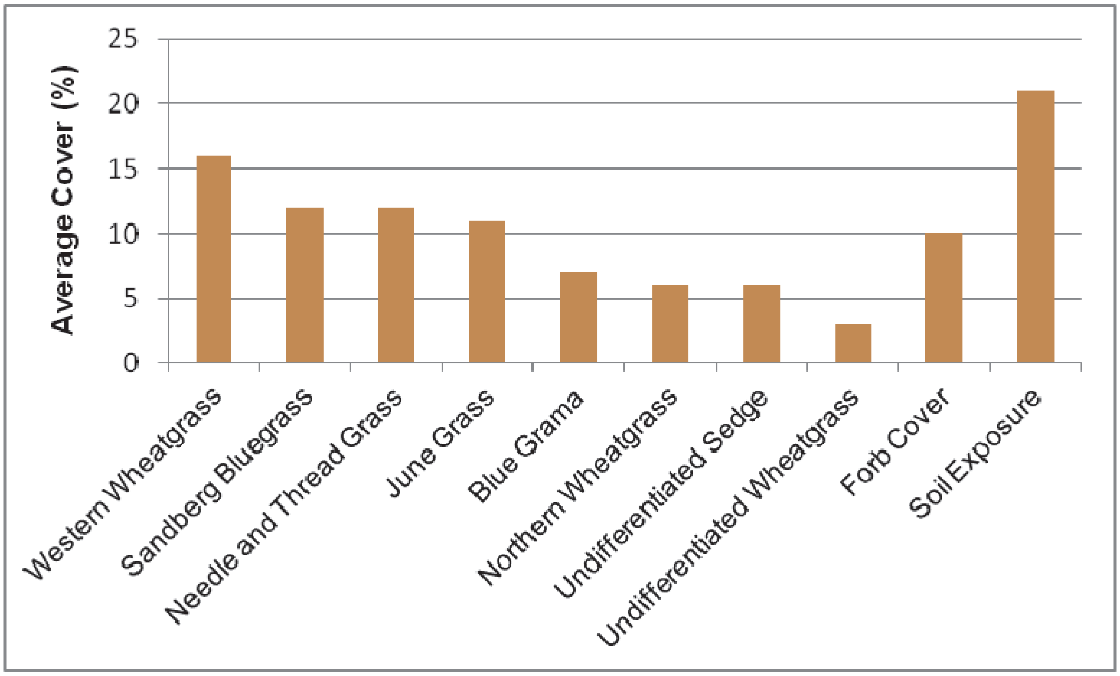
This target recovering plant community is a result of grouping the Blowout ecological range sites as described in the Dry Mixedgrass Range Plant Community Guide (Adams et al. 2005). The grouping includes all Blowout ecological range sites described on all phases of Solonetzic soils in the Dry Mixedgrass. Included in this group are Clayey ecological range sites as they represent a relatively small portion of the landscape in specific areas and have similar species descriptions. Refer to the Dry Mixedgrass Range Plant Community Guide, Table 9 for a listing of the Reference Plant Communities and Successional Community Types for blowout and clayey range sites.

The grouping includes mid and late seral stage and reference plant communities. Common dominant species include northern and western wheatgrass, needle and thread grass, June grass, Sandbergs bluegrass and blue grama grass. To produce this target recovering plant community the mean percent cover of each of the graminoid species described for each plant community within the grouping was sorted and the average value used to describe the target recovering plant community. The average mean percent cover of all forb species, moss and lichen, total vegetation and exposed soil is listed as well to provide a detailed description of the recovering community. The table produced for this grouping is illustrated in Table C3 and Figure C2. The values in table percentages have been rounded to the nearest whole number.

Table C3 - Target Recovering Plant Community Table for Blowout and Clayey Range Sites

Species	Common Name	Average % Cover	% Constancy
Agropyron smithii	Western Wheatgrass	16	73
Poa sandbergii	Sandberg Bluegrass	12	73
Stipa comata	Needle and Thread Grass	12	90
Koeleria macrantha	June Grass	11	96
Bouteloua gracilis	Blue Grama	7	92
Agropyron dasystachyum	Northern Wheatgrass	6	53
Carex species	Undifferentiated Sedge	6	90
Agropyron species	Undifferentiated Wheatgrass	3	4
Average Total Vegetation Cover		**57**	
Average Forb Cover		**10**	
Average Moss and Lichen Cover		**37**	
Average Soil Exposure		**21**	

Figure C2 - Target Recovering Plant Community for Blowout and Clayey Range Sites



This information can then be used to design a native seed mix based on the common dominant species in the grouping 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 grouping could include:

Table C4 - Example Native Seed Mix for Blowout and Clayey Range Sites

Species	Proportion of Seed Mix % PLS by Weight	
Northern Wheatgrass	*Agropyron dasystachyum*	10%
Slender Wheatgrass	*Agropyron trachycaulum*	10%
Needle & Thread Grass	*Stipa comata*	20%
Sandbergs Bluegrass	*Poa sandbergii*	12%
June Grass	*Koeleria macrantha*	20%
Western Wheatgrass	*Agropyron smithii*	16%
Blue Grama Grass	*Bouteloua gracilis*	12%

Slender 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 and western wheatgrasses have been selected to stabilize the soils and provide structure in the stand. The portion of needle and thread and blue grama has been slightly 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.3 Target Recovering Plant Community for Sands, Sandy and Choppy Sandhill Range Sites

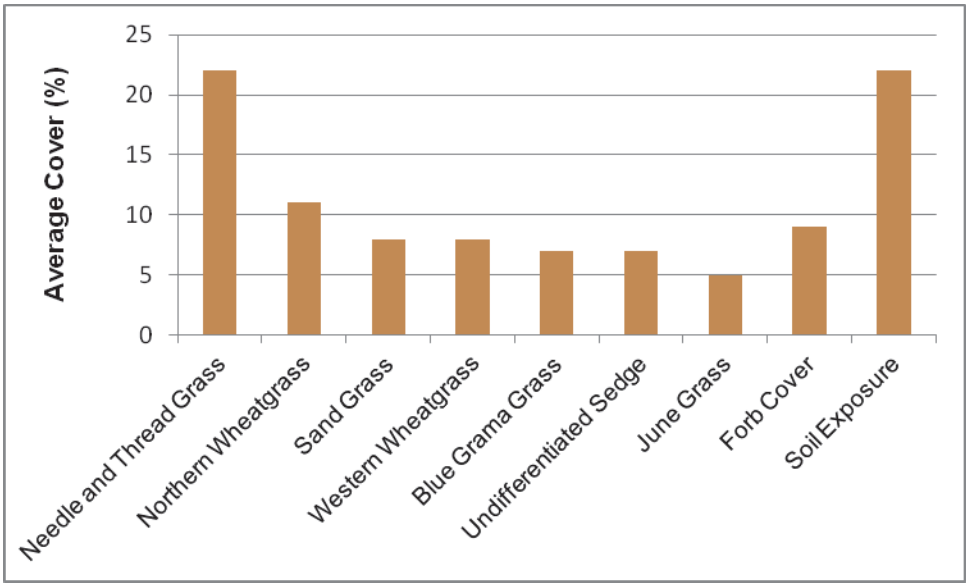
This target recovering plant community is a result of grouping the Sands, Sandy and Choppy Sandhill ecological range sites as described in the Dry Mixedgrass Range Plant Community Guide (Adams et al. 2005). The grouping includes all ecological range sites described on Regosolic soils in the Dry Mixedgrass. Refer to the Dry Mixedgrass Range Plant Community Guide, Table 9 for a listing of the Reference Plant Communities and Successional Community Types for sands, sandy and choppy sandhill range sites. It is important to note that DMGA 14 Western Wheatgrass-Needle and Thread has been included in this grouping.

The grouping includes mid and late seral stage and reference plant communities. Common dominant species include needle and thread grass, blue grama grass, june grass, western wheatgrass and sand grass. To produce this target recovering plant community the mean per cent cover of each of the graminoid species described for each plant community within the grouping was sorted and the average value used to describe the target recovering plant community. The average mean percent cover of all forb species, moss and lichen, total vegetation and exposed soil is listed as well to provide a detailed description of the recovering community. The table produced for this grouping is illustrated in Table C5 and Figure C3. The values in table percentages have been rounded to the nearest whole number.

Table C5 - Target Recovering Plant Community for Sands, Sandy and Choppy Sandhill Range Sites

Species	Common Name	Average % Cover	% Constancy
Stipa comata	Needle and Thread Grass	22	99
Agropyron dasystachyum	Northern Wheatgrass	11	45
Calamovilfa longifolia	Sand Grass	8	52
Agropyron smithii	Western Wheatgrass	8	48
Bouteloua gracilis	Blue Grama Grass	7	88
Carex species	Undifferentiated Sedge	7	87
Koeleria macrantha	June Grass	5	83
Average Total Vegetation Cover		**70**	
Average Forb Cover		**9**	
Average Moss and Lichen Cover		**8**	
Average Soil Exposure		**22**	

Figure C3 - Target Recovering Plant Community for Sands, Sandy and Choppy Sandhill Range Sites



This information can then be used to design a native seed mix based on the common dominant species in the grouping and the performance of each species in the recovery process. 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 grouping could include :

Table C6 - Example Native Seed Mix for Sands, Sandy and Choppy Sandhill Range Sites

Species	Proportion of Seed Mix % PLS by Weight	
Needle & Thread Grass	*Stipa comata*	35%
Western Wheatgrass	*Agropyron smithii*	10%
Sand Grass	*Calamovilfa longifolia*	8%
Northern Wheatgrass	*Agropyron dasystachyum*	15%
Blue Grama Grass	*Bouteloua gracilis*	12%
Slender wheatgrass	*Agropyron trachycaulum*	10%
June Grass	*Koeleria macrantha*	10%

Slender 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 and western wheatgrasses have been selected to stabilize the soils and provide structure in the stand. The portion of needle and thread and blue grama 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.

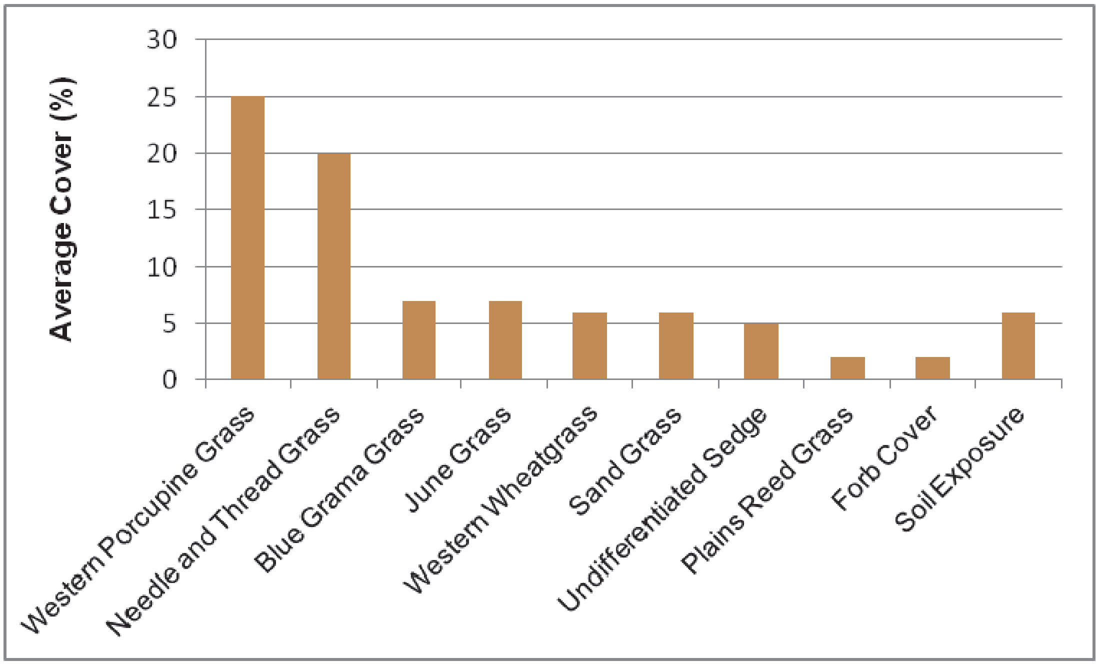
An Important Sandy Range Site Outlier in the Dry Mixedgrass

DMGA13 Western Porcupine Grass – Needle-and-Thread - Sand Grass is a later seral plant community on sandy range sites in the Dry Mixedgrass found on moderately coarse, sandy loam textured soils. An indicator species of this community is western porcupine grass as the dominant species. The target recovering plant community includes:

Table C7 – Recovering Plant Community for Important Sandy Range Site Outlier

Species	Common Name	Average % Cover	% Constancy
Stipa curtiseta	Western Porcupine Grass	25	100
Stipa comata	Needle and Thread Grass	20	100
Bouteloua gracilis	Blue Grama Grass	7	94
Koeleria macrantha	June Grass	7	100
Agropyron smithii	Western Wheatgrass	6	63
Calamovilfa longifolia	Sand Grass	6	4
Carex species	Undifferentiated Sedge	5	75
Calamagrostis montanensis	Plains Reed Grass	2	63
Average Total Vegetation Cover		**82**	
Average Forb Cover		**2**	
Average Moss and Lichen Cover		**35**	
Average Soil Exposure		**6**	

Figure C4 – Recovering Plant Community for Important Sandy Range Site Outlier



This information can then be used to design a native seed mix based on the common dominant species in the grouping and the performance of each species in the recovery process. Table C8 provides an example of the 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 community could include :

Table C8 – DMGA13 Example Seed Mix

Species	Proportion of Seed Mix % PLS by Weight	
Western porcupine grass	*Stipa curtiseta*	30%
Needle-and-thread grass	*Stipa comata*	25%
June grass	*Koeleria macrantha*	15%
Blue grama grass	*Bouteloua gracilis*	10%
Sand grass	*Calamovilfa longifolia*	5%
Western wheatgrass	*Agropyron smithii*	5%
Slender wheatgrass	*Agropyron trachycaulum*	10%

Again Slender wheatgrass has been added to provide initial cover and the values for western porcupine, needle-and-thread and blue grama increased to compensate for wild harvested seed.

C.4 Target Recovering Plant Community for Thin Breaks and Limey Range Sites

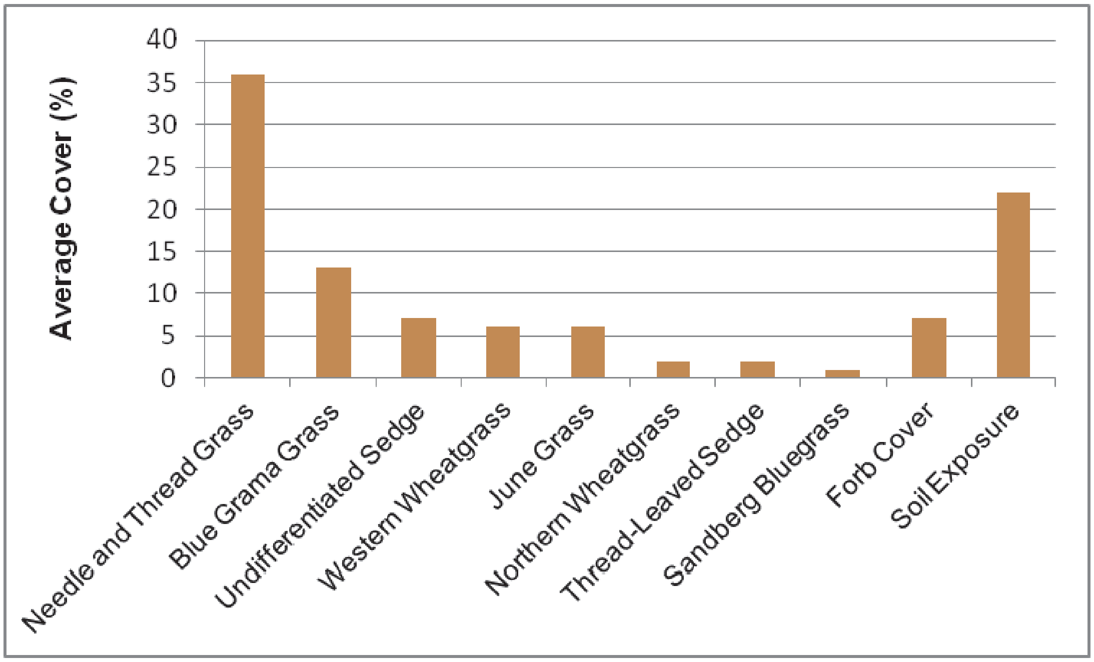
This target recovering plant community is a result of grouping thin breaks and limey range sites due to common weakly developed soils and common dominant species of needle-and-thread, blue grama grass and june grass. Refer to the Dry Mixedgrass Range Plant Community Guide, Table 9 for a listing of the Reference Plant Communities and Successional Community Types for thin breaks and limey range sites (Adams et al. 2005).

To produce this target recovering plant community the mean percent cover of each of the graminoid species described for each plant community within the grouping was sorted and the average value used to describe the target recovering plant community. The average mean percent cover of all forb species, moss and lichen, total vegetation and exposed soil is listed as well to provide a detailed description of the recovering community. The table produced for this grouping is illustrated in Table C9 and Figure C5. The values in table percentages have been rounded to the nearest whole number.

Table C9 - Target Recovering Plant Community Table for Thin Breaks and Limey Range Sites

Species	Common Name	Average % Cover	% Constancy
Stipa comata	Needle and Thread Grass	36	100
Bouteloua gracilis	Blue Grama Grass	13	96
Carex species	Undifferentiated Sedge	7	87
Agropyron smithii	Western Wheatgrass	6	53
Koeleria macrantha	June Grass	6	84
Agropryon dasystachyum	Northern Wheatgrass	2	29
Carex filifolia	Thread-Leaved Sedge	2	18
Poa sandbergii	Sandberg Bluegrass	1	24
Average Total Vegetation Cover		**59**	
Average Forb Cover		**7**	
Average Moss and Lichen Cover		**23**	
Average Soil Exposure		**22**	

Figure C5 - Target Recovering Plant Community for Thin Breaks and Limey Range Sites



This information can then be used to design a native seed mix based on the common dominant species in the grouping 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 grouping could include:

Table C10 - Example Native Seed Mix for Thin Breaks and Limey Range Sites

Species	Proportion of Seed Mix % PLS by Weight	
Needle & Thread Grass	*Stipa comata*	40%
Blue Grama Grass	*Bouteloua gracilis*	15%
Slender wheatgrass	*Agropyron trachycaulum*	10%
Northern Wheatgrass	*Agropyron dasystachyum*	10%
June Grass	*Koeleria macrantha*	15%
Western Wheatgrass	*Agropyron smithii*	10%

In this case northern and western wheatgrass have been increased to provide cover and erosion control on steep slopes, slender wheatgrass has been added to provide initial cover and is expected to disappear within 5 years. The needle and thread and blue grama have been increased to compensate for wild harvested seed.

C.5 Target Recovering Plant Community for Non-saline Overflow Range Sites

Overflow range sites represent a relatively small portion of the Dry Mixedgrass landscape. They are unique in that they receive moisture from the surrounding upland range sites and as a result are more productive. Refer to the Dry Mixedgrass Range Plant Community Guide, Table 9 for a listing of the Reference Plant Communities and Successional Community Types for Non-saline Overflow range sites (Adams et al. 2005).

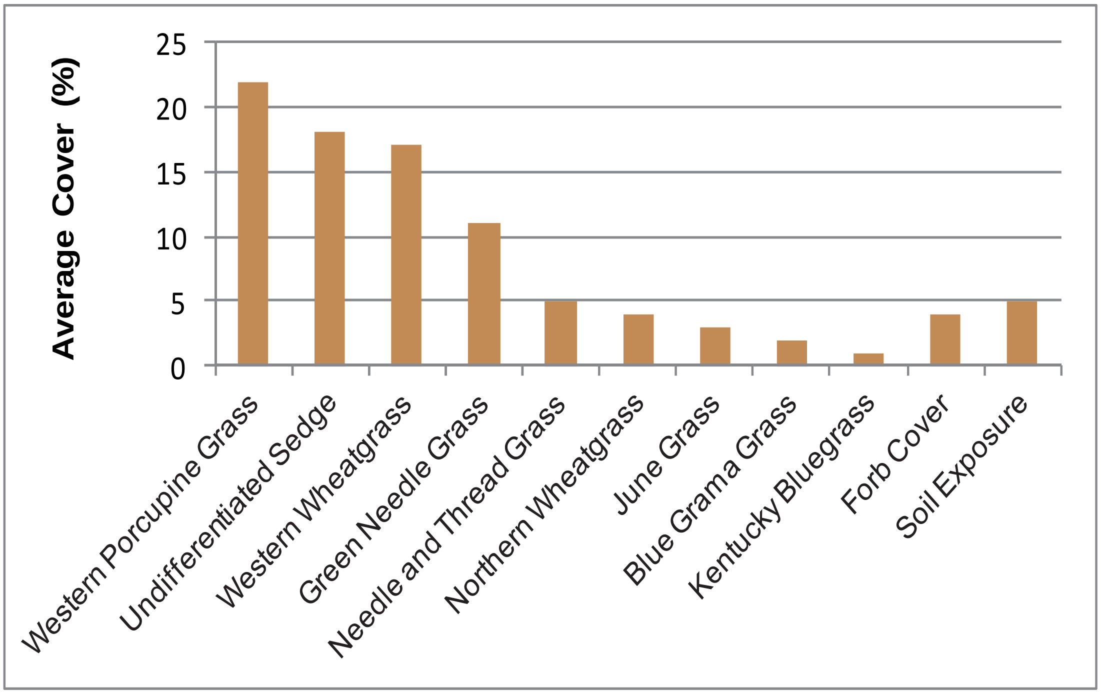
An indicator species of non-saline overflow range sites in the Dry Mixedgrass is western porcupine grass which requires productive chernozemic soils. To produce this target recovering plant community the mean per cent cover of each of the graminoid species described for each plant community within the grouping was sorted and the average value used to describe the target recovering plant community. The average mean percent cover of all forb species, moss and lichen, total vegetation and exposed soil is listed as well to provide a detailed description of the recovering community. The table produced for this grouping is illustrated in Table C11 and Figure C6. The values in table percentages have been rounded to the nearest whole number.

Table C11 - Target Recovering Plant Community Table for Non-saline Overflow Range Sites

Species	Common Name	Average % Cover	% Constancy
Stipa curtiseta	Western Porcupine Grass	22	29
Carex species	Undifferentiated Sedge	18	89
Agropyron smithii	Western Wheatgrass	17	82
Stipa viridula	Green Needle Grass	11	36
Stipa comata	Needle and Thread Grass	5	36
Agropyron dasystachyum	Northern Wheatgrass	4	25
Koeleria macrantha	June Grass	3	11
Bouteloua gracilis	Blue Grama Grass	2	25
Poa pratensis	Kentucky Bluegrass	1	14
Average Total Vegetation Cover		**81**	
Average Forb Cover		**4**	
Average Moss and Lichen Cover		**11**	
Average Soil Exposure		**5**	

Kentucky bluegrass (*Poa pratensis*) is present at a low average mean percent cover value in the reference plant community DMGA40 for overflow range sites in the Suffield area. It is considered non-native and can be invasive following soil disturbance in overflow range sites. If detected in the pre-disturbance site assessment, Invasive plant management is recommended.

Figure C6 - Target Recovering Plant Community for Non-saline Overflow Range Sites



This information can then be used to design a native seed mix based on the common dominant species in the grouping 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 grouping could include:

Table C12 - Example Native Seed Mix for Non-saline Overflow Range Sites

Species	Proportion of Seed Mix % PLS by Weight	
Western Porcupine Grass	*Stipa curiseta*	50%
Slender wheatgrass	*Agropyron trachycaulum*	10%
Northern Wheatgrass	*Agropyron dasystachyum*	10%
Western Wheatgrass	*Agropyron smithii*	5%
June Grass	*Koeleria macrantha*	10%
Needle & Thread Grass	*Stipa comata*	15%

Slender wheatgrass has been added to provide initial cover, and competition to invasive non-native species such as Kentucky bluegrass. It is expected to disappear, allowing space for infill of seeded species and encroachment of native forb species. Green needlegrass has not been included in the mix due to the aggressive performance of the cultivar. Western porcupine and needle and thread have been increased to compensate for wild harvested seed, and june grass increased for seedling survival.

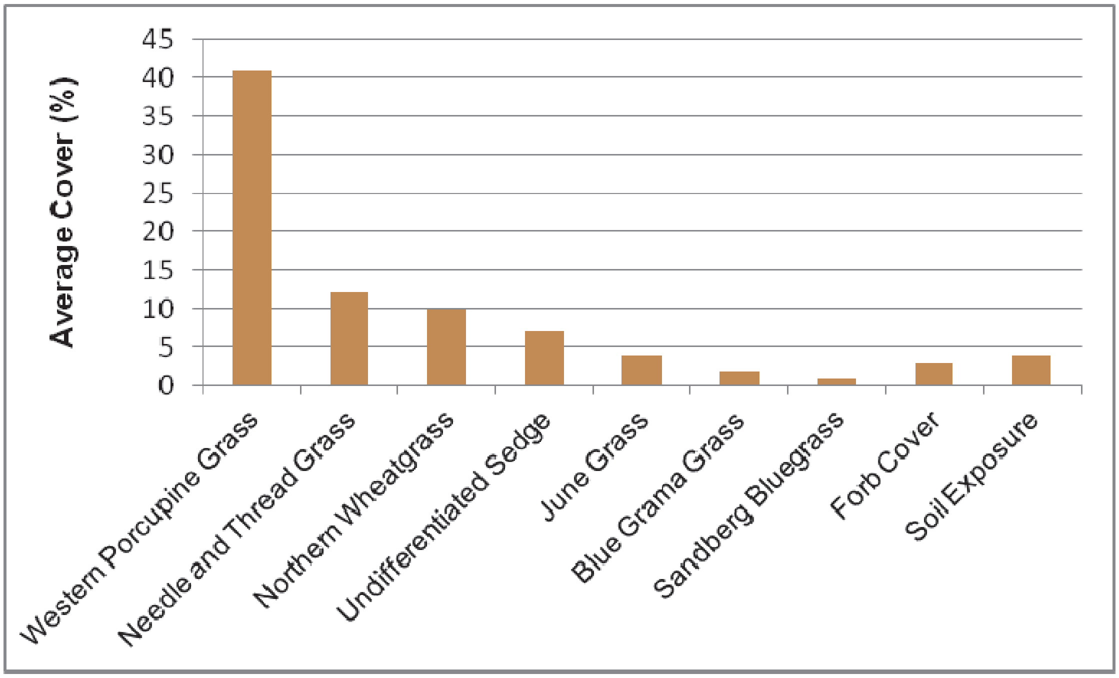
Important Overflow Outlier

DMGA 1 is a reference plant community for overflow and very productive loamy range sites. This community is very site specific and occupies a relatively small portion of the landscape in the Dry Mixedgrass. The presence of western porcupine grass indicates likely a transition to the Mixedgrass NSR. The target recovering plant community includes:

Table C13 – DMGA 1 Target Recovering Plant Community

Species	Common Name	Average % Cover	% Constancy
Stipa curtiseta	Western Porcupine Grass	41	100
Stipa comata	Needle and Thread Grass	12	85
Agropyron dasystachyum	Northern Wheatgrass	10	100
Carex species	Undifferentiated Sedge	7	75
Koeleria macrantha	June Grass	4	65
Bouteloua gracilis	Blue Grama Grass	2	45
Poa sandbergii	Sandberg Bluegrass	1	45
Average Total Vegetation Cover		**82**	
Average Forb Cover		**3**	
Average Moss and Lichen Cover		**12**	
Average Soil Exposure		**4**	

Figure C7—Target Recovering Plant Community for Overflow Outlier Range Sites



This information can then be used to design a native seed mix based on the dominant species and the performance of each species in the recovery process. Table C14 provides an example of the 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 community could include:

Table C14 – DMGA 1 Example Native Seed Mix

Species	Proportion of Seed Mix % PLS by Weight	
Western porcupine grass	*Stipa curtiseta*	45%
Needle and thread grass	*Stipa comata*	15%
Slender wheatgrass	*Agropyron trachycaulum*	10%
Western wheatgrass	*Agropyron smithii*	5%
June grass	*Koeleria macrantha*	15%
Northern wheatgrass	*Agropyron dasystachyum*	10%

Slender wheatgrass has been added to provide initial cover, and competition to invasive non-native species such as Kentucky bluegrass. It is expected to disappear, allowing space for infill of seeded species and encroachment of native forb species. Western porcupine and needle-and-thread have been increased to compensate for wild harvested seed, and june grass increased for seedling survival.

C.6 Ecological Range Sites that are Unique in Species Composition

Saline overflow and saline lowland ecological range sites are very unique in species composition due to the saline nature of the soils. These sites should be avoided if at all possible. If avoidance is not possible, then natural recovery will likely be the most successful revegetation strategy over time. This group includes:

Table C15 - Ecological Range Sites that are Unique in Species Composition

DMGA41	Low Sedge - Western Wheat Grass - Green Needle Grass	Overflow 3
DMGC1	Silver Sagebrush/Western and Northern Wheat Grass	Overflow 4
DMGA45	Western Wheat Grass - Salt Grass - Gumweed	Overflow 4
DMGC7	Greasewood/Salt Grass - Western Wheat Grass	Overflow 5
DMGA20	Silver Sagebrush/Undifferentiated Wheat Grasses	Saline Lowlands 1
DMGA44	Salt Grass - Western Wheat Grass	Saline Lowlands 2
DMGA21	Silver Sagebrush/Wheat Grasses - Nuttall’s Atriplex	Saline Lowlands 2

C.7 Final Step

Seed is ordered by computing the number of seeds per gram for each species, the percentage of pure live seed for each species and the percentage by weight of each species included in the mix. Computer programs are available for this task. Certificates of Seed Analysis for each species and the seed lot available are required to make this final computation. Appendix D—Seeding Pathways provides detailed guidance for this step.

APPENDIX D SEEDING PATHWAYS

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

The Alberta Native Plant Council

http://www.anpc.ab.ca/

and/or

The Native Plant Society of Saskatchewan

http://www.npss.sk.ca/

Seeding Rate Conversion Charts For Using Native Species In Reclamation Projects

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

Introduction

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

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

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

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

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

Calculating Seeding Rates

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

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

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

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

Step 1

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

Step 2

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

Step 3

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

Step 4

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

Step 5

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

Step 6

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

Step 7

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

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

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

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

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

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Table 3.

General seeding rate guidelines.

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

Formula 1.

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

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

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

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

This is an estimate of the weight of the seed.

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

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

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

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

Formula 2.

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

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

Formula 3.

Metric to Imperial conversions:

kg/ha = 1.12 x lbs/acre

lbs/acre = 0.891 x kgs/ha

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

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

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

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

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/m². (Based on seed weights shown in Table 2)

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

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

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Table 8. Converting PLS/m² to kg/ha. (Based on seed weights shown in Table 2.)

Common Name	Seeding Rate (PLS/m²)																		
	15	20	25	30	40	50	60	75	100	125	150	175	200	250	300	350	400	450	500
American sweet vetch	0.75	1.0	1.3	1.5	2.0	2.5	3.0	3.8	5.0	6.3	7.5	8.8	10.0	12.5	15.0	17.5	20.0	22.5	25.0
American vetch	2.5	3.3	4.2	5.0	6.7	8.3	10.0	12.5	16.7	20.8	25.0	29.2	33.3	41.7	50.0	58.3	66.7	75.0	83.3
awned slender	0.58	0.77	1.0	1.2	1.5	1.9	2.3	2.9	3.8	4.8	5.8	6.7	7.7	9.6	11.5	13.5	15.4	17.3	19.2
awned wheatgrass	0.43	0.57	0.71	0.86	1.1	1.4	1.7	2.1	2.9	3.6	4.3	5.0	5.7	7.1	8.6	10.0	11.4	12.9	14.3
big bluestem	0.52	0.69	0.86	1.0	1.4	1.7	2.1	2.6	3.4	4.3	5.2	6.0	6.9	8.6	10.3	12.1	13.8	15.5	17.2
blue grama grass	0.08	0.11	0.14	0.16	0.22	0.27	0.33	0.41	0.55	0.69	0.82	1.0	1.1	1.4	1.6	1.9	2.2	2.5	2.7
bluebunch wheatgrass	0.48	0.65	0.81	1.0	1.3	1.6	1.9	2.4	3.2	4.0	4.8	5.6	6.5	8.1	9.7	11.3	12.9	14.5	16.1
Canada wild rye	0.75	1.0	1.3	1.5	2.0	2.5	3.0	3.8	5.0	6.3	7.5	8.8	10.0	12.5	15.0	17.5	20.0	22.5	25.0
fringed brome	0.49	0.65	0.82	1.0	1.3	1.6	2.0	2.5	3.3	4.1	4.9	5.7	6.5	8.2	9.8	11.4	13.1	14.7	16.3
green needle grass	0.38	0.50	0.63	0.75	1.0	1.3	1.5	1.9	2.5	3.1	3.8	4.4	5.0	6.3	7.5	8.8	10.0	11.3	12.5
hairy wild rye	0.38	0.51	0.64	0.77	1.0	1.3	1.5	1.9	2.6	3.2	3.8	4.5	5.1	6.4	7.7	8.9	10.2	11.5	12.8
Idaho fescue	0.15	0.20	0.25	0.30	0.40	0.51	0.61	0.76	1.0	1.3	1.5	1.8	2.0	2.5	3.0	3.5	4.0	4.5	5.1
Indian grass	0.50	0.67	0.83	1.0	1.3	1.7	2.0	2.5	3.3	4.2	5.0	5.8	6.7	8.3	10.0	11.7	13.3	15.0	16.7
Indian rice grass	0.48	0.65	0.81	1.0	1.3	1.6	1.9	2.4	3.2	4.0	4.8	5.6	6.5	8.1	9.7	11.3	12.9	14.5	16.1
June grass	0.03	0.04	0.05	0.06	0.08	0.10	0.12	0.15	0.20	0.25	0.29	0.34	0.39	0.49	0.59	0.69	0.78	0.88	1.0
little bluestem	0.48	0.65	0.81	1.0	1.3	1.6	1.9	2.4	3.2	4.0	4.8	5.6	6.5	8.1	9.7	11.3	12.9	14.5	16.1
mountain brome	0.79	1.1	1.3	1.6	2.1	2.6	3.2	3.9	5.3	6.6	7.9	9.2	10.5	13.2	15.8	18.4	21.1	23.7	26.3
needle and thread	0.60	0.80	1.0	1.2	1.6	2.0	2.4	3.0	4.0	5.0	6.0	7.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0
nodding brome	0.59	0.78	1.0	1.2	1.6	2.0	2.4	2.9	3.9	4.9	5.9	6.9	7.8	9.8	11.8	13.7	15.7	17.6	19.6
northern awnless brome	0.54	0.71	0.89	1.1	1.4	1.8	2.1	2.7	3.6	4.5	5.4	6.3	7.1	8.9	10.7	12.5	14.3	16.1	17.9
northern rough fescue	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.1	1.5	1.9	2.3	2.7	3.1	3.8	4.6	5.4	6.1	6.9	7.6
northern sweet vetch	2.1	2.9	3.6	4.3	5.7	7.1	8.6	10.7	14.3	17.9	21.4	25.0	28.6	35.7	42.9	50.0	57.1	64.3	71.4
northern wheatgrass	0.44	0.59	0.74	0.88	1.2	1.5	1.8	2.2	2.9	3.7	4.4	5.1	5.9	7.4	8.8	10.3	11.8	13.2	14.7
Nutall's alkali grass	0.02	0.03	0.04	0.05	0.07	0.08	0.10	0.12	0.16	0.20	0.24	0.29	0.33	0.41	0.49	0.57	0.65	0.73	0.81
Parry oat grass	0.68	0.90	1.1	1.4	1.8	2.3	2.7	3.4	4.5	5.6	6.8	7.9	9.0	11.3	13.5	15.8	18.0	20.3	22.5
plains rough fescue	0.34	0.45	0.56	0.67	0.90	1.1	1.3	1.7	2.2	2.8	3.4	3.9	4.5	5.6	6.7	7.9	9.0	10.1	11.2
prairie cord grass	1.1	1.4	1.8	2.1	2.9	3.6	4.3	5.4	7.1	8.9	10.7	12.5	14.3	17.9	21.4	25.0	28.6	32.1	35.7
purple prairie clover	0.48	0.64	0.80	1.0	1.3	1.6	1.9	2.4	3.2	4.0	4.8	5.6	6.4	8.0	9.6	11.2	12.8	14.4	16.0
rocky mountain fescue	0.10	0.13	0.17	0.20	0.27	0.33	0.40	0.50	0.67	0.83	1.0	1.2	1.3	1.7	2.0	2.3	2.7	3.0	3.3
rough fescue	0.27	0.36	0.45	0.55	0.73	0.91	1.1	1.4	1.8	2.3	2.7	3.2	3.6	4.5	5.5	6.4	7.3	8.2	9.1
salt grass	0.13	0.17	0.22	0.26	0.35	0.43	0.52	0.65	0.87	1.1	1.3	1.5	1.7	2.2	2.6	3.0	3.5	3.9	4.3
sand dropseed	0.01	0.02	0.02	0.03	0.03	0.04	0.05	0.06	0.09	0.11	0.13	0.15	0.17	0.21	0.26	0.30	0.34	0.39	0.43
sand grass	0.25	0.33	0.42	0.50	0.67	0.83	1.0	1.3	1.7	2.1	2.5	2.9	3.3	4.2	5.0	5.8	6.7	7.5	8.3
slender wheatgrass	0.43	0.57	0.71	0.86	1.1	1.4	1.7	2.1	2.9	3.6	4.3	5.0	5.7	7.1	8.6	10.0	11.4	12.9	14.3
switch grass	0.24	0.31	0.39	0.47	0.63	0.79	0.94	1.2	1.6	2.0	2.4	2.8	3.1	3.9	4.7	5.5	6.3	7.1	7.9
tufted hair grass	0.03	0.04	0.05	0.05	0.07	0.09	0.11	0.14	0.18	0.23	0.27	0.32	0.36	0.45	0.54	0.64	0.73	0.82	0.91
western porcupine grass	0.75	1.0	1.3	1.5	2.0	2.5	3.0	3.8	5.0	6.3	7.5	8.8	10.0	12.5	15.0	17.5	20.0	22.5	25.0
western wheatgrass	0.63	0.83	1.0	1.3	1.7	2.1	2.5	3.1	4.2	5.2	6.3	7.3	8.3	10.4	12.5	14.6	16.7	18.8	20.8

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

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Appendix

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

Adapted from USDA, NRCS Form ND-CPA-9

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

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

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20/20 Seed Labs Inc.

Interpreting your Report of Seed Analysis:

Important notes:

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

Purity tests

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

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

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

Pure Living Seed

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

Germination Test

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

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

Tetrazolium chloride (TZ) Test:

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

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

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

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

20/20 Seed Labs Inc.

Report Of Seed Analysis

CFIA Accreditation No.1068

This designates Date: Apr 18, 2012

that a sample of Wheatgrass, northern

Lot# 123-4567

Lab No. AB1120401008

was received from:

Scarecrow Enterprises
#201, 509 11 Avenue

Nisku, AB, CA
T9E 7N5

and was tested at:

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

signed by:

SENIOR MEMBER OF

COMMERCIAL SEED ANALYSTS ASSOCIATION CANADA INC

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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

Date: Apr 18, 2012

Lab No. AB1120401008

This designates that a sample of Wheatgrass, northern

Lot# 123-4567

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 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

Date: Apr 18, 2012

This designates

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

Date: Apr 18, 2012

This designates that a sample of Needle And Thread

Lot# 345-6789

Lab No. AB1120401050

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

Nisku, AB, CA
T9E 7N5

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

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

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

% PURE SEED *

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

PURITY *

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

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

Germination *

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

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

ACCREDITED REMARKS

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

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

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20/20 Seed Labs Inc.

Detailed Testing Result Summary

CFIA Accreditation No.1068

Date: Apr 18, 2012

Lab No. AB1120401050

This designates

that a sample of Needle And Thread

Lot# 345-6789

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

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

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