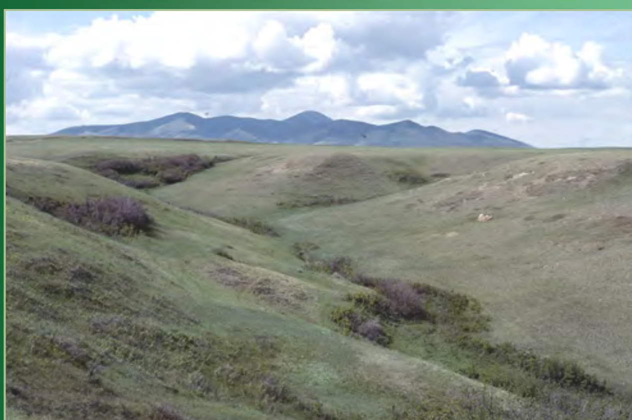
Recovery Strategies for Industrial Development in Native Grassland

for the

Mixedgrass

Natural Subregion of Alberta



Sweetgrass Upland Ecodistrict

Lethbridge Plain Ecodistrict
Minimum Disturbance

Cypress Upland Ecodistrict Pipeline Construction

Second Edition

Grassland Restoration Forum

January 2024

RECOVERY STRATEGIES FOR INDUSTRIAL DEVELOPMENT IN NATIVE PRAIRIE

FOR THE MIXEDGRASS NATURAL SUBREGION OF ALBERTA

JANUARY 2024

Second Edition

Prepared By:

THE GRASSLAND RESTORATION FORUM

In Association With:

PARTICIPANTS OF THE GRASSLAND RESTORATION FORUM TECHNICAL ADVISORY COMMITTEE

AND OTHER GRASSLAND RESTORATION STAKEHOLDERS

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SAMUEL HANEN SOCIETY

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Land Acknowledgement

Alberta's native grasslands are the traditional ancestral and current territory of many indigenous communities. We are dedicated to conserving and restoring these shared lands and honouring their spirit. We are grateful for the continued presence and partnership of indigenous people on our shared journey.

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We are grateful to the members of the GRF Steering Committee and Technical Advisory Committee, who attended stakeholder review workshops and provided verbal and written critique and contributions to the updated document. Their thoughtful reviews of and additions to the material have improved the publication.

We hope the tools developed in the Recovery Strategies Guidance Documents will enable land managers, planners, reclamation practitioners, and community members to make informed choices to minimize loss of native grasslands and promote their effective restoration after disturbance. Further information can be found in the accompanying literature review, *Dry Mixedgrass and Mixedgrass Recovery Strategies Literature Review* (Miller et al. 2023) (available on the Grassland Restoration Forum website).

Oldman River Valley, Lethbridge Plain Ecodistrict

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June Grass (Koeleria macrantha)

Preface

As the population of Alberta expands, the extent and biodiversity of native grasslands is continually decreasing from the cumulative effects of agricultural conversion, energy development, transportation corridors, urban settlement, and recreational activities. The cumulative effects of multiple industries and fragmentation by many linear projects are degrading the overall health of native grasslands and their resilience to disturbance. Disturbance promotes the establishment of invasive species which greatly reduces the ability of these ecosystems to recover the broad suite of ecological goods and services they provide to the benefit of all Albertans.

As the demand for development has increased, so has public pressure to reduce impacts of industrial disturbance and cumulative effects of multiple activities on native grassland ecosystems. The *South Saskatchewan Regional Plan* (GoA 2018b) identifies the retention of biodiversity and healthy ecosystems as a key goal, including to:

- develop a regional biodiversity management framework.
- conserve critical habitats for species at risk.
- avoid, minimize, or mitigate the conversion of native grasslands on public lands.
- apply integrated land management to minimize native vegetation loss.
- coordinate land-use activities to reduce fragmentation by roads, access, and facilities.

Effective recovery strategies are necessary to retain and maintain ecosystem biodiversity, health, and resilience. A cumulative effects approach to land management will encourage restoration of existing footprint and minimize new footprint.

The term grasslands implies a simplicity that is deceptive (Olson and Janelle 2022). Native grasslands have more in common with old growth forests than hayfields. Our native grasslands assembled over centuries, and contain long-lived perennial plants, and high species diversity and structure, both above- and below-ground. From this below-ground structure, many plants can re-sprout after natural disturbances such as fire and grazing (Buisson et al. 2022). The most detrimental disturbances are those that rapidly destroy below-ground structure such as topsoil stripping or tillage. These characteristics also provide a target for restoration, with the understanding that we can only put a grassland on a path towards recovery because actual restoration will take many years, if it is even possible. Knowing this, our goal needs to be to minimize harm.

Reclamation practices following industrial disturbance in native prairie landscapes have been evolving since the early 1980s. Industrial activity in native prairie has also been steadily increasing. The Mixedgrass Natural Subregion (Mixedgrass NSR) of Alberta is rich in resources with a large and diverse development infrastructure in native prairie. Recently, development of renewable resources such as wind energy is also taking place on privately held native grasslands, with similar development impacts to native prairie.

Over time the focus of reclamation practices in native prairie has shifted from controlling soil erosion and establishing sustainable non-native grass cover to development planning with pre-disturbance assessment and implementation procedures designed to enable restoration of native grassland 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 (AEP 2013), and since then has expanded to other industries. The recovery strategies presented here have been developed to support the intent of current reclamation criteria and to provide guidance for reclamation practitioners, planners, contractors, landholders, and Government of Alberta regulatory authorities.

Although the Recovery Strategies Project is designed to assist industry, the concepts and information presented are applicable to restoring most disturbances in native grasslands.

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 being decommissioned or planned on a site-specific basis. The purpose is to provide expectations and understanding 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* (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 and technical innovations developed since 2003. Industry has made major changes to the way sites and associated infrastructure are developed and reclaimed in native prairie. The first approximation captured the key experience and learnings accumulated over the 10 to 20 years since minimum disturbance was first practiced. The second edition of this manual collects the experience of reclamation practitioners and researchers over the past 10 years and reflects current regulatory policy and guidance for Alberta.

Realizing the reclamation challenges faced for development in native prairie and the benefits gained from minimizing the footprint of disturbance, minimal disturbance best management practices are now the norm in native prairie. As invasive species and climate change add pressure to these ecosystems, avoiding and minimizing disturbance are even more important to reduce post-disturbance restoration challenges.

The development of Natural Regions and Subregions of Alberta (Downing and Pettapiece 2006) as the first level of ecological classification in Alberta assists practitioners with understanding restoration opportunities and limitations within the natural subregion context. The development of the Grassland Vegetation Inventory, Range Plant Community Guides and Range Health Assessment protocol by the Government of Alberta Range Resource Management Program has greatly increased our understanding of native grassland ecosystems. These tools were developed to facilitate an understanding of the ability of native plant communities to respond and adapt to natural disturbance regimes such as fire, grazing and drought. These tools are now applied to assess and manage man-made disturbances, incorporating pre-disturbance site assessment, development planning, interim reclamation, decommissioning and reclamation certification for native grasslands. Recovery strategies manuals have been developed for each of the grassland NSRs, this one for the Mixedgrass NSR.

Training and experience in range ecology is an important skill for designing effective recovery strategies.

Cypress Upland Ecodistrict, Mixedgrass Natural Subregion

The Mixedgrass NSR is unique in the challenges it presents to restoring disturbances from industrial development. Plains rough fescue plant communities associated with the upland ecodistricts are difficult to restore, requiring long timeframes for re-establishment, and sources of seed are challenging to come by. The milder winters, particularly in the western portion of the Mixedgrass NSR, are due to the influence of Chinook winds. These strong, warm, westerly winds are a significant factor influencing restoration potential if the native prairie vegetation is removed. Winter thawing of frozen soils presents challenges for operating heavy equipment on native prairie vegetation. The potential for soil loss due to wind erosion is a significant factor that must be considered in development planning. The fertile Dark Brown Chernozemic soils, combined with adequate average annual precipitation, provides the opportunity for non-native plants to invade and colonize disturbed soils, especially in areas fragmented by cultivation. Minimizing soil disturbance is an important strategy to reduce reclamation challenges. Utilizing natural recovery and assisted natural recovery can be effective strategies for restoring smaller disturbances where risk factors are low in the Mixedgrass NSR. Alternate strategies for higher risk or large disturbances are described in the context of restoration tools and recent experience, government policy, and publications. Examples of seed mixes suitable for the variety of range sites and soils encountered in the Mixedgrass NSR are also provided to support setting a positive successional trajectory towards restoring surface disturbances.

Figure 1-1 The Grassland Natural Region and Surrounding Subregions that Support Native Grasslands in Southern Alberta

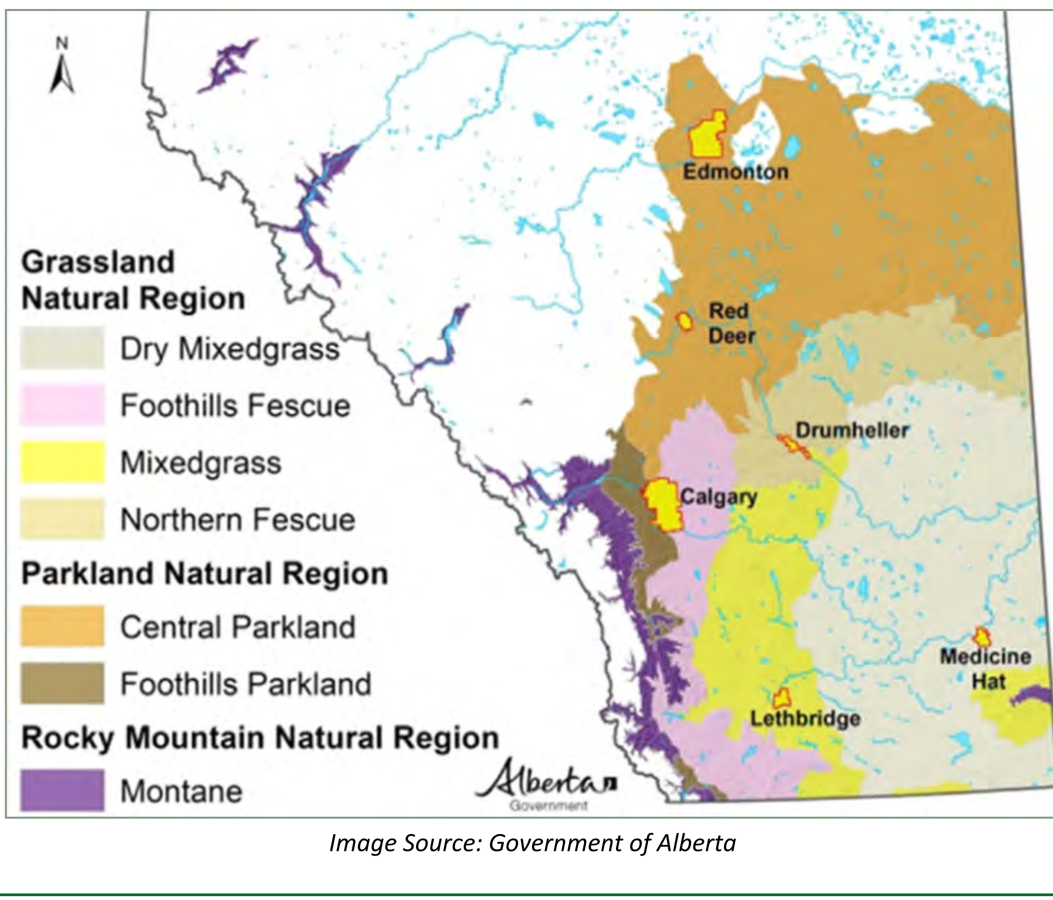

Image Source: Government of Alberta

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Helpful Abbreviations

ACIMS……Alberta Conservation Information Management System
AEP……Alberta Environment and Parks
AER……Alberta Energy Regulator
AGRASID……Agricultural Region of Alberta Soil Information Database
AMF……Arbuscular Mycorrhizal Fungi
AUC……Alberta Utilities Commission
BlO……Blowout Range Site
DMG……Dry Mixedgrass
EAP……Enhanced Approval Process
EPP……Environmental Protection Plan
ERCB……Energy Resources Conservation Board
ERS……Ecological Range Site
ESRRA……Ecological Site Restoration Risk Analysis
FWMIS……Fish and Wildlife Management Information System
GoA……Government of Alberta
GPS……Global Positioning System
GRF……Grassland Restoration Forum
GVI……Grassland Vegetation Inventory
IL……Information Letter
LAT……Landscape Analysis Tool
Len……Lentic (stillwater) Wetland
Lo……Loamy Range Site
MG……Mixedgrass
NSR……Natural Subregion
PDSA……Pre-Disturbance Site Assessment
PLS……Pure Live Seed
Pn……Non-irrigated Cultivated Land
PNT……Protective Notation
RoW……Right-of-Way
RPC……Reference Plant Community
SASCI……Southwest Alberta Sustainable Community Initiative
SSA……Strategic Siting Assessment

1 A Shift in Focus to Restoration

Why is ecological restoration so important to conserving native grassland ecosystems? There is an increasing public awareness of our continually declining native grassland ecosystems and the services they provide Albertans. Grasslands are high-value ecosystems, providing a suite of essential ecological goods and services, and contributing to the social and cultural landscapes of communities. Historically undervalued, grasslands have been subject to rapid conversion and degradation, with the challenge of restoring these complex ecosystems either underestimated, or wholly discounted.

As our understanding of these complex ecosystems has evolved, it has become apparent that grasslands have more in common with old growth forests than hayfields. Our native grasslands assembled over centuries, contain long-lived perennial plants, and have high species diversity and structure, both above- and below-ground. From this below-ground structure, many plants can re-sprout after natural disturbance such as fire and grazing (Buisson et al. 2022). The most detrimental disturbances are those that rapidly destroy below-ground structure such as topsoil stripping or tillage, which can cause grasslands to cross a threshold beyond which restoration is difficult or impossible within decades of these disturbances. Hence the need to minimize disturbance. Grassland restoration should be viewed through the lens of a long-term trajectory guided by knowledge of ecosystem feedback to understand how disturbance impacts and restoration activities can assist with conservation and recovery of these globally valued landscapes. (Buisson et al., 2022).

Development to support our expanding population continues to put pressure on native grasslands. Decommissioning existing industry projects currently requires reclamation certification at abandonment but standards have varied over the years, and implementation is often fraught or unsuccessful in the long-term. All activities taking place on the landscape have a combined effect on ecosystem function.

The purpose of this document is to provide planners, reclamation practitioners, landholders, land managers and regulatory authorities with guidance on a suite of recovery strategies for industrial disturbances in native grasslands and their appropriate use. Developing effective recovery strategies is necessary to mitigate cumulative effects to native grasslands by retaining and maintaining ecosystem biodiversity, health, and resilience. 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 disturbance to soils and native plant communities.
- Understanding the important role that timing plays in the outcome of development activities in native prairie and the timeline required to achieve restoration.

1.1 Linkage to Reclamation Criteria

The principles, guidelines and recovery strategies discussed in this manual are designed to dovetail with Government of Alberta reclamation criteria, 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. **The principles behind these criteria and pathways for decision making are relevant to all industries operating on native grassland.** There is emphasis on native grassland plant communities as indicators of equivalent land capability, defined 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”. It is important that all industries strive to meet these standards in order to retain functioning grassland ecosystems. The bar has been raised and now is the time to meet the challenge.

1.2 Restoration Trajectory and Timing

Restoration efforts and successes vary depending on a suite of variables, and the ability to fully restore a site is dependent on the abiotic and biotic characteristics of a site, and whether they have become barriers to reaching restoration objectives, as well as the effects of year-to-year climatic variation on success along restoration trajectories (Miller et al. 2023).

In practice, any activities undertaken to promote eventual restoration of a disturbance are reclamation activities. For reclamation to be considered successful and meet reclamation criteria such as the *2010 Reclamation Criteria for Wellsites* (AEP 2013) there must be evidence of a positive trajectory within the landscape, plant community and soils towards restoration. The timing for actual restoration of a healthy, functioning plant community that supports species typical of the biodiversity of the area may take many years. Studies indicate that under ideal conditions, it may take 5-7 years to re-develop healthy mid- to late seral plant communities on smaller, well managed surface disturbances in the Mixedgrass NSR. Groundcover components like moss, lichen and little club moss (*Selaginella densa*) may need 25+ years to re-establish equivalent cover (Kestrel Research Inc. and Gramineae Services Ltd. 2011).

Waiting many years to be assured that restoration is occurring is not practical. Therefore, confidence must be established that a recovering site is on a positive trajectory at the time of reclamation certification, with the expectation that recovery will continue unassisted towards restoration over time.

2 Overview of the Mixedgrass Natural Subregion

The first step in restoration planning requires an understanding of Alberta's regional ecological land classification system. *The Natural Regions and Subregions of Alberta* (Downing and Pettapiece 2006) provide the ecological context within which resource management activities are planned and implemented.

The Grassland Natural Region is ecologically diverse; unique restoration challenges are associated with each Natural Subregion (NSR). Natural Subregions in the grasslands are distinguished primarily based on climate, soils, and vegetation factors. These distinctions assist practitioners with the understanding of restoration opportunities and limitations within the Subregion context. This publication focuses on native grasslands in the Mixedgrass Natural Subregion (Mixedgrass NSR) in Alberta (Figure 1-1).

The Mixedgrass NSR occurs in five geographic areas extending north from the United States border to the Red Deer River (Figure 1-1, Figure 2-1). The largest area occurs on the plains to the east of the Foothills Fescue NSR and to the west of the Dry Mixedgrass NSR. This plain borders the Northern Fescue NSR, which is to the north. This area includes the Lethbridge Plain, the Vulcan Plain, the Blackfoot Plain and the Standard Plain ecodistricts (Figure 2-2). Smaller areas of Mixedgrass NSR occur in four highland ecodistricts. The Majorville Upland occurs east of and adjacent to the plains to the north of the Lethbridge Plain (Figure 2-3). The Cypress Hills Upland surrounds the Cypress Hills Escarpment and Plateau (Figure 2-4). The Sweetgrass Upland occurs as a band along the lower slopes of the Sweetgrass Hills along the United States border (Figure 2-5), and the Milk River Upland occurs along the eastern portion of the Milk River Ridge (Figure 2-6) (Adams et al. 2013). It is important to understand the differences between the ecodistricts that occur in the Mixedgrass NSR (Figures 2-2 through 2-6). Topography, elevation, soils and climate have played a major role in the development of sustainable native plant communities unique to each ecodistrict.

The Mixedgrass NSR accounts for 19.8% of the Grassland Natural Region area and 2.9% of the area of Alberta (ASIC 2001). The soils of the Mixedgrass NSR are very productive. Hence, since settlement, the prairie has been highly fragmented by cultivation. Approximately 37% of the original 4.6 million acres of Mixedgrass prairie remain today. The plains are mostly cultivated, with scattered remnant prairies. Only 10% of the Vulcan Plain ecodistrict remains intact (Raven et al. 2022), More extensive native rangelands occur at higher elevations on the slopes of the Cypress Hills, and the Sweetgrass, Milk River and Majorville Upland Ecodistricts (Downing and Pettapiece 2006).

Figure 2-1 Mixedgrass Natural Subregion Grassland Vegetation Inventory

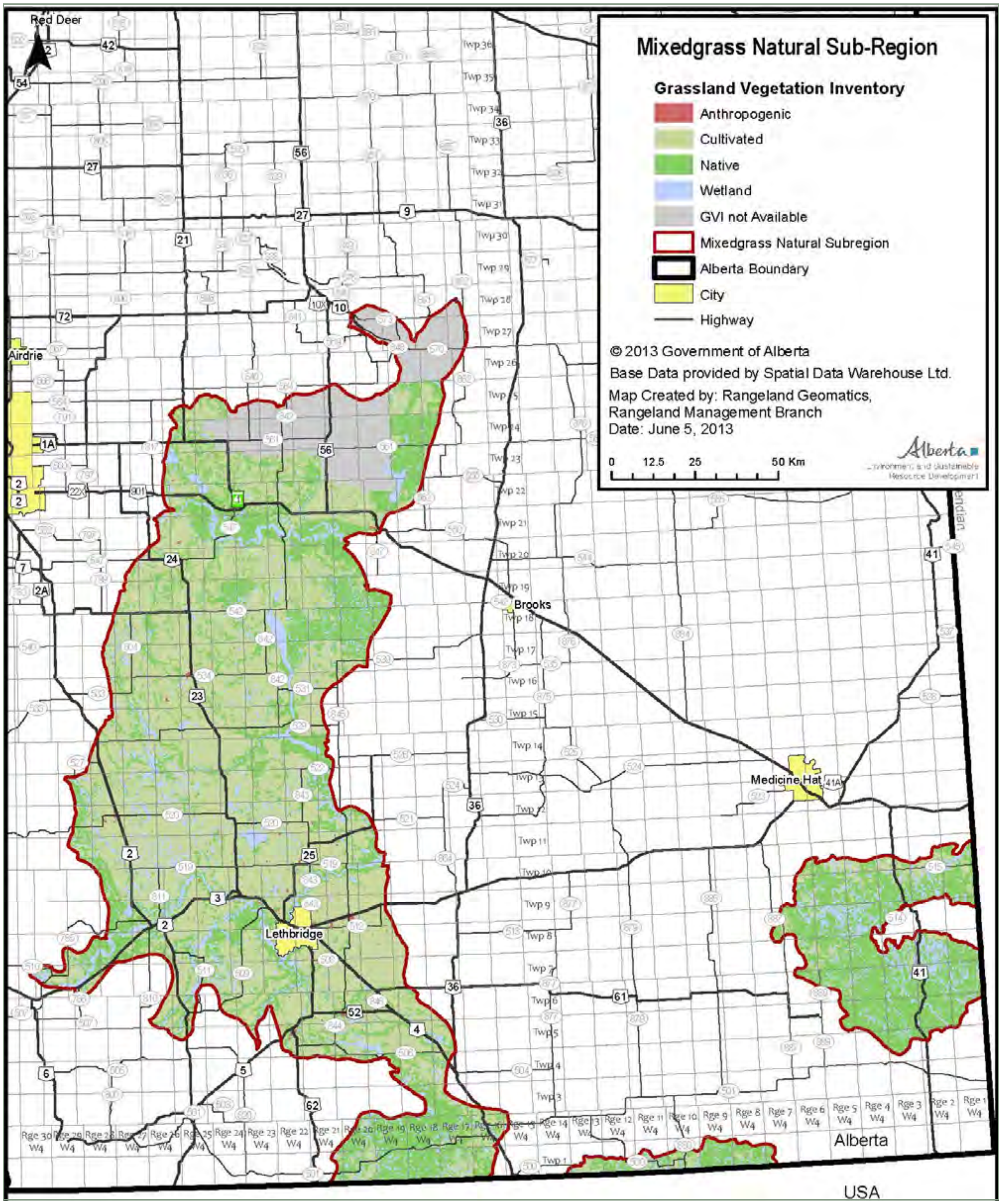


Figure 2-2 Lethbridge & Vulcan Plains Ecodistricts Grassland Vegetation Inventory

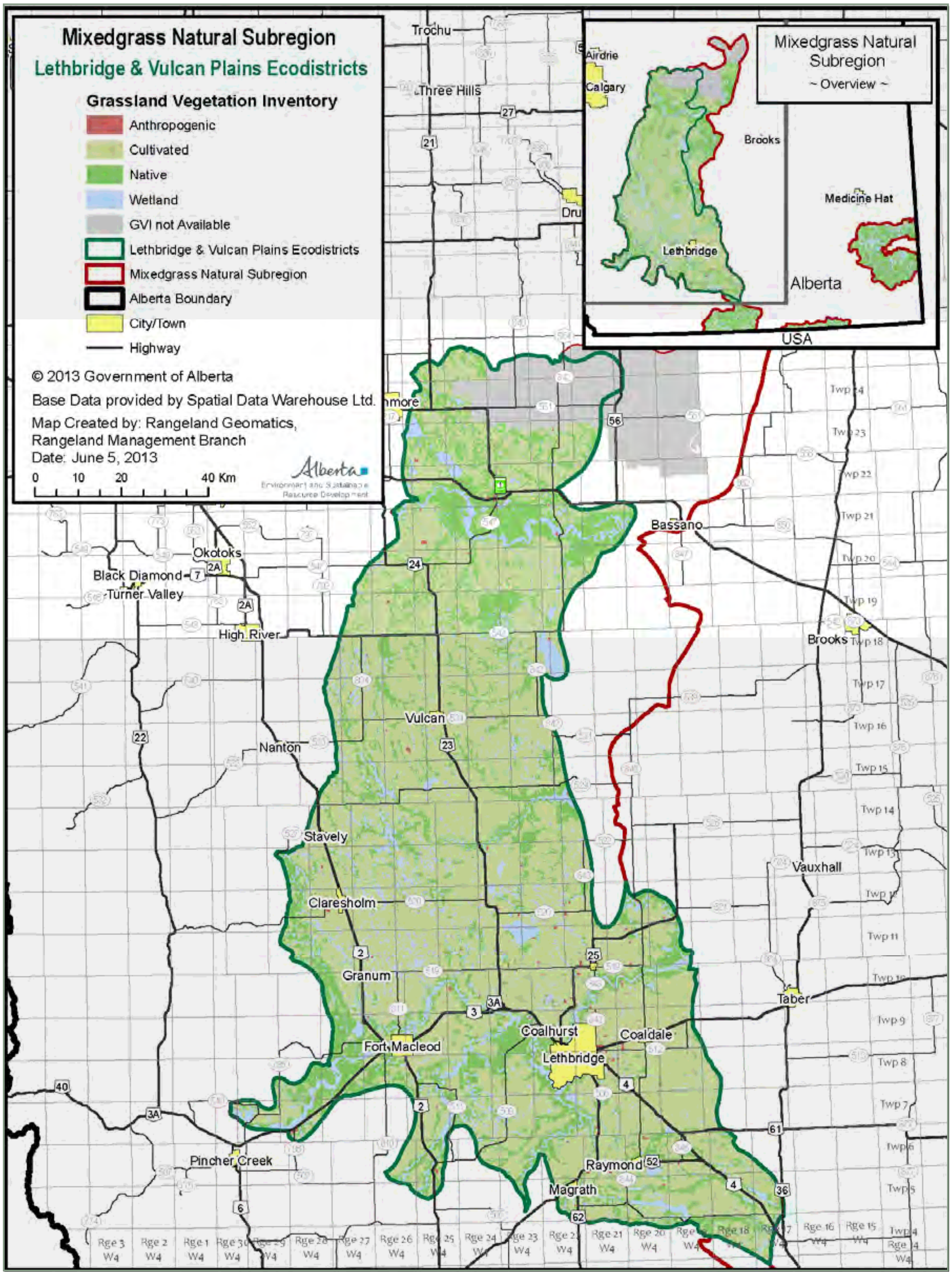


Figure 2-3 Majorville Upland Ecodistrict Grassland Vegetation Inventory

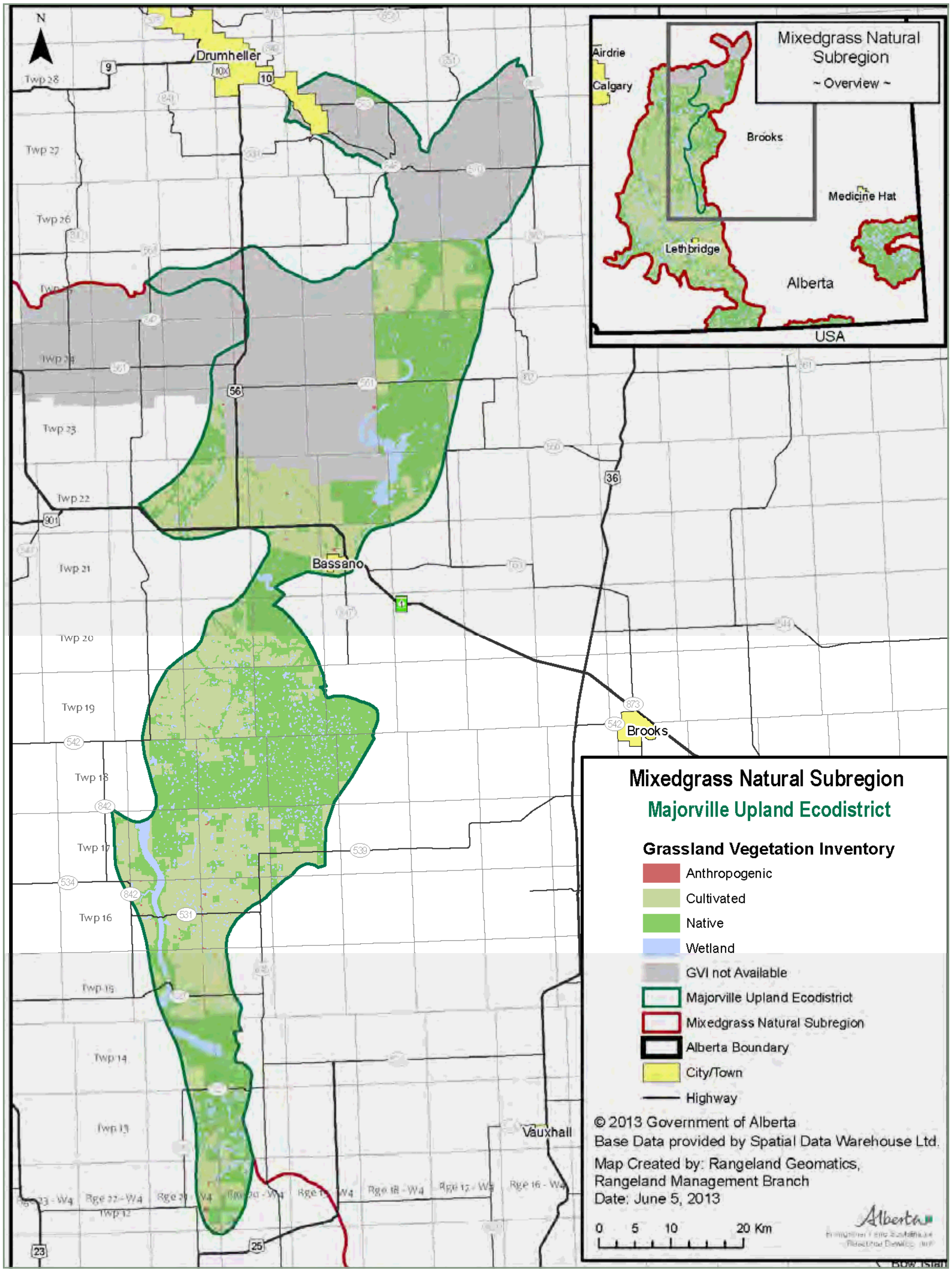


Figure 2-4 Cypress Hills Upland Ecodistrict Grassland Vegetation Inventory

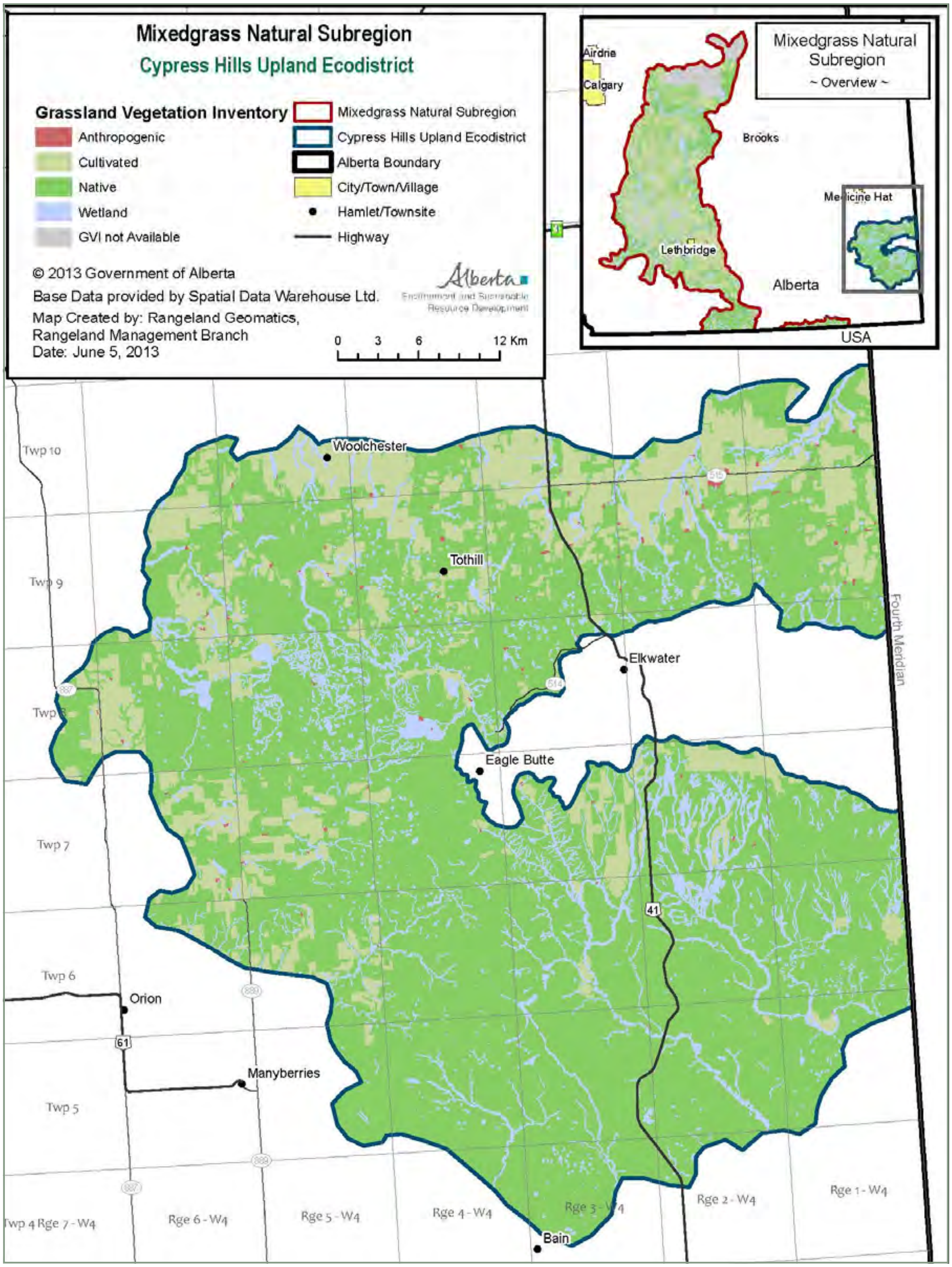
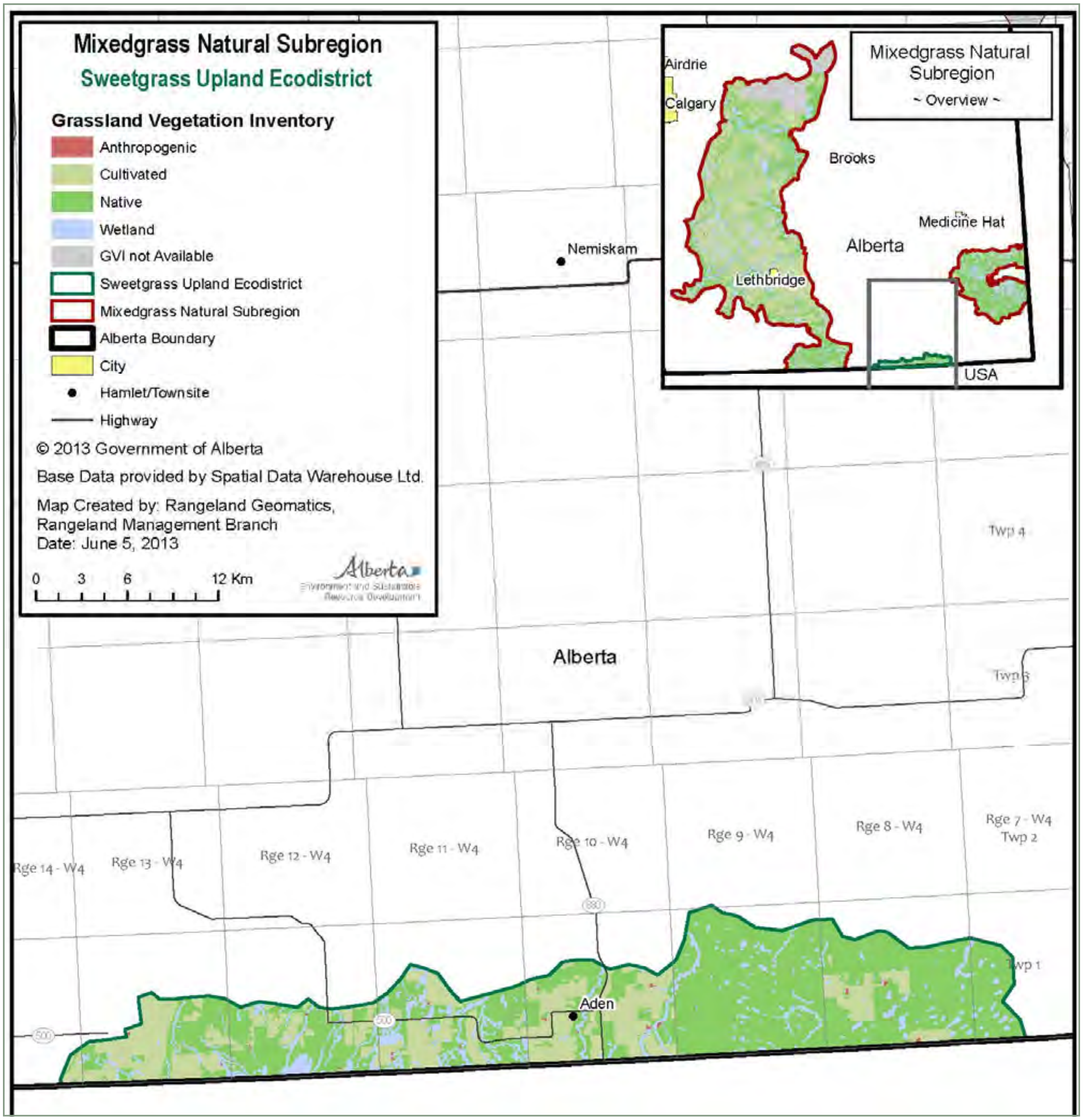
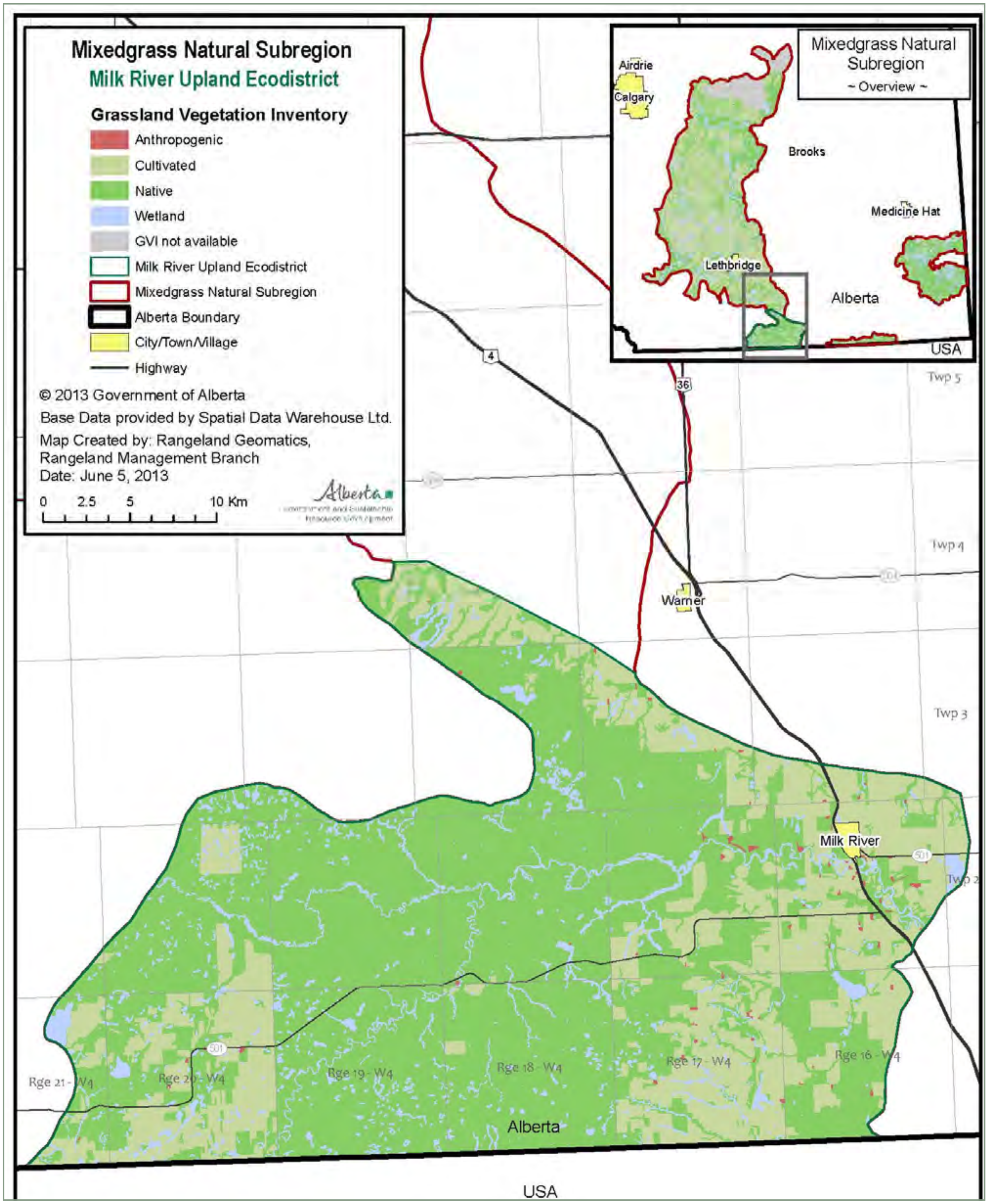


Figure 2-5 Sweetgrass Upland Ecodistrict Grassland Vegetation Inventory



The Grassland Vegetation Inventory (GVI) is the Government of Alberta's first comprehensive, landscape scale biophysical, vegetation and anthropogenic inventory of the Grassland Natural Region.

Figure 2-6 Milk River Upland Ecodistrict Grassland Vegetation Inventory



2.1 Physiography, Soils, Climate and Vegetation of the Mixedgrass NSR

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

Strong, warm westerly winds are a significant factor influencing restoration potential once native prairie vegetation has been removed.

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

The climate of the Mixedgrass NSR is characterized by short summers with warm days and cool nights. Mean summer temperatures are about 15^{o}C and mean annual temperature is about 5^{o}C (Adams et al. 2013). The Mixedgrass NSR has slightly moister and somewhat cooler summers and milder winters than the Dry Mixedgrass NSR to the east. Climatic data and comparisons with the surrounding Natural Subregions can be found in the *Mixedgrass Range Plant Community Guide* (Adams et al. 2013). Even cooler and moister conditions prevail at higher elevations in the Mixedgrass uplands and hills ecodistricts.

Winter thawing of frozen soils presents challenges for operating heavy equipment on native prairie vegetation.

The milder winters, particularly in the western portion of the Mixedgrass NSR, are due to the influence of Chinook winds. These strong, warm, westerly winds are a significant factor influencing restoration potential once native prairie vegetation has been removed. Winter thawing of frozen soils presents challenges for operating heavy equipment on native prairie vegetation. The potential for soil loss due to wind erosion is a significant factor that must be considered in development planning.

The fertile Dark Brown Chernozemic soils, combined with adequate average annual precipitation, provides the opportunity for non-native plants to invade and colonize disturbed soils, especially in areas fragmented by cultivation.

Potential for soil loss due to wind erosion is a significant factor that must be considered in development planning.

The native grassland plant communities of the Mixedgrass NSR are strongly influenced by regional factors. In the Mixedgrass NSR, elevated regional landforms rising above broad plains, combined with soils and climatic factors related to differences in elevation, produce unique and varied native grassland plant communities. The plains ecodistricts of the Mixedgrass NSR (Lethbridge, Vulcan, Blackfoot and Standard Plains) support native plant communities similar to the Dry Mixedgrass NSR, typically dominated by needle-and-thread (*Hesperostipa comata*), blue grama (*Bouteloua gracilis*), and northern wheat grass (*Elymus lanceolatus*). In the Majorville Upland, western porcupine grass (*Hesperostipa curtiseta*) replaces needle-and-thread grass as the dominant species. The lower slopes of the Cypress Hills Upland are dominated by June grass (*Koeleria macrantha*), northern wheatgrass, western wheatgrass (*Pascopyrum smithii*) and needle-and-thread. Higher elevations are dominated by plains rough fescue (*Festuca hallii*), western porcupine grass, and sedges (*Carex species*).

Plains rough fescue and foothills rough fescue plant communities should be avoided as they are very difficult to restore.

The Milk River Upland and the slopes of the Sweetgrass Upland are dominated by northern wheat grass, June grass, Idaho fescue (*Festuca idahoensis*) and sedge communities. It is important to note that plains rough fescue plant communities can also occur in the transition areas between the Mixedgrass NSR and the Northern Fescue NSR to the north, and the Foothills Fescue NSR to the west. Plains rough fescue and foothills rough fescue (*Festuca campestris*) plant communities should be avoided as they are very difficult to restore. A more detailed description of the Mixedgrass NSR is provided in the Mixedgrass Range Plant Community Guide (Adams et al. 2013). It can be found on the Government of Alberta's Open Alberta website or hard copies can be purchased through the Grassland Restoration Forum.

The Cypress Upland Ecodistrict Includes Large Areas of Intact Rangelands on the Southern Slopes of the Cypress Hills

2.2 Development of Guidance for Industry Surface Disturbance Management

The importance of managing surface disturbance and maintaining the integrity of native plant communities during industrial development in native grasslands was formally recognized since 1992 in a series of Information Letters (IL) issued through the Energy Resources Conservation Board (ERCB), the Alberta provincial regulatory body of the time.

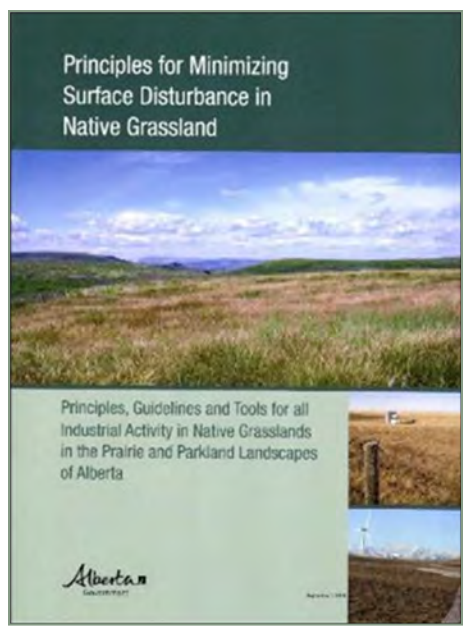
ERCB IL 92-12, IL 96-9: These information letters informed industry that agronomic grasses such as crested wheatgrass (*Agropyron cristatum*) could not be used anymore in reclamation seed mixes in native grassland and moreover, informed industry of the importance of native prairie and parkland areas and the need to minimize surface disturbance through all phases of development activities when undertaking development in these areas.

Special Areas Policy 06-06: Invasive Introduced Forages on Reclamation Sites: The use of native species is required on native prairie and parkland sites constructed or reclaimed after September 1992.

Petroleum Industry Activity in Native Grassland and Parkland Areas, Guidelines for Minimizing Surface Disturbance (Native Prairie Guidelines Working Group 2002) was developed by a collaborative stakeholder working group composed of representatives of industry, Government of Alberta (GoA) regulators and conservation organizations. It expanded and updated the guidelines to incorporate recent regulatory requirements and industry best management practices. This publication was adopted by the **Alberta Energy Regulator (AER) as *Manual 007* in 2014** (AER 2014).

2010 Reclamation Criteria for Wellsites and Associated Facilities for Native Grasslands (Updated July 2013): The aim of reclamation under the *Environmental Protection and Enhancement Act* is to obtain "equivalent land capacity," which is defined as the ability of the land to support various land uses after conservation and reclamation similar to the ability that existed prior to activity being conducted on the land. The criteria are used to evaluate whether a site has met equivalent land capability, based on land function and operability that will support the production of goods and services consistent in quality and quantity with the surrounding landscape (AEP 2013).

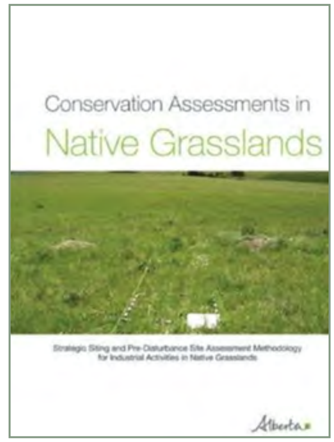
Principles for Minimizing Surface Disturbance in Native Grassland - Principles, Guidelines, and Tools for all Industrial Activity in Native Grasslands in the Prairie and Parkland Landscapes of Alberta (AEP 2016)**:** This document replaces Manual 007 (AER 2014). The document responds the need for a broader application of the principles and guidelines **across all industrial sectors** developing projects in native grassland landscapes. It was prepared by a working group comprised of representatives from government agencies having jurisdiction over industrial activities in native grassland and parkland areas, petroleum, renewable energy and utilities stakeholders, environmental consultants and conservation groups. It provides specific direction for all phases of industrial development including strategic siting, construction and operations and reclamation.



Key general guidelines include:

- Avoid native grasslands where possible, especially in critical ecological sites identified as extremely difficult to reclaim,
- Reduce the area and impacts of industrial disturbance to the extent possible, and
- Develop practical methods that will allow eventual restoration of disturbed areas.

Conservation Assessments in Native Grasslands - Strategic Siting and Pre-disturbance Site Assessment Methodology for Industrial Activities in Native Grasslands (AEP 2018): The intent of the document is to provide a consistent assessment tool to meet legislative requirements of conservation and reclamation in Alberta by:



- Making it applicable across industrial activity types,
- Utilizing pre-existing and established assessment practices in native grasslands, and
- Providing a versatile tool to be used as a best management practice or under any regulatory framework requiring siting or pre-disturbance assessment data.

In addition to petroleum development in the Mixedgrass NSR, there has been a substantial increase in renewable energy projects such as commercial wind and solar developments.

Conservation and Reclamation Directive for Renewable Energy Operations (GoA-AEP 2018): The Government of Alberta is the regulating body including issuance of reclamation certificates. Developers are required to follow the Conservation and Reclamation Directive for Renewable Energy Operations, which points to the requirement to follow the 2010 reclamation criteria (e.g., native grassland criteria) applicable for the targeted end land use type.

Conservation and reclamation of deep geothermal (heating and power) projects in Alberta is regulated by the Alberta Energy Regulator, including issuance of the reclamation certificates. Developers are required to follow the Conservation and Reclamation Directive for Renewable Energy Operations (GoA-AEP 2018) which points to the requirement to follow the 2010 reclamation criteria (e.g., native grassland criteria) applicable for the targeted end land use type.

The **Alberta Utilities Commission (AUC)** regulates transmission lines. To assist these developing industries to understand the challenges faced when working in native grasslands the following documents were developed by a multi-stakeholder working group coordinated through the Alberta Prairie Conservation Forum (PCF).

***Beneficial Management Practices for Renewable Energy Projects: Reducing the Footprint in Alberta's Native Grassland, Parkland and Wetland Ecosystems*: This document addresses industry-specific beneficial management practices for renewable energy developments. Through development of this document, the intent of PCF is to foster a positive working relationship with the renewable energy industry to assist in drafting practical beneficial management practices that sustain prairie biodiversity at the species, community, and ecosystem levels (Prairie Conservation Forum 2017).

Reducing the Renewable Energy Footprint on Native Grasslands: Summary Information for Renewable Energy Developers: This summary sheet provides industry-specific beneficial management practices for renewable energy developments in native prairie landscapes (Prairie Conservation Forum 2018a).

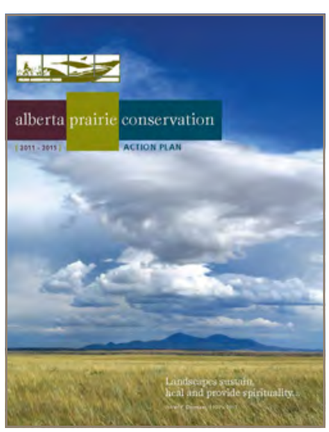
Reducing the Renewable Energy Footprint on Your Native Grasslands: Information for Alberta Landowners (Prairie Conservation Forum 2018b).

Alberta Prairie Conservation Forum Action Plan 2021-2025 (Prairie Conservation Forum 2021): The PCF promotes the conservation of native biodiversity in prairie and parkland environments in Alberta and to provide an ongoing profile for prairie and parkland conservation initiatives. The PCF has published research and guidelines related to energy development in native prairie.

The vision embedded in the 2021-2025 Action Plan (PCF 2021) 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 strategic or long-term environmental 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 native grasslands these three important outcomes must be considered early in any development planning process. The PCF are developing mapping for valued and sensitive isolated habitats and connecting corridors that will assist in constraints mapping for project planning.

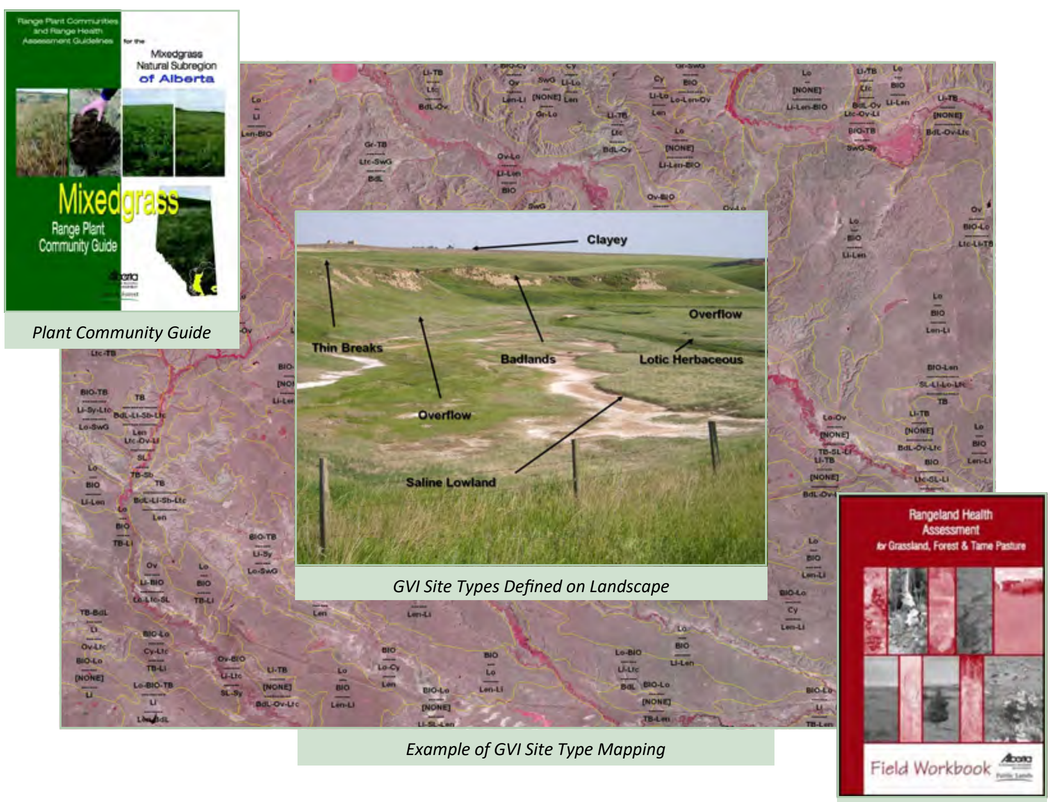


Cumulative Effects: Cultivation, a road ditch with invasive species, a cabin, a wellsite and a gravel pit on native grassland.

3 Tools for the Restoration Toolbox

Implementing improved recovery strategies involves not just practicing change on the ground but also utilizing several tools designed to understand site characteristics and plant communities linked to landforms and soils (Figure 3-1). These tools, described below, will improve project planning, 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. The timing of their use in developing a site-specific recovery strategy is described in Section 5: Preparing the Pathway.

Figure 3-1 Standardized Grassland Assessment Tools



Plant Community Guide

GVI Site Types Defined on Landscape

Example of GVI Site Type Mapping

Range Health Assessment Workbook

Image Source: Government of Alberta

3.1 Agricultural Region of Alberta Soil Information Database (AGRASID)

Site-specific information for soils is found on the Alberta Soil Information Viewer web site (GoA 2021). The Alberta Soil Information Viewer includes maps and data for AGRASID, more detailed soil survey maps and reports, other applied soil information (Figure 3-2).

Figure 3-2 A Grassland Natural Region Landscape Comparing the Scale of GVI Site Polygons (green) Versus AGRASID Soil Polygons (yellow)

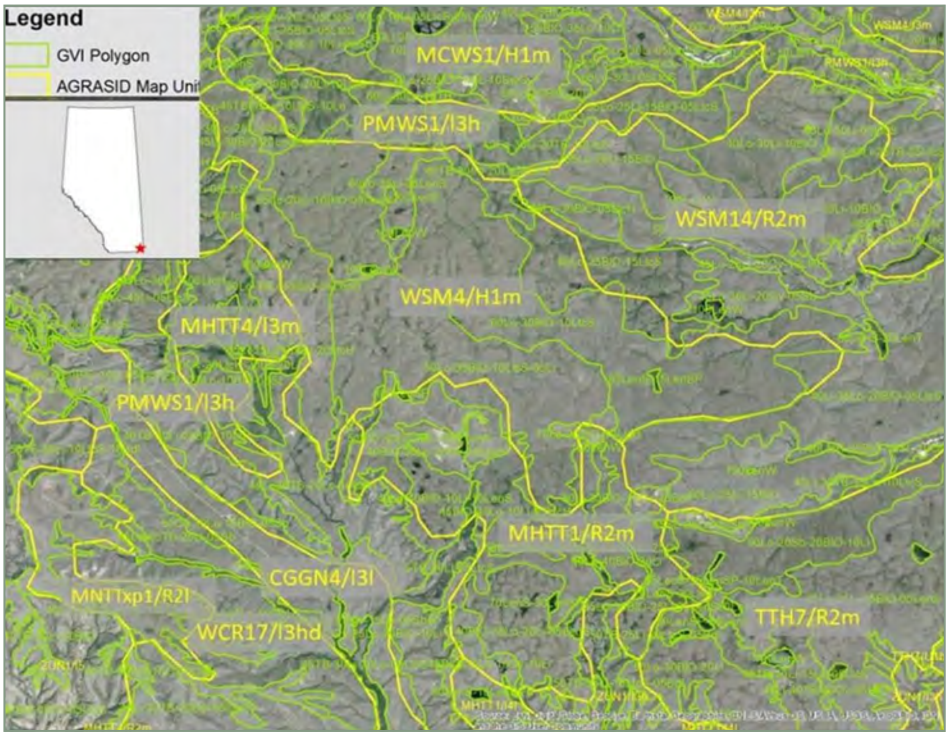


Image Source: Government of Alberta

3.2 Grassland Vegetation Inventory (GVI) Mapping

GVI inventory polygons provide a finer resolution landscape interpretation compared to the relatively coarse AGRASID soil landscape polygons (Figure 3-2).

The Grassland Vegetation Inventory (GVI) is the Government of Alberta's first comprehensive, landscape scale biophysical, vegetation and anthropogenic inventory of the Grassland Natural Region.

Developed by Alberta Environment and Parks (AEP), the GVI provides mapped information of landscape scale soil/landform features and generalized vegetation cover for use in planning and management of rangelands, fish and wildlife, wetlands, land use and reclamation. It also includes a coarse hydrological feature layer.

GVI is comprised of mapped range sites based on landform, soils and vegetation information for areas of native vegetation and general land use for non-native areas (agricultural, industrial, and urban areas). Mapped GVI information within areas determined to be native is about 80% accurate (Craig DeMaere pers. comm. March 2023). Field verification is required on areas of native vegetation. Interpretation guides and examples are included for each natural subregion. Tables correlating soils and range sites can be found in the *Mixedgrass Range Plant Community Guide, Second Approximation* (Adams et al. 2013).

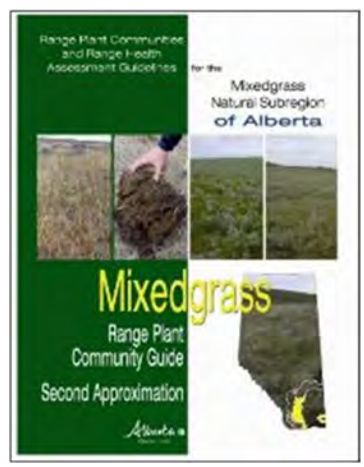
GVI Data: The GVI data, index map, status map, views and specifications documents are available from the Government of Alberta (AEP 2019c).

GVI User Information and Technical Specifications: User information for GVI including an example application of pre-site planning is available on the Alberta Prairie Conservation Forum website, *Grassland Vegetation Inventory Specifications 5th Edition Revised November 2011* (ASRD 2011).

Mapped GVI information within areas determined to be native is about 80% accurate. Field verification of range sites is required on areas of native vegetation.

3.3 Range Plant Community Guides

The Mixedgrass Range Plant Community Guide, Second Approximation (Adams et al. 2013) is an essential field guide for identifying common plant communities and conducting range health assessments, conservation assessments, reclamation planning and monitoring. The plant community guide has been compiled from data collected from detailed vegetation inventories and an extensive system of reference areas established across the province by the Government of Alberta Range Resource Stewardship Section. Assessing composition and health of native grassland plant communities requires taxonomic identification expertise of grasses in vegetative and fruiting stages, in lightly and heavily grazed conditions, and training in range health assessment protocols. The guide provides descriptions of common plant communities linked to range site type and ecodistrict. Ecodistricts are subdivisions of natural subregions based on distinct physiographic and/or geologic patterns. They are distinguished by similar patterns of relief, geology, geomorphology, and parent material genesis.



Plant communities in the Grassland Natural Region are classified based on their association with range sites, determined through key landscape attributes, soil features and textural groupings within larger mapped ecodistricts (Adams et al. 2013). Ecological range sites are subdivisions of range sites based on plant community composition.

Range plant communities are reported in three categories including reference, successional and modified communities, depending on the level of grazing disturbance. The plant community that is an expression of site potential is referred to as the reference plant community since it represents the natural community that develops under light or moderate grazing disturbance. This potential community is described as healthy for comparison in range health assessment.

Assessing composition and health of native grassland plant communities requires taxonomic identification expertise of grasses in vegetative and flowering or reproductive stages, in varying grazed conditions, and training in range health assessment protocols.

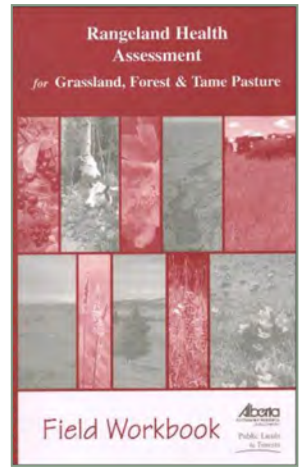
3.4 Navigating the Mixedgrass Range Plant Community Guide

The *Mixedgrass Range Plant Community Guide* (MGRPCG) contains vital information to determine which ecodistrict a project is located in. Knowing the soil series of the location being examined provides a key clue to range site, as cross-over tables have been developed linking soil series to range sites. Steps to determining plant community information for a location in the Mixedgrass NSR are:

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

Upland site types in the Mixedgrass NSR are analogous to range sites in GVI.

3.5 Range Health Assessment



The range health assessment protocol described in the ***Range Health Assessment*** Field Workbook developed by AEP are used to assess, monitor, and manage Alberta's rangelands (Adams et al. 2016).

The assessment approach builds on the traditional range condition concept that considers plant community type in relation to site potential and adds important indicators of natural processes and functions. The methodology provides a visual system that allows users to readily see changes in range health and provides an early warning when management changes are needed.

Understanding range health is an important component of a restoration risk assessment. In the context of reclamation after disturbance, it is a measure of ecosystem recovery.

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

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

1. Integrity and Ecological Status – on native or modified grassland, based on species composition.
2. Community Structure – vertical and horizontal.
3. Hydrologic Function and Nutrient Cycling – litter cover and distribution.
4. Site Stability – erosion, bare soil, moss and lichen cover.
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. A range health score is calculated as a percentage value, classified into one of three categories: unhealthy (0% to 49%), healthy with problems (50% to 74%) and healthy (75% to 100%).

Range health assessment is an important component of strategic siting, selecting a recovery strategy, and reclamation assessment to demonstrate achieving reclamation criteria for certification.

Range health assessment training programs are offered through the Grassland Restoration Forum and the Alberta Prairie Conservation Forum.

3.6 Ecological Site Restoration Risk Assessment (ESRRA)

Ecological Site Restoration Risk Assessment (ESRRA) is a desktop analytical tool to predict the ability of ecological range site components and their component plant communities to recover from direct impacts of industrial activity on native grassland. ESRRA applies mapped information of landscape scale soil/landform features available in the GVI inventory, and soil mapping from AGRASID or more detailed soil maps, to assign **a reclamation risk potential** following topsoil disturbance to each ecological range site. It also identifies native plant communities commonly associated with each ecological range site and assigns **a restoration risk** based on the difficulty of restoring the plant community after disturbance. The assessment is organized geographically by ecodistrict and their common ecological range sites (Appendix A: Table A-1). Ecological range sites common to many ecodistricts are presented in a second table (Appendix A: Table A-2).

Ecological range site descriptions provide useful information for predicting restoration risk. Information on soils, parent materials, moisture and nutrient regime, landform and the associated native plant communities are embedded in ecological site descriptions (Adams et al. 2013). **Practical application of this information is used as a coarse filter for strategic siting when planning industrial development.** The information also provides key linkage to potential construction and reclamation challenges, and the ability of the site to recover following disturbance and meet reclamation criteria at abandonment (Gramineae Services Ltd. and Landwise Inc. 2009).

The ESRRA report for the Mixedgrass NSR has been upgraded from the 2009 version in consultation with Government of Alberta rangeland agrologists and soil scientists to compliment the *Second Approximation of the Mixedgrass Range Plant Community Guide* (Adams et al. 2013) and can be found in Appendix A.

Understanding the ecological range site and range plant communities within a proposed project site is vital to conducting an ecological risk assessment for project planning.

4 Promoting Native Plant Community Succession

4.1 Understanding the Process of Succession

Native plant communities are not static, but rather constantly adapting to changes in the local environment over time. This process of gradual replacement of one plant community by another over time is referred to as succession. It can be positive or negative. **Seral stages** are plant communities that develop in ecological succession relative to their reference community. Seral stages begin at the pioneer stage as plants colonize exposed soils. A positive successional trajectory includes increasing plant community diversity, structure, and establishment of long-lived perennial grasses found in the reference plant community over time. Successional stage descriptions include early seral, mid-seral, then late seral and finally the potential natural community, which is used as the "reference" for comparison. Successional change that results in more than 5% non-native species is described as a, "trending to modified" plant community. These concepts are used to assess reclamation progress.

A positive successional trajectory includes increasing plant community diversity, structure, and establishment of long-lived perennial grasses found in the reference plant community over time.

Figure 4-1 is an example of a successional pathway diagram that illustrates how plant communities respond to disturbance based on current knowledge. The green boxes highlight the portion of grassland succession that are the best known/understood, namely the impact that light, moderate and heavy grazing have on the plant communities. The yellow 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. Much less is known/understood about these dimensions of plant succession, with reduced confidence in predicting outcomes. Nonetheless, this successional tool provides a foundation for capturing and sharing key learnings and for using this knowledge to improve our development and reclamation practices.

The challenge for restoration following disturbance is to establish a positive successional trend towards the plant communities present on site prior to disturbance. The goal is to recognize a trajectory towards recovery with confidence that recovery will continue unassisted towards restoration over time.

4.2 Establishing a Positive Trajectory Following Disturbance

The challenge for restoration following disturbance is to establish a positive successional trend towards the plant communities present on site prior to disturbance. The process typically takes several years after short term disturbance in Mixedgrass NSR communities (e.g., five years for healthy, well managed sites), but may take many years (e.g., 10-20 years) for rough fescue communities. The goal is to recognize a trajectory towards recovery with confidence that recovery will continue unassisted towards restoration over time. The trajectory towards recovery is dependent on the size of the disturbance, the plant community, potential for invasive species establishment, weather conditions and the recovery strategy implemented.

Figure 4-1 A Successional Pathway Diagram That Illustrates How Plant Communities Respond to Disturbance on Loamy Soils in Mixedgrass Grasslands

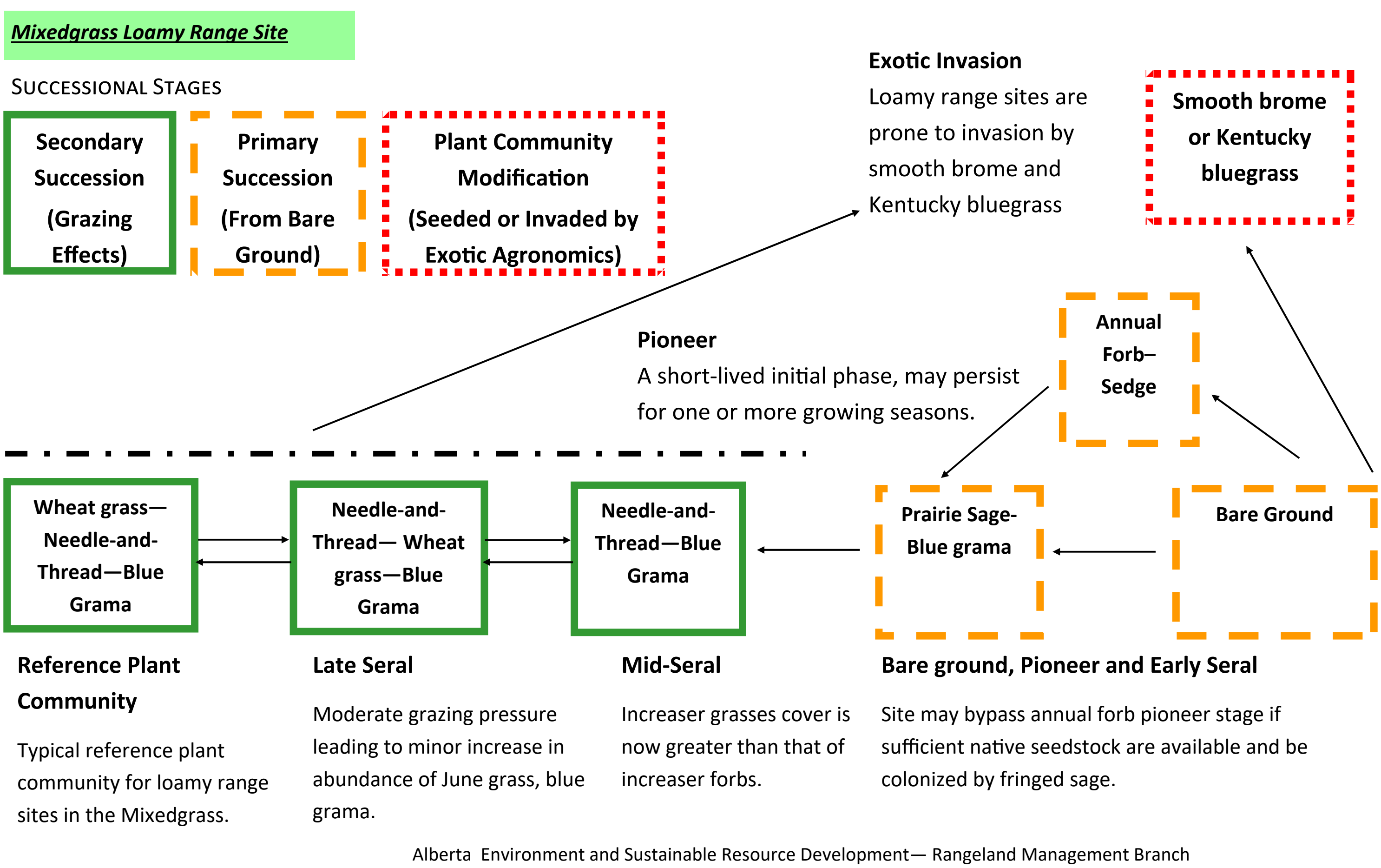


Image Source: Government of Alberta

The old paradigm of only two or three years being required to achieve a reclamation certificate is often not long enough to recognize a trajectory towards restoration of native grasslands.

Proof of a stable successional trajectory toward pre-disturbance plant communities as found in adjacent, non-disturbed areas may not be immediately evident in the two-year period historically used to assess (re)vegetation success.

4.2.1 The Influence of Grazing on Succession

In a multiple-use landscape where livestock grazing is a common land use, reclamation assessment for reclamation certification needs to assess the recovering grassland plant community after three years of "normal grazing management". This ensures the reclaiming/recovering grasslands are resilient to and benefiting from grazing can be a long-term proposition.

Preferential grazing of a recently seeded or early seral communities can result in degradation of the recovering site, not progression (M. Neville pers. comm. March 30, 2023). Seeded native species do not all germinate in the first year; several years are likely required for initial seed mix establishment. On the other hand, eliminating grazing for too long by fencing can result in increased litter beyond what is normal for the site, resulting in moisture regime alteration, suppression of desirable species infill, and invasion by unwanted species, thus degrading a recovering site.

Temporary fencing or other deterrents can be useful tools. Partial removal of fencing (e.g., dropping wire on two sides of a fence) is a useful step to test out grazing pressure. If the site is not at a point to sustain full grazing pressure, the wires can be easily put up again if required.

The timeframe required for the process of succession to take place may not be recognized by industry, landholders, or reclamation practitioners. Patience is required to reach the restoration outcome.

Industry has an ongoing responsibility to landholders to ensure sustainable restoration of project disturbances on native grassland.

4.3 Industrial Surface Disturbance and the Process of Plant Community Succession

Understanding successional stages for recovering plant communities is critical to having confidence that recovery is occurring on disturbed sites. Definitions of successional stages for a series of recovering plant communities on disturbed topsoil (Table 4-1) was developed from the Express Pipeline long-term succession monitoring program (Kestrel Research Inc. and Gramineae Services Ltd. 2011), which monitored 63 sites over a 14-year time frame). These descriptions assist practitioners with assessing the trajectory of reclamation progress and what constitutes a positive or negative successional trend over time.

During the pioneer stage (Figure 4-1 and Table 4-1), colonizing annual forb species, often referred to as nuisance weeds, play an important role in site stabilization and moisture retention. They do not persist or invade into later seral plant communities (Tilley et al. 2022). Examples are Russian pigweed (*Axyris amaranthoides*), flixeed (*Descurainia sophia*), stinkweed (*Thlaspi arvense*), grey tansy mustard (*Descurainia richardsonii*), peppergrass (*Lepidium spp.*) and the goosefoot species (*Chenopodium spp.*).

It is also important to note that pioneer, early seral and mid-seral plant communities (Figure 4-1 and Table 4-1) can contain non-targeted species that still function for erosion control and moisture retention such as the annual species listed above, curly-cup gumweed (*Grindelia squarrosa*) or pasture sagewort (*Artemisia frigida*). They stabilize soils and help facilitate the process of succession over time.

Pioneer species play and important role in the continuum of succession.
Weed control of such species may be counterproductive.

Late seral native plant communities are more likely to develop on disturbances if range health scores for the comparable surrounding area are “healthy” or “healthy with problems”.

Monitoring data indicates that aggressive non-native species may persist over time and result in an alteration of the successional pathway to a modified state. Invasive non-native plants that are known to replace native species and establish permanent dominance in Mixedgrass NSR grassland communities include crested wheatgrass (*Agropyron cristatum*), smooth brome (*Bromus inermis*), sheep fescue (*Festuca ovina*), hard fescue (*Festuca trachyphylla*), Canada bluegrass (*Poa compressa*), Kentucky bluegrass (*Poa pratensis*), downy brome (*Bromus tectorum*), field brome (*Bromus squarrosus*) and Japanese brome (*Bromus japonicus*). If these species are identified during monitoring, they should be controlled quickly and thoroughly to prevent any shift in the successional pathway.

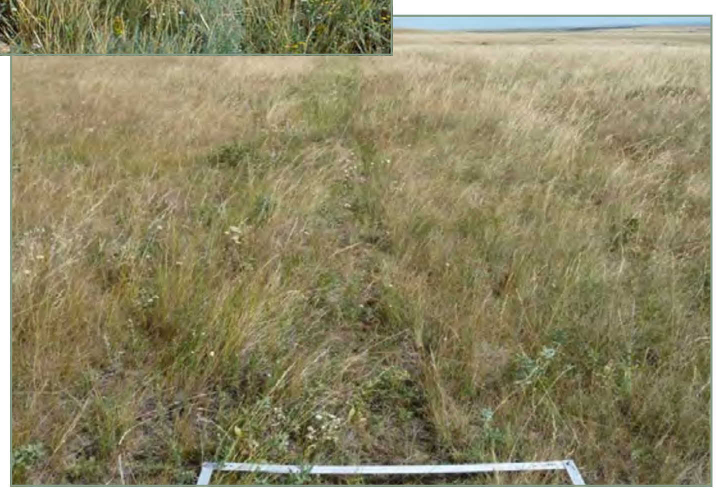
Table 4-1 Successional Stages of Recovering Plant Communities following Topsoil Disturbance

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 (*Artemisia frigida*) and other species such as low sedge. Seeded species and colonizing grasses such as needle-and-thread (*Hesperostipa comata*), or western porcupine grass (*Hesperostipa curtiseta*) 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 seedbank 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 needle-and-thread or western porcupine grass 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 greater than 5% of the total live cover; the time scale for succession to a modified plant community is as little as 5 years and as many as 20 years or more.
Modified	Less than 30% cover of native species.

Figure 4-2 Succession Over Time on a Seeded Pipeline Right-of-Way in the Cypress Upland Ecodistrict

Early Seral Community

Mid-seral Community



Late Seral Community

5 Preparing the Pathway

Planning to minimize impacts to native grasslands is a risk assessment process to optimize project placement and reduce the risk of costly and lengthy reclamation of disturbed native grasslands. Pre-disturbance planning is the first step in identifying the potential footprint of industrial development in native grassland ecosystems. It provides the opportunity to avoid disturbance to native grasslands by locating development on cultivation and previously disturbed lands dominated by non-native vegetation cover. *Principles for Minimizing Surface Disturbance – Principles, Guidelines, and Tools for all Industrial Activity in Native Grasslands in the Prairie and Parkland Landscapes of Alberta* (AEP 2016) alerts and directs industry regarding the importance of avoiding disturbance in native grassland, and the need to minimize disturbance should avoidance not be possible. These principles and guidelines apply to all industrial activity in native grasslands.

5.1 Strategic Siting and Pre-Disturbance Site Assessment

Strategic siting supports native grassland conservation and reclamation of in balance with industrial activities. Strategic site assessment and pre-disturbance site assessment is the decision-making process that enables productive and cost-effective development planning (Figure 5-1). *Conservation Assessments in Native Grasslands, Strategic Siting and Pre-Disturbance Site Assessment Methodology for Industrial Activities in Native Grasslands* (AEP 2018) provides a consistent assessment tool to meet reclamation targets and legislated reclamation requirements in this province. This document and *Principles for Minimizing Surface Disturbance* (AEP 2016) provide detailed instructions on how to complete the assessment process.

Siting industry projects such as solar installations is incompatible with maintaining existing native grasslands and should be avoided. Most native prairie grasses and forbs are not adapted to shade. Solar panels change site conditions by creating shade, cooling soils and air temperatures, and trapping snow. These changes shift site conditions to favour shade-tolerant invasive non-native grasses like Kentucky bluegrass and smooth brome. The installations also hamper necessary management of range health by grazers. Grasslands that are not managed build up litter, which increases fire risk and creates conditions that promote infestation by Canada thistle, Kentucky bluegrass and smooth brome. (Miller et al. 2023).

5.1.1 Strategic Siting Assessment

The purpose of a Strategic Siting Assessment (SSA) is to inventory and map ecological/range sites to determine whether the planned project footprint has potential native grassland components and to identify opportunities to avoid and minimize the disturbance to native grasslands (AEP 2018). The desktop review is the first step in SSA and is designed to capture as many planning variables as possible early in the process to limit the requirement to move the site after more costly assessments have occurred. The desktop review area is established to determine siting options for the planned footprint. **The desktop review area must be large enough to include the maximum allowable movement of the proposed activity on the landscape to avoid native grasslands.**

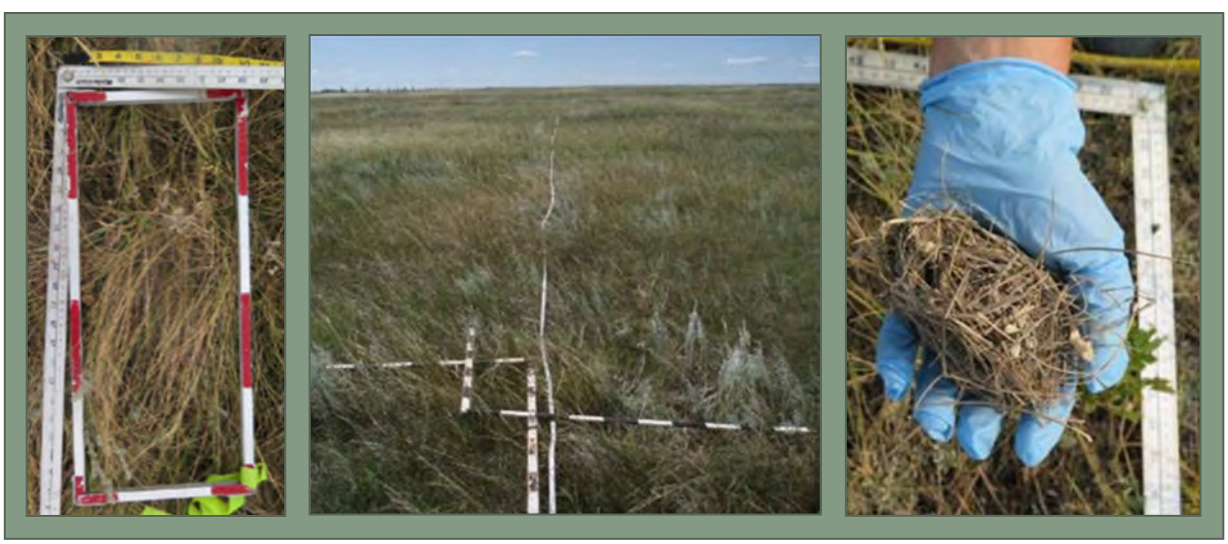
The planned footprint includes full development potential, including temporary or permanent access, utility corridors, as well as the area where offsite impacts to vegetation and soils can be anticipated. The desktop review area could be much larger than the size of the planned footprint to incorporate a variety of plant community types, land uses, or existing disturbance corridors, in order to assess potential options for strategic siting (AEP 2016).

If avoidance is not possible, minimizing disturbance to native vegetation and soils will reduce cost and risk by decreasing the amount of area that needs to be reclaimed.

5.1.2 Pre-Disturbance Site Assessment

A Pre-Disturbance Site Assessment (PDSA) is required if, after conducting a Strategic Siting Assessment, it is determined disturbance of native grassland is unavoidable (Figure 5-1). PDSA procedures are used to conduct detailed field sampling of soils and vegetation associated with the planned project footprint and provide the opportunity to design and implement reclamation and restoration outcomes throughout the lifespan of the project, from initial construction through to final reclamation. The information collected in the PDSA is used to adjust the planned footprint to minimize fragmentation and disturbance, and to shift the disturbance footprint to less sensitive grasslands and range sites. The information can also inform construction methods and can then be used to plan appropriate interim and final reclamation.

Standardized procedures and assessment methods facilitate consistent regulatory review and evaluation for project approval.



Grassland Plant Community and Range Health Assessment

Figure 5-1 Conservation Assessment Flow Chart to Avoid or Minimize Disturbance in Native Grasslands

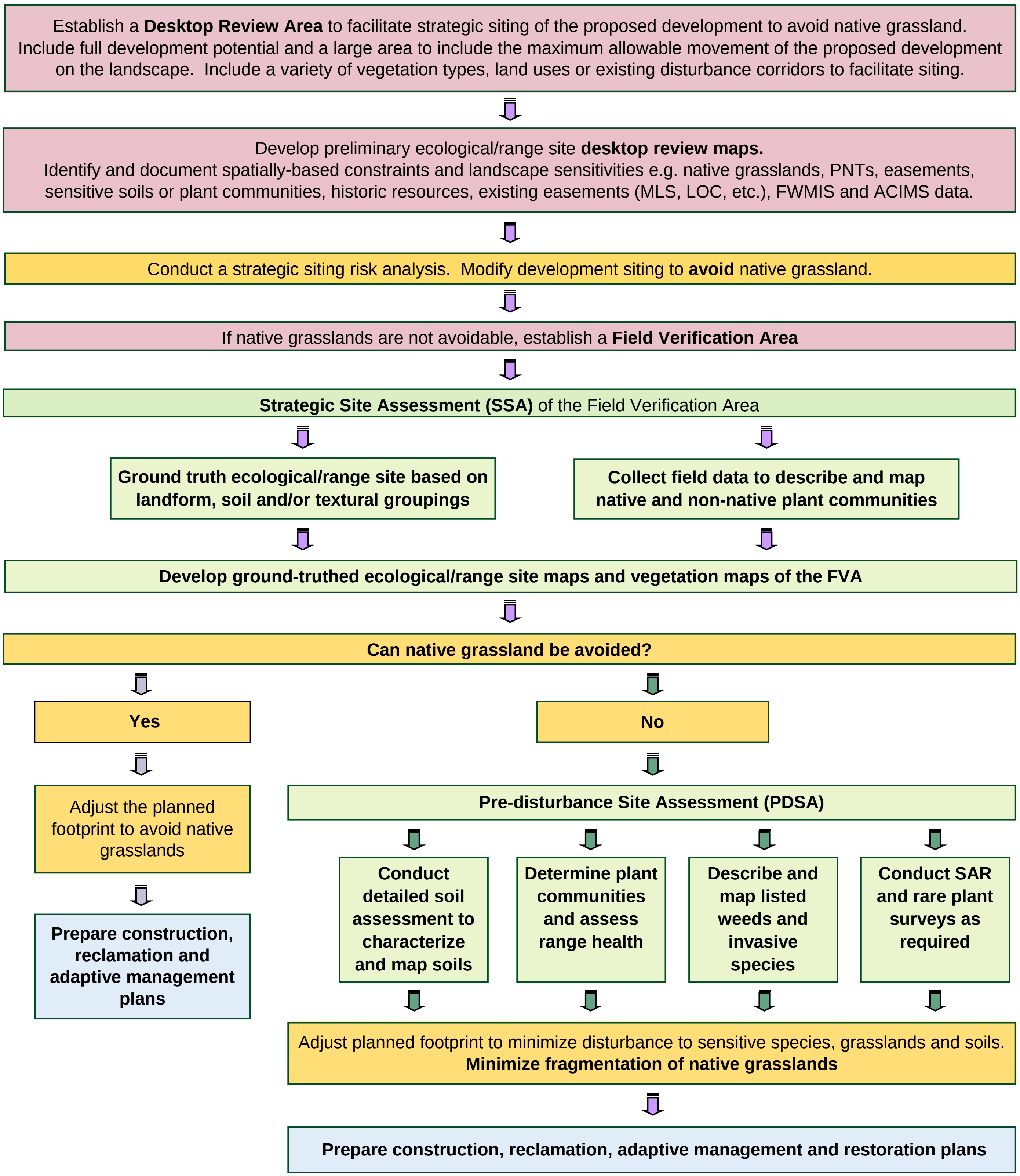


Figure 5-2 Reduce Disturbance Through Strategic Site Selection

Image Source: Government of Alberta

An example of how pre-disturbance planning based on landscape scale vegetation mapping (GVI) can optimize placement of development to minimize disturbance is illustrated in Figure 5-2. In this example, a pipeline passes through a Mixedgrass landscape crossing several landforms. GVI mapping of range sites in a development target area facilitates placement of infrastructure pads and access to minimize new disturbance to Loamy (Lo) and Blowout (BlO) range sites supporting Mixedgrass plant communities.

Four potential wellsite locations are possible:

Site A – is on non-irrigated cultivated land (Pn), previously disturbed, so would be an ideal site.

Site B – is on Blowout (BlO) soils, close to a lentic (stillwater) wetland (Len). Blowout soils are Solonetzic with an impervious hardpan layer which may limit restoration. Riparian areas are to be avoided. Therefore, Site B should be rejected.

Site C – is on Blowout (BlO) soils so the comments for Site B apply and the site should be rejected.

Site D – the site is on Loamy (Lo) soils which have not been disturbed. It requires longer pipeline and access roads but could be the second choice site.

5.2 Ensure Compliance with Regional Land Use Policy

Planning at the "front end" is critical to conserving native grasslands for future generations. The Mixedgrass NSR encompasses several federal, provincial and regional policy directives regarding land use. The ***Reclamation Certification Criteria*** (AEP 2021) does not discriminate between land ownership types (public or private lands). Specific geographic areas where development in native grasslands is managed under specific land use policy through legislation include:

Alberta Energy Regulator (AER) is responsible for regulating the life cycle of oil, oil sands, natural gas, solar, wind energy, and coal projects in Alberta through the *"Responsible Energy Development Act"* (Government of Alberta 2020); The *OneStop* (AER) application system is what industry must use for new applications on public lands and reclamation certification closure on both private and public lands.

The AER implements acts and regulations and issues directives governing energy development such as *Principles for Minimizing Surface Disturbance – Principles, Guidelines, and Tools for all Industrial Activity in Native Grasslands in the Prairie and Parkland Landscapes of Alberta* (AEP 2016).

Alberta Utilities Commission (AUC) is responsible for regulating renewable energy projects and the associated electrical transmission.

Special Areas Board policy requires a specific environmental review process for all proposed industrial development on Special Areas Board regulated public land and has specific policies, guidelines, and operating conditions for industrial activities.

Canadian Forces Base Suffield has specific land use policy through Range Standing Orders and the Oil and Gas Activity Protocols and is regulated under the *Canadian Environmental Assessment Act*.

Canada Energy Regulator (formerly the National Energy Board – NEB) regulates all large diameter pipeline projects which cross international and/or provincial boundaries.

The ***South Saskatchewan Regional Plan*** has been established under the ***Alberta Land Stewardship Act*****,** and the ***Land Use Framework*****.** The plan supports long-term management of land and natural resources including recreation on public land. It includes plans, mapping, signage, and other tools to be used to manage recreation and provide clarity about access to public land (GoA 2018).

Indian Oil and Gas Canada is the responsible authority for oil and gas exploration and development on specified First Nations Reserves. Exploration and development planning and activities are federally regulated and must be compliant with the Canadian Environmental Assessment Act.

Alberta Environment and Protected Areas has issued guidelines for construction and maintenance of small dams: *Inspection of Small Dams* (Government of Alberta 1998). Control of spillways near grassland is of particular importance.

Government of Canada has issued a ***Greater Sage-grouse: Emergency Protection Order*** that identifies areas of habitat necessary for the survival or recovery of the greater sage-grouse and limits activities in this area such as sensory disturbance, destruction of silver sagebrush (*Artemisia cana*), and road and infrastructure development.

The **Government of Alberta *Water Act*** supports and promotes the conservation and management of water, through the use and allocation of water in Alberta. It requires the establishment of a water management framework and sets out requirements for the preparation of water management plans. The Act addresses: Albertans' rights to divert water and describes the priority of water rights among users; the types of instruments available for diversion and use of water and the associated processes for decision-making.

Common industrial activities include agriculture, resource extraction, renewable energy installations, transmission lines and transportation corridors.

5.3 Develop Construction, Reclamation, Adaptive Management and Restoration Plans

Developing and implementing the following plans and practices are key to reducing the impact of industrial development in native grasslands:

Reduce landscape impacts through best management practices. Consider new development technologies that reduce impacts to soils, landscape, vegetation, water and wildlife resources. Use of buffer materials like construction matting can greatly reduce soil stripping requirements if used within season and duration timing constraints. Use existing trails and old roads to minimize further landscape fragmentation.

Prepare clearly defined, reduced impact construction plans that incorporate minimum disturbance, which includes procedures which minimize soil handling, wildlife habitat constraints and the appropriate native grassland recovery strategy. Clearly define reclamation procedures designed to reduce the impact of disturbance for each phase of development including any storage and interim reclamation. Prepare site-specific native plant community recovery strategy(s) designed to enable successional processes to progress over time. Identify and schedule adaptive management surveys and activities required for the first 2 to 3 (4) years. Incorporate all plans into a detailed and site-specific Environmental Protection Plan (EPP).

Ensure the EPP, 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 disturbance and bridge the gap between the operations phase and decommissioning. Alert bidders and contractors to the expected timeframes for reclamation and adaptive management needs.

Engage informed and experienced contractors to optimize the expected outcome of native grassland restoration.

Monitor and inspect during and after construction to ensure contractual compliance. Respond quickly to identified problems to keep them at a manageable level. Ensure adequate monitoring and response is properly budgeted for.

Incorporate Local Knowledge. Foster transparency with landholders and offer the opportunity for dialogue and collaboration on baseline site-specific information and proposed revegetation strategies. Landholders/occupants have often learned from experience how the local area responds to various levels of disturbance/use.

Notify and Consult with Landholders, First Nations and/or Grazing Disposition Holders. Industrial development activity proposed in native grasslands is often controversial within landowner, First Nations and environmental stakeholder groups who value intact native grasslands. Early notification and transparent communication with stakeholder groups is an essential component of pre-development planning. Ensure compliance with regional land-use policy. Maintain that vital communication link through the operations and decommissioning phases. Timely notification of access is important.

Local knowledge is an important and valuable source of information for project and restoration planning.

Multi-stakeholder Consultation

6 Selecting the Recovery Strategy

A first step for selecting any recovery strategy is to understand characteristics of the site. The data collected during the PDSA and the type of disturbance provides physical information necessary to predict site restoration potential. The type of disturbance required will direct specific construction requirements and the recovery strategies that can be used.

Successful reclamation and restoration depend upon maintaining best practice reclamation strategies for all stages of the industrial development.

6.1 Disturbance Phase Considerations for Restoration Planning

Industrial developments typically evolve in the in the following phases:

1. **Initial exploration and development activity required to access the resource.** This can include detailed planning, consultation, and approval processes, followed by construction of infrastructure required for resource extraction or other related industrial activities. Incorporating principles for avoiding or minimizing disturbance to the native grassland ecosystem through detailed project planning with informed construction best practices and procedures are the most important recovery strategies at this phase.
2. **Production** includes construction of further infrastructure required to bring the product to market. This can include construction of pipelines, roads, pump stations, compressor stations, wind and solar harvesting infrastructure, transmission lines, battery sites, access and associated infrastructure required to service the production of the resource. This phase can last for many years so design to reduce disturbance to native prairie through interim reclamation and feature design is important.
3. **Interim reclamation** during the production phase can reduce the footprint of active disturbance to soils and native plant communities by reclaiming infrastructure no longer required, stabilizing and maintaining soil integrity, controlling invasive species and promoting long-term recovery of the native plant communities impacted by development activity. Only native species or short-lived cover crops should be seeded during interim reclamation in order to prevent problem introduced forages from establishing in the seed bank. Good interim reclamation makes final reclamation easier, think of it as a maintenance program that sets the pathway to reach the final outcome.
4. **Decommissioning and abandonment** is the final phase when resource production is either not commercially viable, or the development is at “end of life”. It involves removal of surface infrastructure and precedes final remediation and reclamation.
5. **Final remediation and reclamation** take place last and involves cleaning up the site of any contamination according to the appropriate regulatory standards and reclaiming the site using the most appropriate recovery strategy. The objective is to achieve a site that performs the same function as it did prior to disturbance or that matches the surrounding area. A reclamation certificate is obtained at the end of this phase.

6.2 Natural Feature Considerations for Restoration Planning in the Mixedgrass Natural Subregion

Once physical requirements for the disturbance are understood, factors specific to the Mixedgrass NSR should be considered to choose the most appropriate recovery strategy and reduce impacts on key habitats.

In the Mixedgrass Natural Subregion the following factors affect restoration potential:

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

2. The resistance the site can afford to non-native plant invasion. Non-native plants of concern include Prohibited Noxious and Noxious Weeds listed under the *Alberta Weed Control Act* and aggressive agronomic plants such as smooth brome, crested wheat grass, Kentucky bluegrass, sheep fescue and sweet clover. Kentucky bluegrass has been increasing on mesic grasslands with and without grazing in Alberta (Zapisocki et al., 2022) and throughout the Northern Great Plains (Toledo et al., 2014). This species is the most frequent and abundant non-native plant in Alberta grasslands (Zapisocki et al., 2022), including the Dry Mixedgrass and the Mixedgrass NSRs (Adams et al., 2013). Aggressive non-native grass species such as downy brome and Japanese brome are of particular concern in the Sweetgrass and Milk River Uplands due to their adaptation to semi-arid conditions and disturbed soils.

3. Within the Grassland Natural Region, the potential for non-native plant invasion on disturbed upland soils decreases as soil fertility, topsoil depths and soil moisture decreases. For example, the Black Loamy soils of the Foothills Fescue Natural Subregion are much more prone to non-native plant invasion than the drier climatic conditions and Dark Brown soils of the Mixedgrass Natural Subregion. The same characteristics of soils, landscape type, moisture regime and associated plant community can be applied to assess vulnerability at the ecological range site level. For example, within the Mixedgrass NSR, Overflow ecological range sites are more prone to non-native plant invasion than Sands or Blowout range sites. In general, restoration may be more successful in drier ecosystems, e.g., Mixedgrass or Dry Mixedgrass NSRs, than in moist ecosystems such as Foothills Fescue or Central Parkland NSRs (Figure 4-1). Similarly, moister ecological range sites, e.g., Overflow or Subirrigated sites may create more challenges for restoration.

4. 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 restoration potential.

5. 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.

6. Some ecological range sites are more adapted to soil disturbance than others. For example, wind erosion is a physical process inherent to the reference plant communities of Choppy Sand Hills ecological range sites. Coarse textured soils, significant amounts of bare soil and plants uniquely adapted to colonizing the bare soil are essential factors which maintain the habitat for many species of concern or at risk. Natural recovery facilitates the ecological recovery processes. Seeding can deter these processes and alter the plant community composition.

7. Adjacent land use also affects restoration potential. Remnant native prairie areas in highly fragmented landscapes are of particular concern. Close proximity to transportation corridors or tame pasture seeded to invasive non-native agronomic plants such as crested wheat grass, Kentucky bluegrass, smooth brome, sheep fescue, Canada bluegrass or sweet clover can limit restoration potential. Industrial disturbances that are invaded by weeds and non-native invasive plants can also limit restoration potential and require complex recovery strategies.

8. The range health of the rangeland plant communities surrounding the disturbance plays an important role in restoration potential.

9. The grazing intensity both long-term and present on pastures affected by industrial development must be factored into the restoration potential.

Factors which indicate site sensitivity to development impacts and restoration potential are used in the ecological risk analysis to determine:

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

6.3 Conserving Soils to Enhance Recovery Potential

Knowing expected levels of disturbance will assist in determining the recovery strategies for a project location. Mitigation efforts and successes vary depending on a suite of variables, and the ability to fully restore a site is dependent on abiotic and biotic characteristics of a site, and whether they have become barriers to reaching restoration objectives, as well as the effects of year-to-year climatic variation on success along restoration trajectories.

For example, permanent damage to soil physical and chemical properties may present an abiotic barrier (e.g.: no topsoil or severe levels of topsoil and subsoil admixing) with a reduced recovery potential that cannot support full restoration in short-term timelines and necessitates using alternate target vegetation to reach simple revegetation goals. On the other end of the spectrum, the use of minimal disturbance techniques may result in a largely intact ecosystem that requires relatively minor intervention to support successful ecosystem restoration (Miller et al. 2023).

Soils are the foundation for recovery potential.

Soils are a link between abiotic and biotic components of the ecosystem, playing a complex ecological role by providing the physical medium for plant growth, storing and recycling nutrients, regulating water resources, and providing habitat for soil organisms (Brady and Weil 2017; Evans 2011).

Soil properties are influenced by three major biotic groups: soil microbial communities, vascular plants, and biological soil crusts, all of which influence soil attributes through impacts on soil structure, organic matter, water infiltration/holding capacity, and nutrient cycling/availability (Evans et al. 2017).

Alteration of abiotic soil factors (e.g., nutrients, moisture, pH, bulk density) and disruption of plant communities by industrial disturbances and various land uses have high potential to impact the soil biome (Alberta Soils Advisory Committee 2004; Sherwood and Uphoff 2000).

Arbuscular mycorrhizal fungi (AMF) are mutualistic fungi associated with the roots of many plants. AMF improve plant growth by increasing uptake of essential nutrients and helping stabilize soil aggregates. Soil disturbance affects the hyphal networks in soils, which then must re-establish through extending hyphal networks and spores. Depending on the AMF species present and the type of disturbance, AMF can survive several years following topsoil disturbance, specifically in colder climates. (Morrell, 2023). More detailed information on the effects of a suite of construction activities on soils are documented in the *Dry Mixedgrass and Mixedgrass Recovery Strategies Literature Review* (Miller et al. 2023).

6.4 Minimizing Disturbance

The value and importance of minimal disturbance in native grasslands is widely recognized as a best management practice to support post-disturbance recovery and enable projects to successfully fulfill restoration/reclamation obligations (AEP 2013, AEP 2016). There are five primary approaches to minimizing surface disturbance:

- Reduce width and size of surface disturbance,
- Use physical buffers to conserve vegetation and topsoil,
- Operate on dry or frozen ground,
- Reduce cumulative impacts by implementing traffic control and monitoring soil moisture conditions, and
- Consider timing of construction activities and schedule activities to reduce soil, plant, wildlife, wetland, and watercourse impacts.

Research and results of various approaches to minimizing disturbance are further discussed in the accompanying literature review (Miller et al. 2023).

Minimum Disturbance is a construction practice where the level of impact during construction is kept as small as possible. Generally, soils are not stripped during minimum disturbance and construction occurs under dry or frozen ground conditions. Soils and vegetation are left intact, roads are not built, and infrastructure is placed on top of topsoil. Minimum disturbance is only effective in projects where the construction can be completed during dry or frozen ground conditions while vegetation is dormant, or when construction matting, or other buffers are used temporarily in dry conditions. Various levels of minimal disturbance can be applied to a disturbance and even minimization principles can be applied on sites where full builds are required.

Some factors to consider with the use of minimum disturbance:

Short-term operation of equipment directly on native sod during dry or frozen ground conditions such as during shallow gas well drilling and small diameter pipeline construction can result in minimal damage to vegetation and soils. Increased bare soil or soil shearing, and evidence of soil compaction and impaired hydrologic function are linked to soil moisture, number of passes and soil texture. Further detail from several studies can be found in the *Dry Mixedgrass and Mixedgrass Recovery Strategies Literature Review* (Miller et al. 2023).

Construction matting or other buffers can be used to conserve vegetation and reduce topsoil compaction on temporary access and work pads. Use of construction matting can extend and improve operability on native grasslands without stripping soils (Najafi 2018), but it is important that it is not used early in the growing season (April to July 15) and is removed in 8 to 12 weeks or less to prevent vegetation death due to smothering. Timely removal of matting is critical for success, if it is left this would change/increase the disturbance level from minimal as vegetation has now been impacted and larger areas of bare soil are now present.

Using of matting as a barrier between the vegetation surface and traffic has the potential to:

- retain plant community composition.
- retain soil layers and the seed/root bank.
- increase operability on native grasslands.
- reduce potential for non-native species introductions.
- reduce erosion potential (Miller et al. 2023).

Monitoring soil moisture conditions and traffic control are essential factors for success when implementing minimal disturbance procedures with the expectation of natural recovery. Use of heavy equipment and vehicle traffic over unstripped sod can cause persistent compaction in the soil profile that adversely affects growing conditions and recovery of native vegetation. Repeated traffic on vegetation can pulverize the above ground plant material and damage the crowns and roots from which new growth will develop. Scalping may also occur when soil is retrieved after storage on the grass surface. In wet conditions heavy traffic can also cause ruts and soil profile admixing. The site may no longer be minimum disturbance if these conditions occur, and a different construction and recovery strategy may be needed.

Activity timing during construction, decommissioning and abandonment is also a critical factor in the successful use of minimal disturbance mitigation. It is important to avoid the growing season during April to August (with April to July 15 being the most critical time period), when traffic or prolonged shading by matting can kill vegetation, leaving the site susceptible to erosion and available for invasion by weeds and undesirable agronomic species. In many parts of the Grassland Natural Region, minimal disturbance practices are most successful in reducing impacts to native grasslands when conducted during dry or frozen ground conditions between August and early April (AEP 2016).

Reduce the width and size of surface disturbance. Mixedgrass NSR native plant communities are sensitive to soil handling and minimal disturbance practices are clearly advantageous to promote restoration. When burial of utilities is necessary, limit excavations and soil exposures to a small area ($<4\ m^2$), and linear disturbances from buried utilities to less than 0.5 m wide over the trench line to promote natural infill.

The importance of minimal disturbance in native grasslands has been recognized by provincial regulators and is the focus of guidelines: *Principles for Minimizing Surface Disturbance – Principles, Guidelines, and Tools for all Industrial Activity in Native Grasslands in the Prairie and Parkland Landscapes of Alberta* (AEP 2016).

When minimal disturbance practices are used the pre-disturbance native vegetation may recover with no additional effort (natural recovery), provided the disturbance is small or narrow and the rangeland is healthy and relatively free of invasive and agronomic species.

6.5 Natural Vegetation Infill Potential

Infill is the natural re-establishment of plants on disturbances from propagules including seeds in the soil or surrounding area. Natural recovery, assisted natural recovery, and to some extent sites where plant materials are introduced, depend on infill to increase diversity, resilience and build ecological function over time. The potential for a site to recruit plants naturally depends on the availability of viable seed, living rhizomes and roots in topsoil, and/or on the availability of these propagules adjacent to the disturbance. The health of the surrounding native grassland will affect the availability of propagules for infill. Sites with range health scores of “unhealthy” or “low healthy with problems” will not have a suitable number of propagules available for infill and will be lacking in plant diversity. For example, a heavily grazed site with range health of 47 will have reduced seed production, litter, and may be lacking in various important late succession species. Altered grazing regimes and invasive species, concurrent with climate change impacts have altered seedbanks and pressures on emergent propagules. Higher soil temperatures negatively impact seeding success. The use of high-diversity seed mixes can help mitigate this issue by increasing the probability of plant species that can thrive under altered climatic regimes (Miller et al. 2023).

The shape and size of the disturbance will also influence the ability of plants to spread naturally into the disturbance. Large disturbances may require additional inputs of plant materials to increase diversity. Recovery of perennial forbs other than the disturbance colonizing sageworts is often lacking on sites where grass seed mixes are used (Kestrel Research Inc. and Gramineae Services Ltd. 2011).

In the Mixedgrass NSR, important early to mid-seral infill species include tansy mustard (*Descurainia spp*.), western porcupine grass, needle-and-thread, low sedge (*Carex duriuscula*), and prairie and pasture sageworts (*Artemisia ludoviciana* and *A. frigida*).

The fragmented native prairie landscape in the Mixedgrass NSR presents additional challenges for invasive non-native plant management. In the Mixedgrass NSR, the following invasive plants are common and can rapidly colonize exposed soils, occupying these niches before native infill can occur, and pivoting succession in a negative direction:

- downy brome (*Bromus tectorum*)
- Japanese brome (*Bromus japonicus*)
- smooth brome (*Bromus inermis*)
- Kentucky bluegrass (*Poa pratensis*)
- Canada bluegrass (*Poa compressa*)
- crested wheat grass (*Agropyron cristatum, A. sibiricum*)
- sheep fescue (*Festuca ovina*)
- sweet clover (*Melilotus officinalis, M. alba*)
- alsike clover (*Trifolium hybridum*)
- Canada thistle (*Cirsium arvense*)
- common dandelion (*Taraxacum officinale*)
- toad flax (*Linaria* spp.)
- wormwood absinthe (*Artemisia absinthium*)
- leafy spurge (*Euphorbia esula*)

Assessing presence of invasive species on and adjacent to the project disturbance is a vital part of planning and selecting the recovery strategy and will also determine the level of ongoing monitoring and reclamation mitigation required.

Are the key infill and late seral species present in the community with sufficient vigour and reproductive capability to colonize the site?

6.6 Timeframe for Recovery

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 (An 2019). Wind erosion and hardpan soils found in Blowout range sites in the Mixedgrass NSR can also prolong recovery. It is important to recognize the role annual weeds and forbs play in stabilizing the site during early years of recovery (Gill Environmental Consulting 1996). The timeframe for when desirable late seral 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.

It should be noted that full recovery or restoration is not a requirement for issuance of a reclamation certificate under the *2010 Reclamation Criteria for Wellsites and Associated Facilities for Native Grasslands* (AEP 2013). The criteria indicates that the site must show evidence of restoring ecological function and that the target plant community is on the trajectory to resemble the plant community in the control or adjoining undisturbed native grassland. Examples of recovery trajectories and timing in the Mixedgrass NSR are presented for several range sites and seeding treatments in *Long-term Recovery of Native Prairie from Industrial Disturbance, Express Pipeline Revegetation Monitoring Project 2010* (Kestrel Research Inc. and Gramineae Services Ltd. 2011).

6.7 Considerations for Fragmented and Heavily Disturbed Sites

In many situations, native grassland near existing disturbances such as wellsites and associated facilities is no longer a uniform, undisturbed native plant community. For example, crested wheatgrass was seeded extensively in the Mixedgrass NSR prior to 1993 and produces large amounts of seed, which remains viable in the seedbank for many years (Henderson 2005). Crested wheatgrass readily colonizes disturbances (Desserud and Hugenholtz 2017). However, management can effectively reduce existing populations and reduce the risk of new infestations (Hansen and Wilson 2006).

- Depletion of the seed bank is an important first step in reducing or eliminating established crested wheatgrass infestations. Several tillage events can kill off seedlings on larger sites. Treatments like solarization can be useful on smaller topsoil disturbances to force seedlings of invasive species prior to seedling native species. Heavily grazing plants (pre-disturbance) or clipping/mowing plants can prevent seed production for up to two years in dry conditions. Populations that do not produce seed tend to remain stable and not recruit new plants (Hansen and Wilson 2006).

- Populations on smaller industrial disturbances can be effectively removed by a combination of hand pulling seedlings and digging up larger plants (Edwards, pers.comm. 2023). Timely application of herbicide is effective at reducing crested wheatgrass (Hansen and Wilson 2006), which greens up before most other native plants, providing a window of opportunity for application of herbicides that do not have residual effects in the soil. Wick applicating can be a useful method to target the taller growth of crested wheatgrass in the spring.
- Unmanaged populations of crested wheatgrass will quickly grow, so repeated control will be needed over several years until competition from other species is well established (Henderson 2005, Wilson and Pärtel 2003). Efforts will need to be increased in wetter years to prevent seed production.
- Sites invaded with crested wheatgrass may also benefit from competition for initial establishment from more aggressive cultivars like slender wheatgrass, that establish quickly to compete with crested wheatgrass, but are relatively short-lived in the Mixedgrass NSR.

Management can have strong mitigation effects on existing populations of crested wheatgrass and reduce the risk of new infestations (Hansen and Wilson 2006).

Historic Seeding of Invasive Non-native Crested Wheatgrass Fragments Native Plant Communities and Produces an Ongoing Shadow Effect as it Invades Beyond Seeded Areas (bronze colouration)

Native grassland in urban settings may have been invaded by agronomic grasses such as Kentucky bluegrass (*Poa pratensis*), or noxious weeds. Reclaimed old disturbances might include a patchwork of well-established invasive plant communities (such as problem introduced forages or noxious annual grasses) and native plant communities that create a challenge for restoration. Abandoned cultivation can have a seedbank of undesirable species coupled with topsoil loss from years of wind erosion.

Successful restoration strategies for these hybrid or fragmented sites can be complex. It is important to conduct a detailed vegetation inventory on site, in the near off site, and in undisturbed ecological sites further off site. This can help determine the greatest factors of influence on a heavily disturbed site (e.g., pipelines with shared rights-of-way, existing disturbances that have been re-developed to reduce new impact to native grassland, or sites that have been impacted by heavy grazing or wind erosion) and which revegetation strategy is likely to be most successful.

Approaches to consider prior to further disturbance and during restoration when dealing with heavily disturbed and fragmented sites include the following:

- Spray undesirable invasive species on site prior to construction. This can kill living plants, but a seedbank may persist for older occurrences.
- Remove accumulated litter thatch that may be reducing range health, harbouring undesirable seed or reducing opportunities for infill by native species (e.g., raking or burning).
- Mow the site while native species are not actively growing.
- Eradicate native and non-native communities completely and start from scratch.
- On nutrient-depleted soils, seed wild legumes to add soil nitrogen, such as purple prairie clover (*Dalea purpurea*), buffalo bean (*Thermopsis rhombifolia*), Canada milk vetch (*Astragalus canadensis*), locoweeds (*Oxytropis* spp.) and wild vetch (*Vicia americana*).
- Start with a cover crop of one or several species to allow control of invasive species and build soil organic matter, then seed perennials in subsequent years. (See section 7.2 *Assisted Natural Recovery* for more information on cover crops.)
- On soils vulnerable to erosion, lightly seed nurse crops of annual species (< 10% of the proportion of the mix by seed number) along with a short-lived native cultivar that competes with invasive species while native plants establish (e.g., slender wheatgrass).
- Monitor regularly and often and conduct adaptive management as necessary to promote the establishment of native vegetation (see Section 11 *Maintaining the Successional Pathway*).

Well documented and executed vegetation management plans (including weed and invasive species management plans) will provide data to understand successes and failures and foster future research questions. Documentation is also helpful to prove effort was made to prevent problem introduced forage and invasive species onto the site (e.g., at time of reclamation certificate application).

6.8 Considerations for Communities with Significant Shrub Components

Shrub species, where present in the Mixedgrass NSR landscape, provide important ecological functions such as snow catch and shelter. Shrubs are components of some plant communities associated with Blowout, Thin Breaks, Loamy, Sandy, Sands and Overflow range sites.

For range sites where slow growing, late seral shrubs are common components of the plant community, such as silver sagebrush, include the shrub species in the reclamation plan as wild harvested seed or nursery propagated seedlings (Watkinson 2020).

Silver sagebrush (*Artemisia cana*) is an important component of Blowout range sites in the Mixedgrass NSR, and is also associated with some Badlands, Thin Breaks, Loamy, Sandy, and Clayey range sites, providing an important structural layer and habitat for wildlife. When cut flush to the ground during minimal disturbance construction it will regenerate naturally (Hickman et al. 2013). Wild harvested seed applied to disturbed sites has established, although success is dependent upon site conditions and adequate precipitation in the early years (Watkinson et al. 2020). Silver sagebrush plugs have been successfully re-introduced in reclaimed disturbances (Downey et al. 2013).

Early to mid-seral shrub species with spreading growth forms, like buckbrush (*Symphoricarpos occidentalis*), wolf willow (*Elaeagnus commutata*) and common wild rose (*Rosa woodsii*) may re-establish naturally on smaller disturbances. Cut flush to the ground during minimal disturbance construction these shrubs with creeping roots, stolons or rhizomes will regenerate naturally. These species produce an abundance of seed that could be re-introduced on larger disturbances or grown out into plugs.

Silver Sagebrush Community on a Blowout Range Site

6.9 Considerations for Wetlands

In most cases, government policy and regulations will strictly limit industrial activities which disturb lotic (flowing water) or lentic (still water) wetlands. When disturbance does occur, maintaining the health and function of all classes of water bodies is extremely important. *Alberta's Wetland Policy* provides specific direction regarding development activity near all classes of wetlands (Government of Alberta 2015).

There are offset requirements for industrial disturbance near most classes of wetlands and water bodies and it is important that they are adhered to when planning industrial development. Details are provided in the *Enhanced Approval Process* (AEP 2019b).

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

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

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

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

Barriers to restoration of grassland lentic wetlands include:

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

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

For riparian areas (transitional areas influenced by surface and sub-surface water between aquatic and upland areas) adjacent to rivers and streams, more intensive mitigation and/or reclamation strategies may be required to control water erosion and promote restoration. Examples include: the use of erosion control fabric and geotextiles, mulching, nursery-raised shrub and forb transplants, and soil bioengineering procedures such as shrub live staking or fascines (dormant branch cuttings bundled and tied together and placed in shallow trenches on slopes to reduce erosion).

7 Recovery Strategies for the Mixedgrass Natural Subregion

The accompanying flow charts (Figures 7-1 and 7-2) provide a pathway for decision making when considering which recovery strategy to utilize for disturbances to grasslands in the Mixedgrass NSR. **Potential recovery strategies are natural recovery, assisted natural recovery and re-seeding with native seed mixes.**

Figure 7-1 provides pathways for selecting the appropriate recovery strategy for small disturbances to vegetation and soil (bare soil less than 50 square meters or linear soil exposures less than two metres wide) and where minimum disturbance was used. The Figure 7-1 pathway generally applies to activities such as shallow wells and associated infrastructure where much of the development activity takes place on the vegetation surface, and workspaces associated with transmission line construction, where the surface is successfully protected by short-term placement of construction matting.

Figure 7-2 provides guidance for selecting the appropriate recovery strategy for sites where soil exposures are greater than 50 square metres or linear soil exposures are greater than two metres wide. Examples are larger buried utilities where soils have been stripped and replaced, graded access roads and infrastructure pads, and matted areas where the vegetation has died due to prolonged cover. In these situations, assisted natural recovery and/or seeding native species is more suitable.

The shape of the soil disturbance and the edge-to-disturbance-area ratio are important factors in determining appropriate recovery pathways and strategies. For example, 100 square metres of pipeline disturbance will have more successful natural recovery than a 100 square-metre wellsite in the same healthy native pasture due to the disturbed pipeline area being in greater contact with the adjacent undisturbed native prairie. Reclamation options also differ depending on whether the disturbance is short or long term.

Several strategies may be required to appropriately mitigate for project effects. In this example of a wind energy project, strategies include operating on dormant grass during construction, temporary soil storage on grass, burying power transmission infrastructure along the edge of the road to reduce fragmentation, and stripping and storing topsoil where constructed roads are needed for heavy vehicles or operations.

Figure 7-1 Recovery Strategy Selection for Minimal Disturbances to Vegetation and Soil

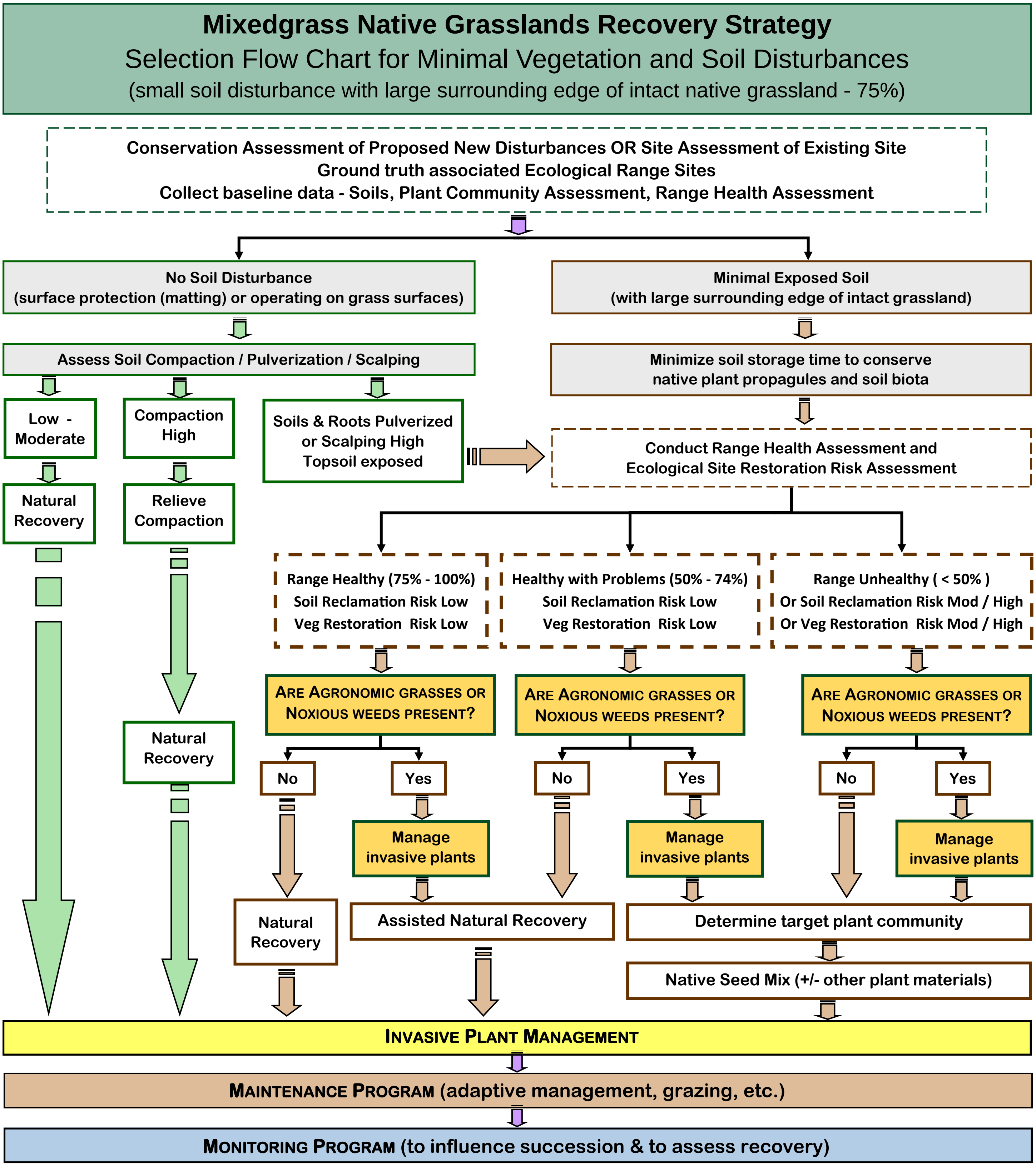
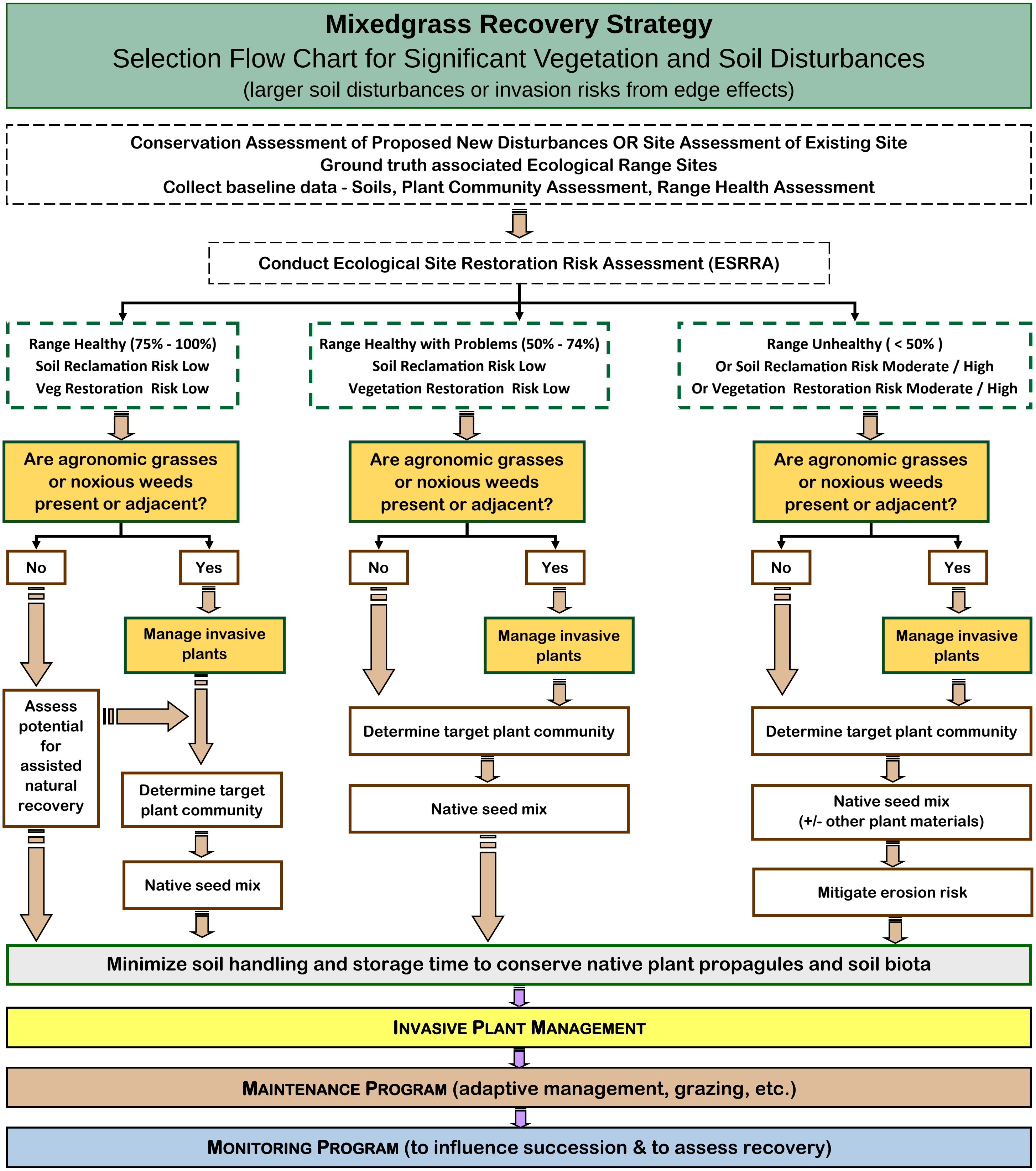


Figure 7-2 Recovery Strategy Selection for Significant Disturbances to Vegetation and Soil



7.1 Natural Recovery

Natural recovery is a strategy that relies on the native seed bank present in the disturbed topsoil, seed dispersal from the surrounding undisturbed native plant community, and resprouting of native plant propagules (rhizomes and crowns, etc.) present in the disturbed soil to revegetate areas where soil disturbance has occurred.

Natural recovery potential is linked to procedures which minimize disturbance to soils and native vegetation. Examples include shallow gas wells drilled and operated with native sod and soils intact except for a small disturbance area at well center, and small-diameter linear infrastructure construction where the only soil disturbance is over the trench line. The native vegetation can recover from the disturbance provided the impact is short term, and disturbance is conducted under dry or frozen ground conditions. Short-term disturbance and dry or frozen ground conditions are important factors to adhere to when relying on natural recovery (Kestrel Research Inc. and Gramineae Services Ltd. 2011, Pyle 2018).

When considering natural recovery, it is important to determine the ecological status of the native grassland surrounding the disturbance. The native plant community needs to have the infill species present to be able to re-establish, particularly the dominant grasses for the desired plant community. In unhealthy range or range with invasive species, the desirable infill species may not be present or have enough vigour to colonize the site.

Timing of topsoil stripping and replacement can have a dramatic effect on the success of natural recovery. Soil stripping after seed set (late summer to early winter) and replacement prior to spring germination will optimize recovery. These timing constraints need to be considered before the method is chosen. It is also important to reduce the timeframe between topsoil stripping and replacement to reduce erosion losses (Low 2016), and to avoid soil re-disturbance. Observations made during the Express Pipeline long-term monitoring project (Kestrel Research Inc. and Gramineae Services Ltd. 2011) indicate **re-disturbance of stored topsoil during the spring and summer months, when the seed bank and propagules have germinated during storage, sets back the recovery process significantly.** The number of viable seeds and the diversity of species represented in the seedbank of stored topsoil will decrease with time (Miller et al. 2023).

On natural recovery sites, seeded cultivars which compete for soil moisture and nutrients are absent, which also results in better potential to match off-site communities in terms of plant composition, structural characteristics and genetics. Native forb species play an important role in the process of native plant community succession and ecosystem function. Early seral forbs such as pasture sage colonize sites quickly after disturbance, which reduces the risk of invasive non-native species colonizing the site through competition.

Timing of topsoil stripping and replacement can have a dramatic effect on the success of natural recovery. Soil stripping after seed set (late summer to early winter) and replacement prior to spring germination will optimize recovery.

Minimal Disturbance Pipeline Constructed During Frozen Ground Conditions With No Soil Stripping

Natural Recovery of Construction Disturbance in Healthy Rangeland

7.2 Assisted Natural Recovery

Assisted natural recovery refers to the use of short-term additions of materials to a disturbed site to modify the site to create more favourable conditions for the reestablishment of vegetation from resources naturally present on the site and surrounding areas (Miller et al. 2023). It provides an option to using native seed mixes for sites vulnerable to erosion or competition from non-natives, if other conditions for natural recovery are sufficient. Assisted natural recovery includes strategies such as the use of cover crops, native hay, native mulch, and soil amendments to maintain site stability while allowing infill of native species.

Assisted natural recovery maintains the native genetics and plant diversity of the surrounding plant community while providing mitigation for identified problems such as erosion. Choosing this strategy requires the same pathway for decision making as natural recovery (Figure 7-1). 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, Sands, Limy or Thin Breaks ecological range sites.

7.2.1 Cover Crops

Seeding soil disturbances with an annual or short-lived perennial "cover crop" is a method to stabilize erosion prone soils and facilitate the natural revegetation process. In the Mixedgrass NSR, a combination of fall rye (*Secale cereale*) and annual flax (*Linum usitatissimum*) at a light seeding rate (half bushel per acre of each species) has been successfully used since the late 1990s, although fall rye can be aggressive and has allelopathic characteristics. Wheat (*Triticum aestivum*) or triticale (*×Triticosecale*), mowed before seed set, can also be effective cover crops (Miller et al. 2023). Short-lived perennial native cultivars such as Canada wild rye (*Elymus Canadensis*) and slender wheatgrass (*Elymus trachycaulus ssp. trachycaulus*) have been used as well. A low seeding rate in terms of plants per unit area is required to ensure space for native species infill over time. Short-term fencing may be necessary to manage grazing. The addition of cover crops does delay the process of natural recovery. However, where erosion is a concern, it provides an option to native seed mixes if conditions are suitable.

It is important to obtain Certificates of Seed Analysis before purchasing the crop seed and to ensure there are no Prohibited Noxious or Noxious weeds or undesirable invasive agronomic species such as smooth brome, Kentucky bluegrass or sweet clover present in the seed. Retain the Certificates of Seed Analysis on file as they may be required during an environmental audit.

7.2.2 Native Hay

Another method of assisted natural recovery involves mowing and collecting native grasses and forbs adjacent to the area to be restored, spreading the mowed "native hay mulch" over the bare soil, and then leaving the site to recover with no additional added seed. To be successful the desired dominant grass species such as needle-and-thread or western porcupine grass or plains rough fescue must be in the mature seed set stage. Timing is essential to success with this method.

Advantages of this method are the potential to increase seed source diversity available on the disturbed soils and the mulch conserves moisture and protects the surface of the soil from erosion. The procedure is also very site-specific, as the plant material used is obtained from within the same ecological range site as the disturbance.

The areas to be harvested must be free of invasive plants. For example, species such as crested wheat grass are prolific seed setters, and only a few plants in the harvest area could result in dominance by this invasive plant (see Section 8.2 Guidelines for Wild Harvest Native Plant Materials for details). Weather plays a role in successful native hay harvesting. Wind may affect successful cover of the disturbance. The chopped hay mulch is normally sprayed onto the disturbance. Windy conditions will cause chaff and light-weight seeds to be carried away. The harvest area must be dry as wet grasses cannot be cut properly, and any cut material would rot.

7.2.3 Soil Amendments

Nitrogen is a key element in grassland ecosystems, because of its capacity to limit primary and secondary production. Native plant species are generally adapted to nutrient-poor conditions. Many native species can outcompete introduced species in nutrient-poor soils. While addition of fertilizers and moisture may stimulate species productivity, it can favor establishment of weeds and non-native invasive species over native species on reclamation sites. **Use of fertilizers should be avoided.**

Reducing the available nitrogen in exposed soils can also be used to shift competitive advantage toward native plants. Impeding nitrogen take-up with a carbon addition to the soil such as clean straw or sawdust is a procedure that can be useful to reduce or eliminate weedy species on disturbed soil. Soil amendments reduce nitrogen by increasing micro-organism activity, thus aiding native prairie grasses, tolerant of low-nutrient soils (Desserud and Naeth 2013). Plains rough fescue, June grass, western wheatgrass and blue grama respond well to straw amendments and lowered nitrogen (Desserud and Naeth 2011; Desserud and Naeth 2013).

Use of fertilizers on topsoils are not recommended on native grasslands as they can favor the establishment of weeds and non-native invasive species over native species, which are adapted to low nitrogen levels.

7.3 Native Seed Mixes

Introducing native seed on topsoil disturbance is required where native vegetation propagules on or adjacent to the disturbance are not sufficient to revegetate or outcompete invasive species on a restoration site (Figures 7-1 and 7-2). Seed mixes are designed to lay a framework to reach a late seral plant community endpoint and prevent undesirable species establishing. Seed mixes are complex, including species that establish quickly and provide initial groundcover to reduce erosion, mid-seral species that drive succession and late seral species that are dominant in the target plant community. Mixes introduce species diversity and structural diversity, to build resilience to climate events and herbivory.

Seed mixes are designed to lay a framework to reach a late seral plant community target and prevent undesirable species establishing.

Disturbances that require introduction of plant materials to re-establish a native plant community include:

- large surface disturbances,
- sites situated in unhealthy native grassland that does not have the resources to re-establish desired species on the disturbance,
- areas that are fragmented and no are longer a uniform, undisturbed native plant community,
- sites with large non-native linear edge (for example, next to a roadway), and
- communities with a significant component of invasive agronomic grasses or other invasive weeds such as sweet clover, Japanese brome, or downy brome.

The most common sources of plant materials for reclamation are cultivars of native seeds. **The downside to this recovery strategy is that commercially available native seeds are often cultivars originating from beyond Alberta's borders, with different genetic origins and physical characteristics than the surrounding plant community.**

Seed of plants originating from southern latitudes or warmer climates may not be hardy in Alberta. Other concerns being equal, always choose a locally grown and sourced seed over seed from out of country or province.

Seed varieties have been developed from locally sourced material by Innotech Alberta (formerly Alberta Research Council) but are not readily available as of the time of publication (2023). Wild harvesting of native seed is a means to acquire locally adapted materials, particularly for species that are difficult to propagate commercially for seed, but supplies are in high demand and dependent on cycles of seed production and suitable harvesting sites.

Some seed lots may also be contaminated with invasive species. There is a very real risk that weeds and invasive species, sometimes new to the area, are present in seed lots and will be introduced to the reclamation site. Reviewing seed certificates prior to purchase is crucial, although the assessment and reporting process for native seed is flawed, so weeds and invasives species may still be present in the seed lot. Frequent early monitoring after seeding and control when necessary is crucial.

Native hay is also an excellent method of introducing species diversity and organic matter to reclamation sites, but hay is not typically plentiful in dry years so can present sourcing challenges. The use of cultivars, alternatives, and seed mix design is further discussed in Section 8.

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7.3.1 Seed Mixes for Target Recovering Plant Communities

Seed mix design considerations addressed in this publication encompass the species, plant communities and ecological range sites described in the current Mixedgrass Range Plant Community Guide.

The goal of using native seed mixes is to establish the pathway(s) to restore pre-disturbance plant communities associated with each ecological range site that has been disturbed. On larger projects, particularly linear projects, this creates a major challenge, given the diversity of ecological range sites and successional plant community types that can be encountered within a relatively small area.

To assist with cost effective and practical seed mix design, establish which ecological range sites have similar growing conditions (based on AGRASID soil and landscape correlations) and species in common. In Appendix B, plant communities associated with these combinations of ecological range sites, including mid-seral, late seral and reference plant communities, were pooled to include plants that are drivers of succession at earlier stages in plant community development. These groupings of ecological range sites with common dominant native grass species are referred to as target recovering plant communities (Appendix B). Target recovering plant communities are not composed of all the same species and proportions as the reference range plant community. Target recovering plant community descriptions are designed to provide easy reference to the suite of species that could be used to re-seed disturbances in each ecological range site in the Mixedgrass NSR.

Example native seed mixes for each target recovering plant community are provided in Appendix B, as well as a discussion of why each species and their relative proportions were selected.

Pipeline Seeded with Native Plant Cultivars

Figure 7-3 **Example Target Recovering Plant Community Table for Saline Lowland Ecological Range Site (See Appendix C).**

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

Salt grass
(Distichlis spicata ssp stricta)

Saline Lowland Ecological Range Site

8 Native Plant Materials

The Express Pipeline case study (Kestrel Research Inc. and Gramineae Services Ltd. 2011), summarized in Appendix B, illustrated the need for change in the way seed mixes are designed for native prairie. The native seed industry needs to evolve if the expected outcome is restoration. In the Mixedgrass NSR, several of the native grass cultivars used in the past are too competitive to allow infill from the surrounding native plant community to occur. A reliable supply of native seed of the dominant species in Mixedgrass NSR plant communities such as needle-and-thread, western porcupine grass and plains rough fescue is essential. This will be achieved by changing the way native seed mixes are designed and developing a reliable supply of the required key native species.

Regulators and industry have 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. These disturbances include:

- decommissioned production facilities with significant soil exposure due to contaminated soils, reclaimed access roads, large diameter stripped and graded pipelines.
- large areas of disturbance with erosion and site stability concerns.
- areas of disturbance requiring soil stabilization (interim reclamation) during the production/ operation phase.
- large disturbances in rangeland where surrounding native plant communities have low plant community integrity and ecological status.
- disturbed sites where the surrounding native plant community does not have sufficient plant material resources to colonize the disturbance.
- disturbances where seeding is required as part of an Ecologically Based Invasive Plant Management Plan (Appendix C).

Figure 8-1 Examples of Native Grass and Forb Seed Shapes and Sizes

Seeds vary considerably in size, required planting depth, and ability to flow through a seeder.

8.1 Native Seed Cultivars and Varieties

Cultivars for several native grasses are available in Canada and are widely used in the reclamation industry. However, they can be problematic. Many were developed much further south in the United States and are structurally taller and more robust than local plant materials.

The following information provides case-study observations on imported cultivars, from the Express Pipeline long-term succession monitoring study, summarized in Appendix B.

- Persistent cultivars that developed taller structure on the Express Pipeline Right-of-Way (RoW) are green needle grass (*Nassella viridula*), prairie sandreed (*Sporobolus rigidus*), northern wheatgrass and western wheatgrass.
- Two cultivars of prairie sandreed were used in the Express Pipeline seed mixes. Cultivar “ND95” and cultivar “Goshen”, originating from North Dakota and Wyoming, respectively. Although seeded cover was comparable to natural cover of prairie sandreed on the monitoring sites after 14 years, the cultivars are one and a half to two times taller than the local native prairie sandreed, creating a persistent change in plant community structure on the recovering RoW.
- While a cultivar may improve seed germination reliability, it often results in a loss of species diversity because of genetic shift (Woosaree 2007). In Alberta, successful native plant varieties suitable for use in the Mixedgrass NSR have been developed by Innotech Alberta (formerly Alberta Research Council). Several varietal collections are still available as breeder seed, “AITF Badlands” blue grama, “Aspen” Canada milkvetch, “ARC Centennial” Canada wild rye, and “Porter” Indian ricegrass, and could be increased to commercial production given sufficient advance timelines (2 to 3 years) and funding.

8.1.1 Guidelines for the Procurement of Commercially Available Native Seed

For projects requiring commercially available native seed in the Mixedgrass NSR the following guidelines are recommended:

- For large projects such as large diameter pipelines, wind energy projects, mines, borrow pits or large plant sites, it is important to plan at least two years in advance to ensure an adequate supply of key species required for the project.
- Ensure the seed lots of each species proposed are tested for purity, viability 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 native wheatgrasses or needle-and-thread requires a minimum sample size of 50 grams, while small-seed species such as June grass or blue grama grass require a minimum sample size of 10 grams.

- When possible, order native plant cultivars or varieties developed specifically for the Mixedgrass NSR or the Mixedgrass Ecoregion of Alberta/ Saskatchewan, from reputable research institutions such as InnoTech Alberta or Agriculture Canada. **Consider forward contracting to ensure an adequate supply of appropriate species**.
- Specify source-identified seed to improve chances that the seed is fit for survival in northern climates and latitudes. Seed originating from much further south or from lower elevations may not be cold hardy. Seed from southern latitudes may not be adapted to northern photoperiods (day length and night length) which are important for plant growth and reproduction. Purchase only from seed suppliers that can provide necessary quality assurance. Obtain, review, approve and retain on file Certificates of Seed Analysis for each species prior to purchase or blending.
- When ordering seed include the scientific nomenclature as well as the common name, and cultivar/variety or ecovar if applicable.
- There is zero tolerance for use of seed lots containing Prohibited Noxious and Noxious weeds. This includes noxious weeds such as downy brome, Japanese brome, leafy spurge, Canada thistle and toadflax.
- Avoid seed lots containing invasive agronomic species such as crested wheatgrass, smooth brome, Kentucky bluegrass, Canada bluegrass and sheep fescue. Seed lots containing other troublesome weeds like quack grass (*Agropyron repens*) or foxtail barley (*Hordeum jubatum*) should also be rejected. During seed shortages, where clean seed can not be found, using seed lots contaminated with nuisance weeds that are already present on site may be a necessary compromise.
- 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 a Certificate of Seed Analysis and an explanation of interpretation can be found in the document, *Plant Material Selection and Seed Mix Design for Native Grassland Restoration Projects* (Tannas and Webb 2016) posted on the Grassland Restoration Forum website.

Care and diligence in sourcing suitable seed is worth the effort to avoid problems later.

8.1.2 Aggressive Cultivars to Avoid

Persistent aggressive cultivars that maintain relative cover beyond control levels influence the trajectory of plant community succession. Aggressive cultivars should be avoided or used sparingly on sites where they will not outcompete other seed mix components. Case study examples are provided below:

- Western wheatgrass established early on the Express Pipeline and cover slowly increased over the 14 years. Western wheatgrass persists at greater cover on site than in off-site controls.
- Green needle grass – "Lodorm" cultivar increased steadily in cover 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 on site than in off-site control locations resulting in taller on-site plant community structure than found in controls.

8.1.3 Unacceptable Substitutions

Seed shortages are a common problem when acquiring seed mixes. Forward planning and ideally forward growing produce the best results. Changes in the relative proportions of species within a mix should not vary by more that five percent from the prescribed proportions. However, when substitutions are needed, there are a few replacements to avoid:

- Green needle grass (*Nassella viridula*) is not a substitute for needle-and-thread (*Hesperostipa comata*) or western porcupine grass (*Hesperostipa curtiseta*).
- Sheep fescue (*Festuca ovina*) and hard fescue (*Festuca trachyphylla*) are not native in Alberta and should not be substituted for any species. They are both invasive in native rangeland. Idaho fescue (*Festuca idahoensis*) seed cultivars and common seed are often mis-identified and are actually sheep fescue. Idaho fescue should be avoided in seed mixes unless the seed is tested by growing it and confirming the identification with a plant taxonomist.
- Intermediate wheatgrass (*Thinopyrum intermedium*) is not a substitute for native wheatgrasses.
- Kentucky bluegrass and Canada bluegrass are not native to Alberta grasslands and should not be substituted for any species.

Be wary of species substitutions in seed mixes!

8.2 Wild Harvested Native Seed

Several dominant, long-lived, late seral species in Mixedgrass NSR ecosystems, such as needle-and-thread, western porcupine grass and plains rough fescue, are not grown commercially in large quantities. Wild harvesting these species can be a valuable source of locally adapted species for restoration. Successful use of wild harvested June grass in the Special Areas is documented on the Express Pipeline (Kestrel Research Inc. and Gramineae Services Ltd. 2011). "Bycatch" of other native species during the wild harvesting process can also be useful to add diversity to a site. However, seed harvested from wild populations may be slow to establish or have poor establishment, so proportions in a seed mix may benefit from being increased relative to cultivars or varieties.

Pre-planning is important for wild harvesting. Seed production varies from year to year so forward planning is important. Select seed harvesting locations on healthy range sites with species compatible with the disturbed site. For harvest sites on private land, written permission should be obtained from the landholder prior to accessing the land or harvesting seed. On public land an authorization must be obtained in advance of harvest, and permission from the public land occupant may be required. Engage with the local Public Lands Range Agrologist responsible for the area to determine process.

Hand Harvesting Silver Sagebrush Seed

Mechanized Native Grass Seed Harvesting

8.2.1 Guidelines for Wild Harvested Native Plant Material

Wild harvesting should only be considered on sites that are in “healthy” or “healthy with problems” range condition, and free of Prohibited Noxious and Noxious weeds and invasive non-native agronomic species such as crested wheatgrass, sheep fescue, Kentucky bluegrass, Canada bluegrass, alsike clover and sweet clover.

Methods of obtaining necessary material include:

- Use of specially designed equipment that harvests only the seed from flowering stems of select species such as needle-and-thread, western porcupine grass, June grass or blue grama. **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.
- Using wild harvested seed collection for field propagation and production.
- Seed collection of specific native grasses and forbs for nursery propagation of live plant material to be planted on site in the form of native plugs. The purpose is to install islands of live plant material within the disturbed area that will create vegetation diversity and a future seed source.
- It is important to specify the ecological range sites from which the material should be harvested (i.e., Blowouts vs Loamy vs Sands and/or Choppy Sandhills, etc.). Obtain, review, approve and retain on file Certificates of Seed Analysis for each species harvested.

The products of wild harvesting provide valued goods and services to the landholder. 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 harvest timeframe. Some native seed harvesting companies are listed on websites for the Alberta Native Plant Council and the Saskatchewan Native Plant Society.

8.2.2 Wild Harvesting on Public Lands

Authorizations to wild harvest on public lands will be issued at the discretion of the Government of Alberta Range Agrologist responsible for the selected area. The disposition holder must also consent to the activity and an authorization must be issued by the Agrologist before the activity can proceed. The Agrologist may issue an authorization if the activity is deemed appropriate and not conflicting with other approved uses on the disposition. If issued, the authorization will come with requirements including those listed in this section, but possibly other requirements as well depending on the location:

1. At present, the proponent is required to obtain written consent from the disposition holder for the area where the seed harvest is proposed prior to approaching the regional Government of Alberta Range Agrologist. A detailed sketch of the proposed harvest location must be provided. Check with the Public Lands Administration Regulation (PLAR) in case there are procedural changes https://open.alberta.ca/publications/plar-approvals-and-authorizations-administrative-procedures.

2. The proponent must apply for an authorization to the Government of Alberta Range Agrologist responsible for the selected area. A map to locate a local agrologist is available at: https://geospatial.alberta.ca/portal/apps/webappviewer/index.html?id=9fb06be568ac4365b62bbb08c56742b9.

3. Only healthy range sites will be selected for seed harvest that are free of Prohibited Noxious and Noxious weeds, and invasive non-native species.

4. Harvesting equipment must be clean and free of seeds from other areas.

5. Seed harvesting will be done using an alternating strip approach such that only half of the area is harvested.

6. Seed harvesting will not occur on the same site for a period of 2 to 3 years following the harvest (depending on climate and range health conditions).

On Special Areas public lands, a temporary workspace must be applied for when considering wild harvesting on lands outside of the disposition.

It is recommended that these harvesting guidelines be implemented on private lands as appropriate.

Large Scale Wild Harvesting of Native Grass Seed

8.3 Certificates of Analysis versus Certified Seed - What is the difference?

An emerging misunderstanding in conditions applied to some reclamation projects is that native seed can and should be "certified" to be used for revegetation. There are very few native reclamation species that have this designation under the *Canada Seeds Regulation* (Government of Canada 2019). Applying this condition would prevent the use of many species, including any wild-harvested local seed, a potentially valuable seed source for reclaiming native ecosystems.

The *Canada Seeds Act* and *Canada Seeds Regulations* establish standards for grading crop seeds as described in the Seeds Regulation Grade Tables. Crop seeds include the majority of cultivated crops (including forage crops) grown in Canada. In the *Canada Seeds Act*, certified status, with respect to seed, means that:

a) in situations where the crop from which the seed is derived was grown in Canada,
   i. a crop certificate designated "Certified" has been issued for that crop by the Association, and
   ii. the seed meets the standards for varietal purity established by the Association for seed of that kind or species, or
b) where the crop from which the seed is derived was not grown in Canada,
   i. the crop meets the standards established by an official certifying agency and approved by the Association, and
   ii. the seed meets the standards for varietal purity established by the official certifying agency for seed of that kind or species and approved by the Association;
   (Qualité Certifiée) (Government of Canada 2019)

Some of the native wheatgrasses and blue grasses developed as varieties for forage and reclamation are included in the list of registered crop seed (e.g., northern wheatgrass, western wheatgrass, slender wheatgrass, fowl bluegrass). However, there are many native species (or non-crop seeds) produced and traded in low volumes for reclamation and restoration of native ecosystems that do not have grading standards and are therefore ineligible for certified seed designations.

What is important and necessary is that all reclamation seed lots, whether wild harvested or otherwise, are tested by a laboratory for species composition (purity) and documented with a "Report of Analysis", the document issued by the laboratory, giving the final results of laboratory tests.
Other names for the report include Report of Seed Analysis, Certificate of Seed Analysis and Laboratory Report of Analysis.

This **Report of Analysis** is also based on the standards for grading crop seed and is not well adapted to the needs of the native plant reclamation industry. Categories of the analysis methodology that are applicable to native species seed testing include the assessment of pure seed, ergot, weed seed count, individual seeds per sample, inert matter, pure living seed, germination, and the tetrazolium chloride (Tz test) for seed viability. Categories of the analysis methodology that need revision for native species seed testing are the “other weed seeds” and “other crop seeds” categories. These categories can often include species that are either also native and may be beneficial to the reclamation or species that are invasive and must be avoided.

An additional step, worthwhile for seed that is easily misidentified such as rocky mountain fescue (which is frequently confused with invasive non-native sheep fescue), is double-checking the validity of the seed identification. This can be done by obtaining a “Certificate of Authenticity” for the seed lot, supplied by a qualified plant taxonomist who obtains a sample plant or inspects the field or harvest location to ensure the species identification is accurate (Tannas and Webb 2016).

There are problems with the specifications currently being applied to native seed lot analysis. Native seed lots may be contaminated with invasive non-native plants, which are not required to appear on the Certificate of Seed Analysis.
Native seed is unique in the seed industry and the specifications need to be revised to accurately reflect seed lot species composition.

It is important to monitor what is germinating and establishing. Be prepared for surprises and management to control potential problem species.

It is important to use and know the current scientific name of species being purchased. Common names for plant species can differ by region or nation and scientific names can change over time as well.

Suitable native seed can be difficult to source and expensive, a cost of disturbing native grasslands.

8.4 Seeding Forbs

Inclusion of forb propagules in reclamation mixes can increase diversity and resilience on recovering disturbances and create habitat for pollinators and other wildlife. Industry experience is that there are challenges with establishing enough decreasers (i.e.: plant species, typically late seral grasses preferred by grazers) and diversity on sites to meet reclamation criteria. Forb seeds can be included in the original seed mix or introduced later, by broadcast seeding or as seedlings. Staged introduction of forbs is a useful strategy if reclamation sites are likely to use herbicides initially to control broadleaf weeds.

Ground plum (Astragalus crassicarpus)

Buffalo bean (Thermopsis rhombifolia)

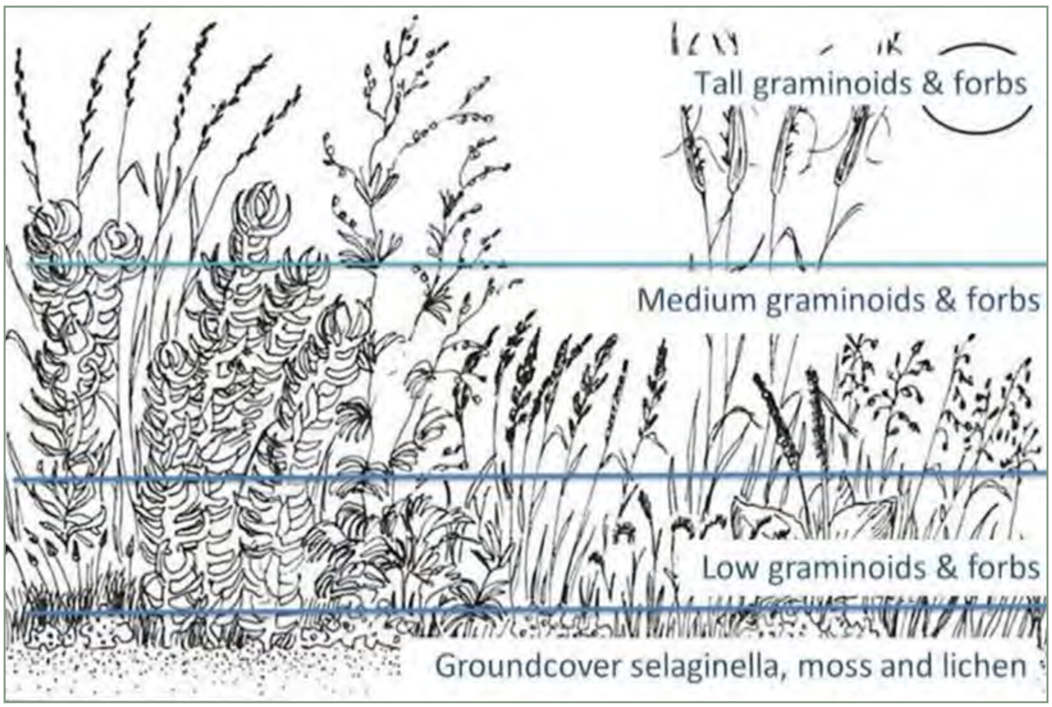
Forb seed is often collected by hand from wild populations. Forb seed can be expensive and difficult to source in quantity but there are suppliers for several species common to the Mixedgrass NSR. The Alberta Native Plant Council maintains a Native Plant Source List (Alberta Native Plant Council 2021). Suitable species will be those found in the surrounding plant community as well as colonizers and early to mid-seral species. Native forb species that have been seeded successfully in the Mixedgrass NSR include pasture sage, purple prairie clover, Canada milk vetch, common yarrow, prairie coneflower (*Ratibida columnifera*) and American vetch (but be sure it is not invasive tufted vetch (*Vicia cracca*)). It is important to note that common yarrow and pasture sage are type 2 increasers that rebound after short-term topsoil disturbances, so may not be desirable to seed in some instances.

Many native plants have specific requirements to break seed dormancy, germinate and increase seedling survival including freeze thaw cycles, scarification by coarse textured soils or acid treatment from being ingested by wildlife or livestock. Other factors include soil temperature, moisture, or sunlight intensity or duration requirements. Establishment of seeded forbs may take several years.

8.5 Designing Native Seed Mixes

Native plant communities are complex assemblages of species that provide diversity in above- and belowground structure (fibrous and rhizomatous grasses), timing of growth (early and late season), strategies for reproduction and responses to climate events. Planning seed mixes considers the concepts of range health (refer to Section 3) to build a plant community that stabilizes disturbances, excludes Noxious weeds and agronomic invaders and builds resilience and diversity similar to pre-disturbance plant communities over time. Healthy native rangeland communities include tall, mid, low and ground cover structural layers (Figure 8-2). Diversity in the canopy structure provides resilience to herbivory and climate events. Seed mixes can be used to develop vascular plant structure for the low, medium and tall vegetation layers. Typically, development of the groundcover layer (e.g., little club moss) relies on natural recovery and takes many years (Kestrel Research Inc. and Gramineae Services Ltd. 2011).

Figure 8-2 Structural Layers in a Healthy Native Grassland Community

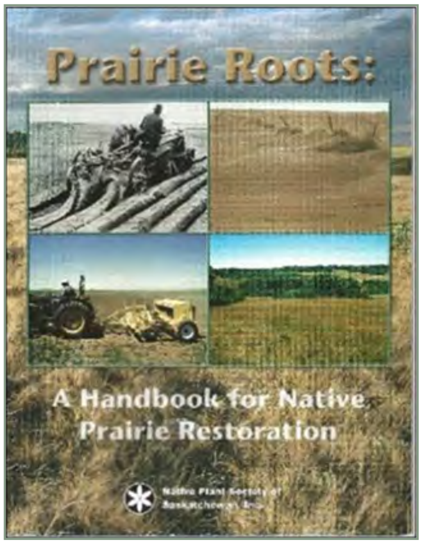


Background image source: Government of Alberta

For range sites where slow growing shrubs are common components of the plant community, such as silver sagebrush, include the shrub species in the reclamation plan as wild harvested seed or nursery propagated seedlings (Watkinson 2020). Early to mid-seral shrub species with spreading growth forms, like buckbrush (*Symphoricarpos occidentalis*), wolf willow (*Elaeagnus commutata*) and common wild rose (*Rosa woodsii*) may re-establish naturally on smaller disturbances.

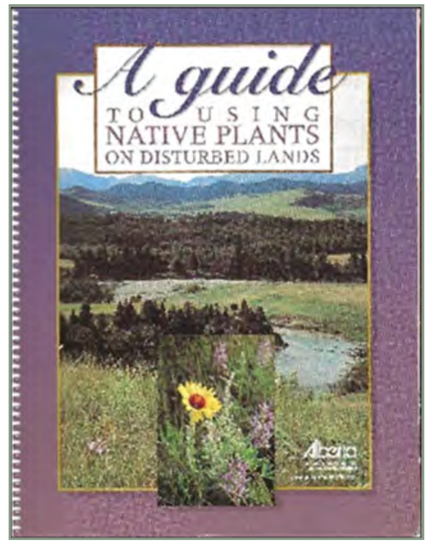
Seed mix design also requires assessment of seed availability, viability, purity, size, seeding rates and seeding methods.

Guidance for seed mix design can be found in the following publications:

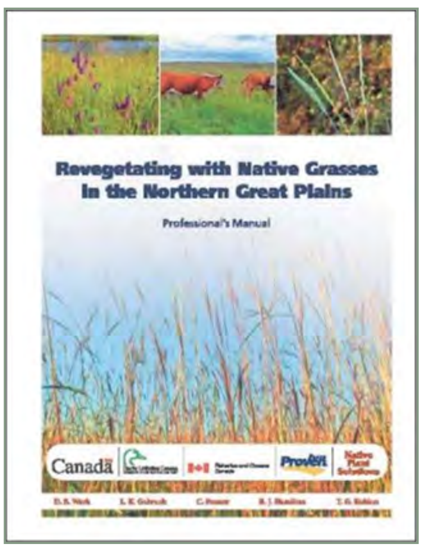


Prairie Roots: A Handbook for Native Prairie Restoration (Morgan et al. 1995)
https://www.npss.sk.ca/store/publications

Revegetation Guidelines for Western Montana (Goodwin et al. 2006)
https://www.montana.edu/extension/sanders/Revegetation%20Guidelines.pdf

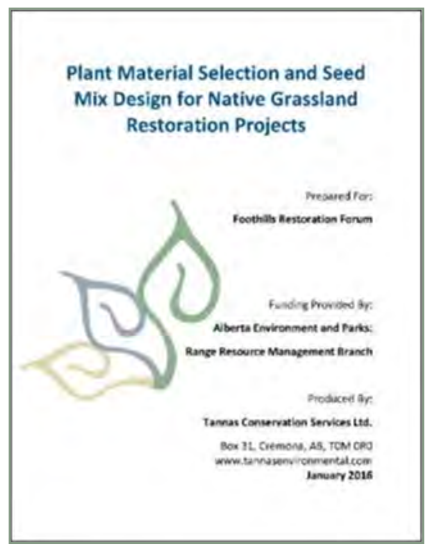


A Guide to Using Native Plants on Disturbed Lands (Gerling et al. 1996)
https://www.agric.gov.ab.ca/app08/ppslogin?pID=272



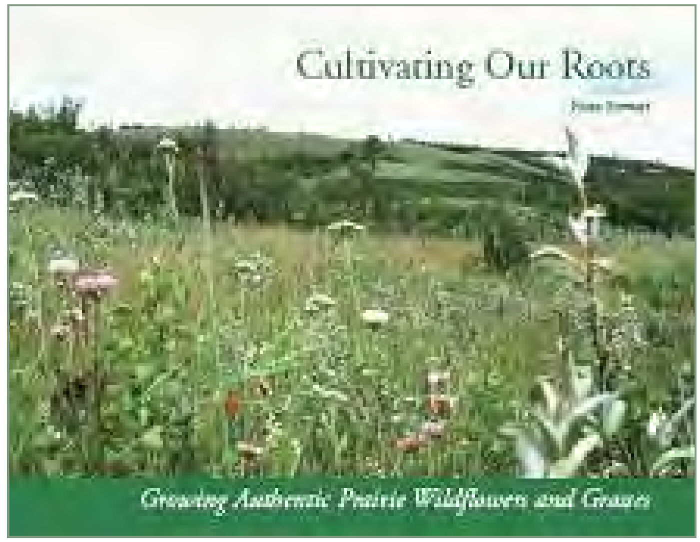
Revegetating with Native Grasses in the Northern Great Plains – Professional's Manual (Wark et al. 2005)
https://www.albertapcf.org/rsu_docs/

Seeding Rate Conversion Charts for Using Native Species in Reclamation Projects (Hammermeister 1998)
https://grasslandrestorationforum.ca/guidelines-reference/



Plant Material Selection and Seed Mix Design for Native Grassland Restoration Projects (Tannas and Webb 2016)
https://grasslandrestorationforum.ca/guidelines-reference/

British Columbia Rangeland Seeding Manual (Dobb and Burton. 2013) https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/rangelands/bc_rl_seeding_manual_web_single_150dpi0904.pdf



Cultivating *Our Roots: Growing Authentic Prairie Wildflowers and Grasses (Stewart 2009)* provides information on native seed collection and propagation of native grasses and forbs.

8.6 Native Hay

Haying native grassland can be a viable technique for procuring a seed source that is adapted to local site conditions. Native hay also provides mulch to retain moisture and prevent erosion. Its success depends on the viability of native seed production from year to year, the timing of harvest/cut, which will result in the dominance of whichever species have set seed at that time; and application methods, such as crimping, to keep the hay in place. Desserud and Hugenholtz (2017) used native hay to reclaim three 1-hectare wellsites in the Mixedgrass NSR. Good recovery was observed on the wellsites by the third year. Other wellsites, treated with native hay seven years earlier, showed very good recovery, almost identical to adjacent grassland vegetation species, with the exception of the absence of little club moss.

However, haying on native grassland can be hard on equipment in uneven or rocky native terrain, grass may be too short to bale, and access to suitable sites may be limited. Timely assessment of potential productive haying sites is important for success.

The area of haying required to gather sufficient material is relatively large and will reduce forage availability, litter and potentially the range health of the harvested grassland. On public lands (Special Areas and Government of Alberta) an approval would be required similar to that required for native seed harvesting.

8.6.1 Guidelines for Harvesting Native Hay

Follow the Guidelines for Wild Harvesting Native Seed for site access permissions and site selection. Additional guidelines pertaining to native hay cutting are:

1. Native seed harvesting equipment varies from small mowers that cut and collect hay to larger modified combines, all equipped with specialized blades to handle hard native grasses. Timing the harvest is essential (and can vary each year) as dominant grasses must have produced seed. Some modified harvesters include a vacuum, which collects surface litter including seeds from earlier in the season or the previous year, in which case timing is less essential.

2. Cut native grassland in strips, leaving uncut strips to act as a seed-rain source for the cut areas.

3. The amount of native grassland required for harvesting varies with between Natural Subregions. In the Mixedgrass NSR, a harvest area roughly 2 to 3 times the disturbance area is needed to ensure sufficient areas of uncut strips are accounted for.

4. Weather plays a role in successful native hay harvesting. Wind may affect successful cover of the disturbance. Chopped hay mulch is normally sprayed onto the disturbance. Windy conditions will cause chaff and light-weight seeds to be carried away. The harvest area must be dry, as wet grasses cannot be cut effectively, and cut material will rot.

5. Crimp or harrow the hay into the soil to ensure good contact and prevent it being blown away.

6. Chopped material may also adhere better to the soil if wet from a rainfall or watering.

7. If the source area is grazed, suspend grazing until after harvesting. Ideally, grazing should continue the following year, after the cut areas have had a chance to recover.

8. Avoid harvesting native hay mulch on the same site for a period of 2 to 3 years following the harvest (depending on climate and range health conditions) in the Mixedgrass NSR.

***Finally, wild harvested native plant material is a precious resource.
Before harvesting, 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 in cool dry conditions.***

Native hay harvester developed by Ron Johnson and Marshal Gillespie

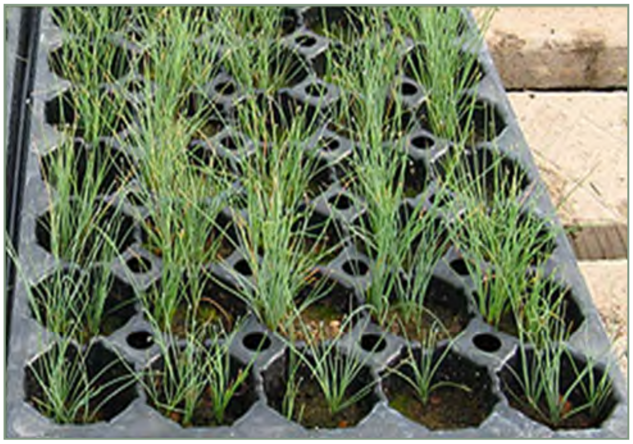
8.7 Nursery Propagated Plant Materials

Nursery propagated native plant materials are used to promote establishment of trees, shrubs, forbs, grasses, sedges and rushes on disturbed sites. They are used to establish species that are key components of ecological range sites that are difficult to establish by other strategies, to enhance diversity and infill, and to create key habitat features for wildlife and/or rare plants. This strategy requires the engagement of suitably qualified and experienced practitioners and nursery staff to assess site requirements, prepare the site design, and then collect, propagate, install, and maintain plant material. It is important to understand that nursery propagated plant material will require monitoring and maintenance for at least the first two growing seasons.

Plant material harvested for propagation should be sourced from the same Natural Subregion, the same ecodistrict and an equivalent ecological range site to the disturbed area to be restored. Propagated plant material must be removed from the nursery and allowed to adapt to the climate conditions where they will be planted to prevent transplant shock and die-back. Planting rates should account for herbivory and climate related mortality. Rodents are also attracted to bone meal and fertilizers in plant growth mediums. A monitoring and adaptive management program is required to maximize the success rate of this recovery strategy. Prairie climate conditions in are harsh for young tender plants.

Considerations for transplants or plug planting include:

- Successful establishment is often better with older seedlings, 4 to 6 months old.
- Fall planted plugs may be susceptible to frost heave, where plugs are pushed out of the soil.
- Plugs and transplants may be susceptible to herbivory, e.g., mice, ground squirrels, antelope and other wildlife, especially if newly planted in spring or fall when other species are not yet green.
- Including native seed of the same species with plug planting may provide a backup and improve success.
- Expect transplant losses if watering is not an option. Protecting the seedlings from wind erosion and covering the adjacent soil surface can reduce water stress and promote survival.



Needle-and-thread seedlings

Silver sagebrush (Artemisia cana) Plugs

June grass (Koeleria macrantha)

Early yellow locoweed (Oxytropis sericea) – a native legume

9 Implementing the Strategy

Pre-disturbance site assessment findings and the size and type of disturbance will determine the most appropriate revegetation strategy for the site. Site preparation, seasonal 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 (see Section 8). 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 sufficient volumes.

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

9.1 Recommended Timing of Restoration Activities

Natural recovery is most successful on sites where the soils are 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 birds and some wildlife, (early spring to mid-summer) when timing constraints and/or conditions for industrial activity in native prairie may apply. Natural recovery is not as successful when topsoils are stored over winter and replaced in the summer of the following year (Kestrel Research Inc. and Gramineae Services Ltd. 2011).

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 wheatgrasses, needle-and-thread and western porcupine grass. Warm season grasses such as blue grama can be seeded in early spring or later when the soil remains consistently warm for germination and emergence, ideally late May to early June. Seeding is not recommended during the heat of the summer months when moisture is at a deficit.

9.2 Salvaging Native Plant Material Resources

Topsoils in the Mixedgrass NSR are dominantly Dark Brown Chernozems, with average A horizon depths in the 10 to 15 cm 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 cm of soil. To conserve this resource, it is important to:

- Reduce the amount of area disturbed.
- Minimize soil handling within the area disturbed.
- Minimize the timeframe between topsoil stripping and replacement.
- Avoid pulverizing and mixing soils.

Do not harrow to break down the sod or pulverize the soil. Clumps of sod contain soil biota and live plant material and the native seed bank that can accelerate re-establishment of plant cover.

9.3 Site Preparation and Micro - Contouring

Native prairie is not flat. Micro-contouring facilitates seedling survival in the Mixedgrass NSR. Retain the sod as intact as possible during stripping and replacement. Do not harrow to break down the sod or 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).

Prairie Selaginella (Selaginella densa) in Sod Replacement on Ditchline

A Roughened Surface Retains Moisture

9.4 Selecting Seeding Equipment to Suit the Strategy

When seeding a native seed mix is determined to be the appropriate recovery strategy, it is important to understand that native seed mixes usually contain a combination of large and small seeds and often fluffy seeds, which can lead to uneven seed dispersal and bridging in the seeding equipment. Native grass seeders are the best solution to planting mixes with diverse shapes and sizes. Most rangeland seeders used in reclamation are specially designed with two seed boxes to accommodate large and small seeds, and agitators to keep the different seed types flowing and in suspension. The three functions of seeding equipment that are most important are seed metering to ensure the seeding rate is as designed, seed placement depth and distribution, and packing to ensure good seed to soil contact.

An option for diverse mixes is to have the small seeds blended and bagged separately from the large seeds. Drill seeding of large seeded species and then broadcasting, harrowing and packing the small seeds, or drill seeding at two different depths can be effective. This method also facilitates more accurate seeding depth and reduces competition for moisture between large and small seeded species.

Conventional drills and air drills can be used successfully for seeding native grasses. No-till drill seeders are useful for minimizing soil disturbance during seeding and for over-seeding into existing vegetation.

Seed drills that leave an imprint in the soil create microsites that shelter seedlings from wind erosion. For example, the Kinsella Accuroller is an imprinter seeder designed to seed the coarse textured soils of Choppy Sand Hill, Sands and Sandy ecological range sites. The seed is broadcast, rolled and imprinted into the sand. Rangeland drill seeders can have problems maintaining accurate seed placement depth in coarse textured soils. Imprinter seeders evenly disperses the seed and facilitates uniform seed placement at the appropriate depth.

Steep slopes may be too steep to operate a tractor and seeder safely. For these sites broadcast the seed and track pack seed into the soil with a small dozer or tracked skid steer. If erosion control is required apply a suitable soil tackifier separately. Do not apply the seed within a mulch as too much seed is left suspended in the mulch, and will yield poor seed to soil contact.

Ensure compliance with recommended seeding rates. More is not better in the arid climate of the Mixedgrass NSR. Calibration rates for seeding will depend on the type of equipment used and seed mix design. Calibrate equipment prior to accessing the site and monitor calibration throughout the seeding operation.

Wild harvested needle-and-thread and western porcupine grass can also contain considerable amounts of inert material from the cleaning and de-awning process. The amount of inert material is recorded on the Report of Seed Analysis. The application rate is adjusted to compensate for the amount of inert material. Seed containing unusually high amounts of inert material should be re-cleaned.

Seed carriers are sometimes used to improve flow characteristics for extremely small seeds, or to prevent bridging of fluffy seed in seeding and handling equipment. Examples of seed carriers include cracked or roasted grains, vermiculite, or other inert materials. The seeding application rate will have to be adjusted to accommodate the weight of the inert carrier (Dobb and Burton 2013).

Haybuster 107C
No Till Seeder

Brillion No Till Seeder

Imprinter Seeder

10 Soil Handling and Erosion Control

Erosion prone soils in the Mixedgrass NSR require erosion control during the reclamation stages of construction, decommissioning and abandonment. Soil handling needs to be precise, accurate and stabilized if surface or subsoil disturbance or storage is required for any length of time. The potential for soil loss due to wind erosion in the Mixedgrass NSR is a significant factor that must be considered in development planning.

10.1 Wind Erosion Risk

Wind erosion in the Mixedgrass NSR is an issue due to the semi-arid climate and frequent wind, which presents a challenge for soil handling and conservation. For example, the coarse textured soils of Choppy Sandhill, Sands and Sandy range sites are very prone to wind erosion once the protective vegetative cover is disturbed (Bradley and Neville 2010, Pyle 2018).

Western areas of the Mixedgrass NSR are prone to strong, warm, westerly Chinook winds that are a significant factor influencing restoration potential once the native prairie vegetation has been removed. Winter thawing of frozen soils presents challenges for operating heavy equipment on native prairie vegetation. Chinook winds pose increased risk for rutting and compaction of soils during winter construction and development activities.

As well, vehicle and equipment traffic (and heavy livestock use) on dry soils can cause pulverization of the topsoil and protective vegetative cover, increasing the erosion potential of Loamy and Blowout range sites when soil structure and rooting zones are destroyed.

Classification for wind erosion risk is based on bare, unprotected soil with a non-crusted surface. Attributes that affect wind erosion are surface roughness and aggregation, soil resistance to movement, drag velocity of wind on the soil surface, and soil moisture (Pedocan, 1993). Wind erosion risk ratings are summarized in the table below and are based on interpretations from Pedocan (1993) and general erosion ratings for specific soil textures as set out by Coote and Pettapiece (1989).

Table 10-1 Soil Textures and Associated Wind Erosion Ratings

Wind Erosion Rating	Soil Texture
Low	Clay loam (CL), silty clay loam (SiCL), silty clay (SiC), clay (C), and heavy clay (HC)
Moderate	Loam (L), very fine sandy loam (vfSL), silt loam (SiL)
High	Sand (S), loamy sand (LS), fine sand (fS), sandy loam (SL), fine sandy loam (fSL)

10.2 Water Erosion Risk

Water erosion is an issue, especially in sloped areas in, near, and leading to river valleys, creeks and ephemeral drainages, as these drain very large areas during spring runoff and high rainfall events. This is a serious issue for construction and reclamation, and pro-active planning work to avoid seasonal runoff and precipitation events or these high-risk areas can reduce impacts. Disturbance to soils can be avoided by using directional drilling on sloped areas such as river valley approach slopes and water course crossings, which results in no surface disturbance to the landscape. It has also proven more cost effective over time compared to implementing the extensive erosion controls required for steep slopes (Des Brisay 2018). Water erosion risk ratings are summarized in the table below and are based on interpretations from Pedocan (1993) and general erosion ratings for specific soil textures as set out by Tajek et. al (1985) and DEFRA (2005).

Table 10-2 Soil Textures and Associated Water Erosion Ratings

Soil Texture	Steep (>Slope Class 5)	Moderate (Class 4-5)	Gentle (Class 3)	Level (Class 1-2)
Fine (HC, SiC, C, SC)	Very High	High	Moderate	Low
Medium (SiCL, CL, SCL, Si, SiL, L)	High	Moderate	Low	Low
Coarse (SL, LS, S)	Low	Low	Low	Low

10.3 Pre-emptive Erosion Control Measures for Planned Disturbances

The importance of minimal disturbance planning for construction and reclamation in the Mixedgrass NSR has been recognized by industry and regulatory authorities since the 1990s. Advanced preparation using soil series mapping, field sampling and detailed mitigation planning is important to help limit erosion and soil handling risks for any development activity in the Mixedgrass NSR.

The Ecological Site Restoration Risk Assessment (ESRRA) (Appendix A) provides guidance by identifying ecological range sites and associated soil series with erosion risk potential. The ESRRA should be consulted for any development activity that would result in disturbance to vegetative cover and/or soils.

There are three basic principles that apply to all stages of industrial development activity that address erosion control in the Mixedgrass NSR:

- **Dry and/or frozen ground conditions:** Any activity with the potential to cause disturbance to grassland sod or soils must be conducted when soils are either dry or frozen, with contingency planning in place for unforeseen changes in soil moisture conditions and erosion potential. This can mean frequent work stoppages during winter construction in the Chinook belt areas of the province.
- **Minimal disturbance:** Reduce all areas of soil exposure to wind and water erosion and conserve soil resources and desirable vegetative cover.
- **Traffic control:** Use existing industrial access roads and defined prairie trails. Pre-plan by checking mapping software such as AbaData™ to view existing industrial dispositions within project areas or proposed disturbances. Consult with land managers. Organize each activity efficiently with suitable equipment that reduces impacts to grassland sod. Reduce vehicle numbers and traffic on site, and plan where equipment is to be off loaded and staged within the site. Plan traffic flow to and from the site to avoid widening existing unsurfaced prairie trails and stay within the surveyed footprint boundary. Where possible and safe to do so, use of ATVs/UTVs generally results in less impact to native plant communities than trucks.

10.4 Minimal Disturbance Access Measures

Where access to a project site is short-term, avoiding road construction can minimize landscape fragmentation and topsoil disturbance. However, where access is required for operations or during wet conditions, minimal disturbance access is not sufficient to prevent erosion. Minimal disturbance access includes:

- **Existing Prairie Trails:** In many cases, existing ranch tracks/trails or existing tracks from other industrial development could be used or shared for site access.
- **Matting:** Use geotextile fabric barriers or interlocking rig matting for temporary access. Matting must be cleaned of soil and vegetative material before entering the site for installation to prevent introductions of invasive plants or soil diseases (e.g., clubroot). Timely removal and contingency planning for adverse weather is required to ensure minimal impact to grassland.
- **Two-track Gravel Trails:** Designing access trails in grasslands using a two-track gravel method significantly reduces disturbance to soils and native plant communities when compared with fully developed, stripped, and graded access road construction. Two-track trails also help to reduce rutting and pulverization of otherwise unprotected prairie soils which would be difficult to repair at the reclamation stage. Gravel is applied only to where the two-wheel tracks will occur. The gravel hardens and stabilizes the surface soils only within the wheel tracks. Over time native grassland species will infill the tracks when not in use.

Occasionally two-track gravelled trails will not meet reclamation criteria due to a reduction in vegetation and an increase in surface coarse fragments. In these situations, the reclamation practitioner is encouraged to consult with the landowners and occupants to obtain a sign-off for a feature to remain in place. AER requires that all features to remain in place be stable, non-hazardous and non-erosive, as well as desirable for the land user (AER 2019). A two-track gravel trail meets these requirements. The sign-off would need be approved by landowners and occupants and included in the routine reclamation certificate application. If a sign-off cannot be obtained the reclamation practitioner could pursue a non-routine application utilizing the justification that the two-track gravelled trail will be revegetated over time. It is always best to consult with the landowner to find a solution prior to utilizing the non-routine application route.

Newly Constructed Flow Line and Adjacent Two-track Gravel Access Trail

Matting to Protect Grassland and Allow Short-term Access

10.5 Soil Handling and Erosion Control for Significant Disturbances

Industrial development projects such as large diameter oil and gas pipelines, wind farms, solar farms, transmission lines, strip mines and gravel pits all have significant impacts on native grassland soils and vegetation. Detailed soil mapping and conservation planning is key to construction and reclamation success and the eventual recovery of the native grassland over time. The following soil conservation mitigation measures should be included for development activity requiring topsoil handling and replacement:

- Separate topsoil and subsoil lifts into low-profile piles or windrows with sufficient separation to prevent admixing of soil lifts. Consider separating soil lifts with geotextile to prevent admixing.
- For most rangeland sites in healthy condition, topsoil and subsoil can be temporarily stored separately on the unstripped vegetated sod.

- Reduce fragmentation and pulverization of stripped soil by specifying the most appropriate size and type of equipment for soil handling (such as low ground pressure (LGP) equipment).
- Evaluate wind erosion risk based on soil texture, extent of pulverization, the timeframe for storage, and potential for exposure to prevailing winds.
- Reduce the time between topsoil stripping and replacement. Limit soil storage times.
- Reduce risk of scalping the underlying sod during topsoil/subsoil replacement by using a smooth cleanup bucket and a track hoe to replace stored soils. Use of geotextile between the vegetation surface and stored material will also reduce scalping.
- Avoid steep slopes by using alternative construction procedures such as horizontal directional drilling (HDD) below watercourses, wetlands, and other sensitive landscape features.
- Sediment fence can be used during and after construction to prevent sedimentation of waterbodies, or movement of stored soils in general.
- Protect erosion prone soils by controlling traffic. All soils in the Mixedgrass NSR are vulnerable to pulverization during summer and autumn construction timeframes. It may be necessary to apply soil tackifier and/or water to the traffic lane at the end of the day if drought conditions persist.
- Apply a suitable soil tackifier to stored topsoil that could be subject to wind erosion. This includes the coarse-textured soils of Choppy Sand Hills, Sands, and Sandy range sites.

10.6 Post-Construction Erosion Control for Significant Disturbances

Large, erosion prone disturbances will require erosion control during reclamation. Ensure local, well -experienced reclamation companies are contracted for this task. The following procedures are useful to stabilize replaced erosion prone soils through the critical first growing season:

- **Rough and Loose Soil Replacement:** Replace stored topsoil using a minimum of soil handling. Avoid grading to a smooth, uniform and level surface as would be required in cultivation. Grassland soils are not uniform or smooth.
- **Tackifiers:** There are many types of soil tackifiers, polymer-based mulches and hydromulches available. Several commonly used types only provide protection for a few weeks, while others can last up to a year. It is important to specify the length of time protection is required when contracting companies that are providing this service. Considerations when using tackifiers include:

  * Livestock and/or wildlife may have impacts on, or be attracted to, the site and mulch. The site may have to be fenced.
  * Water availability and access to it for hydromulch may require a travel control plan to reduce impacts of access, transport, and application (Edwards 2019).
  * Seed should not be applied within a hydromulch or other tackifier mixture as this results in bridging/stranding of seed above the ground in the mulch. Seed should be applied separately first, then covered with the mulch.

- **Erosion Control Materials:** In addition to sediment fence, coconut matting, straw wattles, etc. are useful to mitigate water erosion. Consider that erosion control materials do not degrade as readily in the Mixedgrass NSR due to the dry conditions when compared to other areas of the province. Coir matting can also create a hazard for snakes and should be avoided if the project area is located in critical snake habitat. It is important to use materials with biodegradable mesh to prevent wildlife entrapment (e.g., snakes get trapped in or under plastic netting).

Erosion Control Fabric with a Biodegradable Mesh

- **Straw Crimping:** This method has been successfully used to stabilize erosion prone soils in the Mixedgrass NSR for many years. It is particularly effective for post-construction stabilization of large diameter pipeline rights-of-way. Ensure that straw used is weed free and obtain permission from the landowner prior to the use of this technique. Native hay can also used as a mulch on seeded soils (Edwards 2019) but is impractical on large disturbances due to the amount required.

10.6.1 Straw Crimping

Effective use of straw crimping will incorporate consideration of the following:

- Minimize introduction of weeds or other undesirable species in straw by surveying the field the straw was harvested from and the stored straw bales for weeds, consulting with the municipality (e.g., ag fieldman or agrologist) for known weed occurrences in the area of bale harvest and storage, and inspecting and testing bales for weeds, especially Prohibited Noxious and Noxious weeds (*Weed Control Act* and *Weed Control Act Regulation*, GoA 2017 and GoA 2016).

- Straw used should be obtained near the project area, ideally from the landholder of the project site, where possible.
- Ensure there is sufficient straw length (30+ cm long) to crimp into the soil and provide an artificial stubble. It is critical to use machinery that will crimp straw in deep enough that it remains in the soil and does not blow away. Straw of sufficient length is harder to find now as cereal crops have been developed with shorter stem length. Also, some modern combines mulch the straw.
- Wheat straw crimps better than softer barley straw.
- Straw samples should be sent to a seed lab to test for weeds prior to purchase. Test results should be kept on file and may be required for approval/use by regulatory authorities.
- Only use straw if it meets sampling criteria (e.g., weed free, adequate type, and length). to decrease the risk of introducing weeds to the site, which is especially vulnerable following disturbance.

Straw Crimping to Mitigate Erosion Potential and Shelter Seedlings on a Large Surface Disturbance

10.6.2 Other Techniques to Reduce Disturbance

Traditional cut-and-cap abandonment of oil and gas well casings and pipelines require intrusive soil excavation. Depending on the soils and size of excavating equipment used, the disturbance can average 15 to 20 square metres of re-disturbed soil (to an average depth of 1.5-2 metres below ground level) that requires revegetation and recovery to meet reclamation criteria. Alternative well casing and pipeline abandonment techniques such as hydro-cutting significantly reduces the amount of soil disturbance required to abandon casings and piping. This is accomplished because cutting and capping is done inside the piping, rather than on the outside of piping. Thus, the disturbance to the soils is limited to approximately the size of the wellbore or pipeline. No soil handling is typically required, which reduces erosion and revegetation risks.

10.6.3 Reclamation Criteria and Avoiding Re-disturbing Reclaimed Grassland Soils

Procedures that re-excavate reclaimed native grassland soils create greater erosion and restoration risks. The re-disturbed soils are more difficult to reclaim, thus making it more difficult to meet reclamation criteria. Impacts can be decreased through minimal disturbance practices which in turn can also reduce reclamation inputs, efforts, and disturbance during site abandonment and closure.

The Native Prairie Protocol for Reclamation Certification of Salt-Affected Wellsites (Native Prairie Protocol) (GOA 2019b) can be followed to avoid disturbing (or re-disturbing) sensitive native grasslands where salt contamination has occurred from industrial activities, and remediation might typically be warranted. The Native Prairie Protocol provides an approach for identifying sites where adverse effects are not occurring from elevated salinity and are not expected to occur in the future. When it can be shown that salt contamination is not causing an adverse effect to soils, vegetation, and the landscape, remediation and potential associated disturbances to sensitive grasslands can be avoided. Sites that meet the conditions specified in the Native Prairie Protocol are eligible for reclamation certification without further remediation even though salt concentrations may exceed *Alberta Tier 1 Soil and Groundwater Remediation Guidelines* (GOA 2019a).

10.6.4 Importing Topsoil

Importing topsoil to achieve sufficient depths is very risky and should be avoided. Sourcing adequate quantities of compatible topsoil can be difficult, and should not be relied upon as a reclamation solution since imported topsoil may create other new problems. There is significant risk of introducing non-native invasive species in topsoil. If importing topsoil is required, the source must be inspected, tested and documented to ensure it is free of undesirable plant propagules or other contaminants.

Mowing and Collecting Native Hay

Wild Harvested Hay Spread on Replaced Topsoil - Pipeline RoW

11 Maintaining the Successional Pathway

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

The purpose of monitoring is two-fold. In the first few years after disturbance, monitoring is a component of an adaptive management approach to maintaining a site to ensure that erosion, invasive species, or herbivory do not inhibit establishment of desirable species. In the long-term, monitoring is required to demonstrate a positive trajectory towards restoration targets.

Reclaimed sites that are not monitored or managed can quickly deteriorate, resulting in costly measures to mitigate problems. A standardized method of monitoring industrial restoration projects and evaluating restoration success is required to communicate progress among stakeholders with increased confidence. Standardized methods also assist in defining areas where improvement in the methods are needed. An adaptive management plan incorporates goals for expected recovery, with monitoring frequency and methods, linked to successional stages. Protocols for monitoring are presented in Appendix D.

Ecologically Based Invasive Plant Management (EBIPM) (Rangelands SRM 2012) is an approach to rangeland invasive plant management which applies scientific principles and management experiences in a step-by-step plan (Appendix C).

The principles of adaptive management combine research and monitoring with flexible management practices. By formulating clear restoration goals and then monitoring achievement of those goals as the project develops, a "feedback loop" of continuous learning is created. The restoration activity can then be modified and enhanced by that learning (Gayton 2001).

11.1 Colonizers, Weeds and Invasive Species Management

Establishment and spread of persistent undesirable or invasive species is one of the most common reasons for failure of restoration projects. Common offenders in the Mixedgrass NSR include sheep fescue, hard fescue, sweet clovers, Kentucky bluegrass, Canada bluegrass, smooth brome, timothy, and downy brome, Japanese brome and crested wheatgrass on drier soils. These may be present in the seedbank or surrounding area, or as contaminants in reclamation seed mixes.

The main priority is control (eradication) of Prohibited Noxious and Noxious weeds, required under the *Alberta Weed Control Act* and *Weed Control Act Regulation* (GoA 2017 and GoA 2016). Weed and invasive plant management can be achieved by both mechanical and chemical methods, depending on the circumstances. Hand pulling or digging can be very effective on smaller areas. Mowing before seed set can mitigate spread on larger disturbances.

Targeted grazing uses livestock timing, frequency, intensity, and selectivity to apply herbivory pressure on target plant species or portions of the landscape to reach specific vegetation objectives. Although a simple concept, it is more complex in practice and relies on an understanding of several different interacting factors, including the interactions between plants and herbivores. It can be a useful tool to manipulate plant cover in both mature plant communities and in areas recovering from disturbance (Michalsky et al. 2022). For instance, early spring grazing can reduce competition from Kentucky bluegrass (Miller et al. 2023). Persistent defoliation pressure to continually stress plants can effectively reduce vigour and has the potential to reduce infestations of species like crested wheatgrass (Wilson and Pärtel, 2003).

Use of pesticides is a specialized area of expertise. Herbicide selection and application requires a Commercial Pesticide Applicator's license. Contractors hired should be aware of the desired long-term outcome of native grassland restoration. For wellsites, contractors need to be familiar with the 2010 *Reclamation Criteria for Wellsites and Associated Facilities for Native Grasslands* (AEP 2013), which identifies measurable goals for species diversity and cover.

Control of specific invasive species at identified locations by spot spraying with targeted herbicides is preferred over wide application of herbicide for a broad spectrum of species. Herbicides can have secondary effects on seeding success and may result in the creation of spaces for other invasive plants to establish (Miller et al. 2023). A targeted approach will improve the chances for native forbs to establish and encourage plant community restoration. However, blanket spraying or wick application is sometimes necessary. Careful timing when desirable species are dormant or shorter in stature can be effective and reduce collateral impacts to desirable species.

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 (Hickman et al. 2013, Pyle 2018). Where necessary, mowing annual weeds prior to seed set can reduce the competition for available soil moisture and enhance seedling survival of desired species.

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

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.

11.1.1 Information Sources for Invasive Species Management

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 local knowledge of weeds of concern and effective methods of control is very useful in vegetation management planning. **Local municipalities may have additional weed restrictions or concerns to be aware of.**

The USDA Agricultural Research Service has conducted considerable research in the field of vegetation management. The publication, *Revegetation Guidelines for the Great Basin: Considering Invasive Weeds* (Sheley et al. 2008) is a valuable source of information relevant to the Mixedgrass NSR of Alberta.

Transportation Corridors are Sources of Ongoing Invasive Species Introductions

11.2 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 occupant is important. Grazing management plans implemented to enhance recovery of industrial disturbances should incorporate local knowledge, be designed in consensus with the occupant, and be well documented regarding the responsibilities of involved parties.
- Use the Range Health Assessment Field Workbook protocol (Adams et al. 2016) and consultation with the landholder to determine when temporary fencing might be appropriate. Restoration sites located in fields with unhealthy range health scores will require temporary fencing to protect the re-establishing vegetation.
- 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, and stocking rate will need to be factored into the decision.
- To protect small, reclaimed disturbances from grazing, a geogrid made from plastic piping laid flush to the ground can be successful in deterring livestock impact. The geogrid works very much like a cattle guard, allowing some grazing through it but reducing significant livestock trampling and laying. The vegetation grows up between the piping and when established the geogrid is removed and reused at another site.

Geo-grid Livestock Deterrent

Portable, Solar Powered, Electric Fencing System

- 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.
- The size and type of disturbance also determines the requirement for fencing. For example, reclaimed wellsites with more than 25% topsoil disturbance may require fencing. **Seeded native species do not all germinate in the first year; several years are likely required for initial seed mix establishment. Allow seeded areas at least one growing season, and often two to three years, 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 midsummer) 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.

Seeded native species do not all germinate in the first year; several years are likely required for initial seed mix establishment. Allow seeded areas at least one growing season, and often two to three years, for seed to germinate and establish a root system before grazing is allowed.

- Ensure temporary fencing is removed when the plant community has reached the target and litter is at optimum rates for the Mixedgrass NSR (Figure 6 in the Range Health Assessment Field Workbook) (Adams et al. 2016). 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/time 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 time 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 Mixedgrass NSR. Antelope are particularly vulnerable to fencing. Information on wildlife friendly fencing is presented in the literature review (Miller et al. 2023). Consult with the local Fish and Wildlife biologist for recommendations for wildlife-friendly fencing.

- **Ensure temporary fencing is monitored and maintained. Maintenance is not the landholder's responsibility. Budget for maintenance and monitoring.**
- Ensure fencing is removed in a timely manner. Long term prevention of grazing can allow the establishment of problem introduced forages and affects the community succession. Reclaimed sites are required to be able to withstand grazing pressure at the same rate as the offsite area. If vegetation growth is not sustained following fence removal the reclamation certificate may be cancelled (AER 2019).

Ensure fencing is removed once the plant community has reached target litter levels. Fence maintenance and removal is not the landholder's responsibility.

Fences are often left up too long. On this ungrazed industry reclamation site, seeded native cultivars have become lodged, extensive litter buildup alters surface moisture, creating conditions that favour invasive species like Canada thistle and Kentucky bluegrass. Infill by native species is not occurring.

12 Monitoring Recovery

Long-term monitoring is important to continue to develop best management practices and appropriate revegetation strategies for industrial disturbances in native prairie in order to minimize negative impacts and promote industry stewardship on increasingly pressured prairie landscapes.

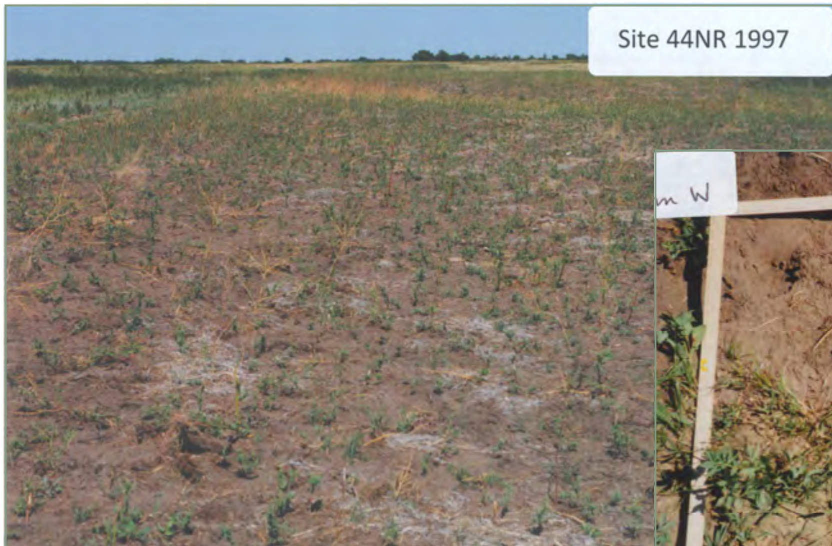
Conserving what remains of our native grasslands for future generations requires continued improvement in recovery practices in native prairie landscapes. In the past, equivalent land capability focused on soil conservation. Today, equivalent land capability includes restoration of native plant communities in native landscapes.

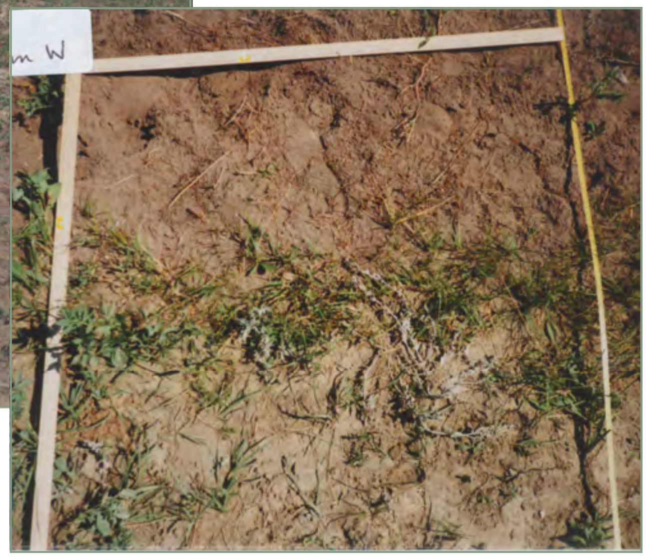
Time is an important factor in the process of recovery from industrial disturbance in native grasslands. Extended timeframe monitoring using standardized methods of evaluation provides the opportunity to reflect on construction and reclamation procedures used in the past and make informed choices that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

The results of long-term monitoring presented in the literature review (Miller et al. 2023) and the Express Pipeline 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 (Kestrel Research Inc. and Gramineae Services Ltd. 2011). Otherwise, limited information is available on the long-term efficacy of various native grassland reclamation and recovery techniques for the Natural Subregions of Alberta. Ongoing data collection is required to fully understand native plant community successional pathways following industrial disturbance in a changing climate, with ongoing spread of invasive species into native ecosystems. 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. Protocols for monitoring can be found in Appendix D.

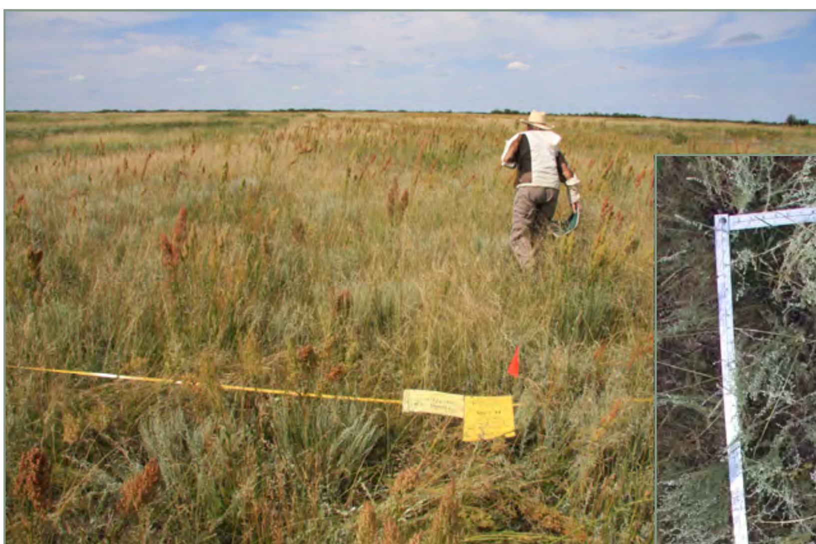
Extended timeframe monitoring using standardized methods of evaluation provides the opportunity to reflect on construction and reclamation procedures used in the past and make informed choices that will improve future restoration potential.

Long-term Monitoring of a Natural Recovery Site in Healthy Native Grassland





Pipeline RoW and 1 m^2 Frame
One Year Post-disturbance



Pipeline Row and 1 m^2 Frame
Fourteen Years Post-disturbance

13 FUTURE RESEARCH REQUIRED

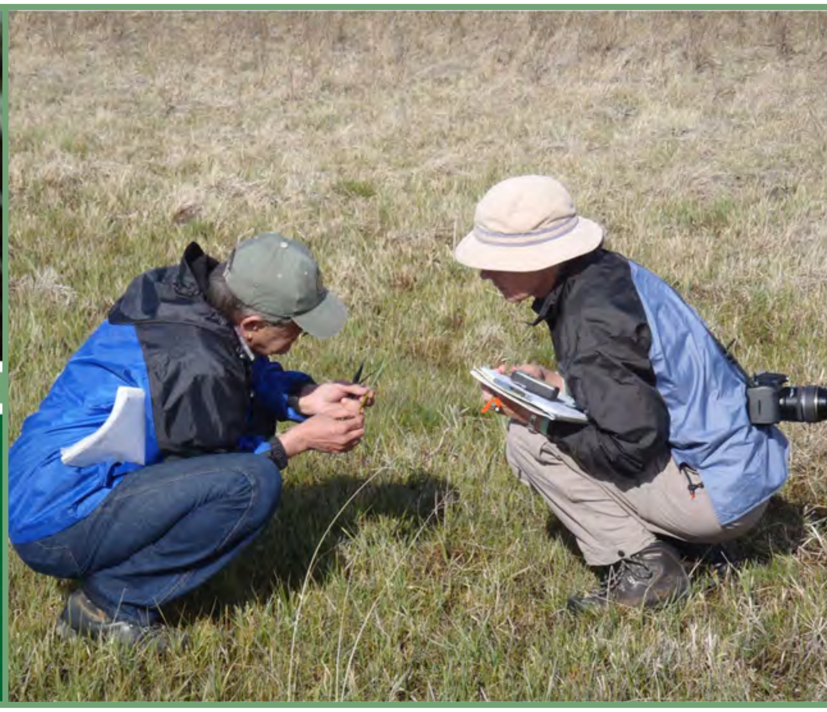
The development of new native grass ecovars and cultivars for the Mixedgrass NSR is a research priority. Collection for foundation seed stock must come from within the Mixedgrass NSR and should be renewed every three to five years. Species required include plains rough fescue, Idaho fescue, slender, northern and western wheatgrass; green needle grass; June grass; Sandberg bluegrass; Indian rice grass; needle-and-thread; western porcupine grass; blue grama and prairie sandreed. These species are major components of the native seed required for restoration.

Further concepts for research projects include:

- Research to support seed zones and seed transfer guidelines for grassland species.
- Consideration of potentially shifting zones as climate change impacts become more pronounced.
- Genetic diversity thresholds of plant materials used in restoration to maintain genetic diversity and resilience in restoration projects.
- Use of cover crops for assisted natural recovery.
- The value of incorporating early successional species into seed mixes and restoration projects.
- 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?
- The potential of using 'trait-based' approaches to restoration, where the selection of restoration species is linked to the traits and habitat niches utilized by invasive species of concern in Alberta's grasslands.
- Efficacy of various amendments across a variety of soil and range sites.
- The role AMF play in grassland restoration.
- Grazing regimes that compliment recovery and restoration of native plant communities.
- Construction access mat timing and duration considerations across different range sites.
- Impact of longer-term construction traffic impacts, the effects of different sizes and forms (wheeled vs. tracked) of vehicles, and varied traffic frequencies, both with and without construction matting to refine understanding of traffic impacts on soil and vegetation.
- The efficacy of erosion mitigation measures implemented on steep approach slopes to water courses are lacking and a knowledge gap that should be addressed.
- Road removal and restoration techniques to better support restoration success on road footprints.

- Renewable energy impact mitigation and restoration.
- Effects of solar farms on native grasslands.
- 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.
- Mechanisms and timeframe for recovery of the moss and lichen layer following industrial disturbance.
- 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?
- Impacts of litter build up on positive successional change during restoration.
- 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.
- Successful strategies for the control of problem introduced forages.

Communication & Collaboration are the Keys to Innovation



14 GLOSSARY

Blowouts: 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: Ecological range sites characterized by loamy sand and sand soils with a duned land surface.

Clayey: 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.

Constancy: refers to how often a species is associated with a component plant community in the grouping.

Cultivar: 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.

Ecodistricts: Geographic subdivisions of land based on distinct physiographic and/or geologic patterns. They are distinguished by similar patterns of relief, geology, geomorphology and genesis of parent material.

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: The degree of similarity between the present plant community and the **reference plant community.**

Ecovar: The offspring of native species that have been selected for their ability to survive and reproduce in specific ecological regions. Selection is done without emphasis on improving agronomic characteristics. Ecovars have greater genetic diversity than cultivars.

Forb: Primarily broad-leaved flowering plants with net-like veins. The category can be broadened to include those parallel-veined plants with brightly coloured flowers such as orchids or lilies.

Graminoid: 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 wellsite, 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.

Hard pans: soil horizons or layers in soils that are strongly compacted, indurated, or very high in clay content.

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.

Infill: The natural re-establishment of plants on disturbances from propagules including seeds in the soil or surrounding area.

Interim reclamation sites: 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: Standing or still water (i.e. lakes, ponds, enclosed wetlands and sloughs).

Limy: Ecological range sites with eroded or immature soils with free lime ($CaCO_3$) at the soil surface. Soils pH generally 7.5.

Loamy: Ecological range sites with medium to moderately - fine textured soils.

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

Plant Community: 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.

Problem Introduced Forages: non-native species but are commonly found and grown in the area for livestock feed. In the Mixedgrass NSR these can include crested wheatgrass, smooth brome, sheep's fescue, sweet clover and many others. Many problem introduced forages are adapted to semi-arid conditions and disturbed soils, making them particularly challenging to remove from native prairie.

Rangeland: 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.

Reclamation: The process of reconverting disturbed land to its former or other productive uses (Powter 2002). All practicable and reasonable methods of designing and conducting an activity to ensure:

(1) stable, non-hazardous, non-erodible, favourably drained soil conditions, and

(2) equivalent land capability.

(3) The removal of equipment or buildings or other structures and appurtenances,

(4) The decontamination of buildings or other structures or other appurtenances, or land or water,

(5) The stabilization, contouring, maintenance, conditioning or reconstruction of the surface of land,

(6) Any other procedure, operation or requirement specified in the regulations. (Regulatory definition)

Reduced Soil Disturbance: 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: 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: 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: The ecological range site with very coarse textured soils that are not on a duned landscape.

Sandy: The ecological range site with sandy loam, moderately coarse textured soils.

Scalping: The undesirable removal or partial removal of portions surface sod and/or topsoil layers. This can occur during winter snow blading, adjacent road grading, and removal of storage piles from the ground surface.

Seral stages: plant communities that develop in ecological succession relative to their reference community.

- Seral stages begin at the pioneer stage of early seral and progress through successional processes to **mid-seral**, then **late seral** and finally **potential natural community** since it is used as the "reference" for comparison.
- **Reference plant community** is the term used for the potential natural plant community since it is used as the "reference" for comparison.

Shallow to Gravel: 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.

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

- **Successional pathways:** The predictable pathway of change in the plant community as it is subjected to types and levels of disturbance over time.
- **Primary Succession:** the process of plant community development from bare soil, starting with pioneer species then progressing through the seral stages listed below.
- **Secondary Succession:** the process of plant community development after an established plant community is subject to additional disturbances like burning and grazing. The level of disturbance does not eliminate vegetation cover.

Thin Breaks: The 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.

Red Deer River Valley, Majorville Upland Ecodistrict

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Bison Grazing, Mixedgrass Natural Subregion

16 PHOTO CREDITS

Cover Photos

Sweetgrass Upland Ecodistric, Lethbridge Plains Ecodistrict, Cypress Upland Ecodistrict, Jane Lancaster, Kestrel Research Inc.

Acknowledgements / Contributors / Preface / List of Tables

Oldman River Valley, Junegrass, Cypress Upland Ecodistrict, Jane Lancaster, Kestrel Research Inc.

2 - Overview of the Mixedgrass Natural Subregion

Cypress Upland Ecodistrict Cumulative Effects, Jane Lancaster, Kestrel Research Inc.

4 - Promoting Native Plant Community Succession

Livestock/Dugout, Marilyn Neville, Gramineae Services Ltd.

Seral Stages, Jane Lancaster, Kestrel Research Inc. & Marilyn Neville, Gramineae Services Ltd.

5 - Preparing the Pathway

Grassland Range Health Assessment, Monitoring Frame & Consultation, Jane Lancaster, Kestrel Research Inc.

6 - Selecting the Recovery Strategy

Historic Seeding/Fragmentation of Native Plant Communities, Lorne Fitch

Silver Sagebrush Community on Blowout Range Site, Jane Lancaster, Kestrel Research Inc.

7 - Recovery Strategies for the Mixedgrass Natural Subregion

Wind Energy Project Example, Barry Adams, AEP Rangeland Management Branch (Retired)

Minimal Disturbance Pipeline, Natural Recovery of Construction Disturbance, Pipeline Seeded with Cultivars, Marilyn Neville, Gramineae Services Ltd.

Saltgrass, Saline Lowland Ecological Range Site, Jane Lancaster, Kestrel Research Inc.

8 - Native Plant Materials

Examples of Native Grass and Forb Seed Shapes and Sizes, Alberta Environment and Parks

Hand-harvesting silver sagebrush, Mechanized grass seed harvesting, Large Scale Harvesting of Native Grass Seed, Ground plum, Buffalo bean, Needle-and-thread seedlings, Silver Sagebrush Plugs, Early yellow locoweed, Jane Lancaster, Kestrel Research Inc.

Native Hay Harvester, Ron Johnson, Prairie View Consulting

9 - Implementing the Strategy

Selaginella in Sod Replacement on Ditchline; A Roughened Surface Retains Moisture, Marilyn Neville, Gramineae Services Ltd.

9 - Implementing the Strategy Continued...

Haybuster 107 No Till Seeder, Brillion No Till Seeder, Jane Lancaster, Kestrel Research Inc.

Imprinter Seeder, Roger Didychuk, I.W. Kuhn Construction Ltd.

10 - Soil Handling and Erosion Control

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Matting to Protect Grassland, Marilyn Neville, Gramineae Services Ltd.

Mows and collects Native Hay, Wild Harvested Hay Spread on Replaced topsoil, Ron Johnson, Prairie View Consulting

11 - Maintaining the Successional Pathway

Geo-grid Livestock Deterrent, Joel Conrad, Salix Resource Management

Transportation Corridors, Portable Electric Fencing System, Jane Lancaster, Kestrel Research Inc.

Fenced Remote Sump Site, Marilyn Neville, Gramineae Services Ltd.

12 - Monitoring Recovery

Extended Timeframe Monitoring, One Year Post Disturbance, Jane Lancaster, Kestrel Research Inc.

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13 - Future Research Required

Vegetation Ecologists, Marilyn Neville, Gramineae Services Ltd.

Glossary / References / Photo Credits

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Appendix A - Ecological Site Restoration Risk Assessment

Needle Grass Community/Red Deer River, Marshall McKenzie, Innotech Alberta

Appendix D - Monitoring Methods to Inform Adaptive Management

Invasion of Yellow Sweetclover, Jane Lancaster, Kestrel Research Inc.

Gaillardia (Gaillardia aristata)

Appendix A Ecological Site Restoration Risk Assessment (ESRRA) - Mixedgrass NSR

The following Ecological Site Restoration Risk Assessment (ESRRA) tables for the Mixedgrass NSR provide information on disturbance risks to ecological range sites, soils, and vegetation to assist with restoration risk reduction during project planning. Risk ratings are presented for each Ecodistrict in the Mixedgrass NSR.

A structural change from the first edition of the ESRRA document is splitting the table into two ratings:

- a reclamation risk rating for ecological range sites and soils, and
- a restoration risk rating for plant communities.

For example, ecological range sites such as Blowouts with Solonetzic soils, Sands with Vendisant soils, and Saline Lowlands are difficult to reclaim once disturbed.

Ecological Range Sites that are common to all Ecodistricts are clustered in a second table (e.g., Badlands, Saline Lowlands, Sub-irrigated, etc.).

Needle Grass Community Bordering the Red Deer River, Majorville Upland Ecodistrict

Table A-1 Ecological Range Site Reclamation Risk and Vegetation Restoration Risk Ratings for Ecodistricts in the Mixedgrass NSR

Ecodistrict	Ecological Range Site	Soil Series	Reclamation Risk Rating for Range Site or Soil	Plant Community	Vegetation Restoration Risk Rating	Issues
Milk River Upland	Overflow 1	Purescape, Whitney	Low	MGB2	Moderate	Disturbance may increase Kentucky bluegrass invasion.
	Overflow 2	Craigower, Glenbanner	Low	MGC2	Moderate	Disturbance may increase Kentucky bluegrass invasion.
	Overflow	Hegson, Milk River	Low	MGC7	Low	
	Loamy 2	Lupen, Purescape, Wilda	Low	MGA10	Low	
	Loamy	Purescape, Lupen, Purescape, Wilda	Low	MGA12, MGA13, MGA11	Low	Disturbance may increase Kentucky bluegrass invasion.
	Loamy 6	Purescape, Heartbreak, Kessler, Lethbridge, Milk River	Low	MGA14	Low	Needle-and-thread seed is difficult to source.
	Loamy	Purescape, Hegson	Low	MGA17	Low	
	Loamy	Purescape, Hegson, Milk River	Low	MGA37		Needle-and-thread seed is difficult to source.

Table A-1 Ecological Range Site Reclamation Risk and Vegetation Restoration Risk Ratings for Ecodistricts in the Mixedgrass NSR continued...

Ecodistrict	Ecological Range Site	Soil Series	Reclamation Risk Rating for Range Site or Soil	Plant Community	Vegetation Restoration Risk Rating	Issues
Milk River Upland Continued	Clayey	Orthic Regosol	High	MGA17	High	Clay soils are prone to compaction and destruction of soil structure (e.g., "puddling"). Structure is very difficult to restore.
		Purescape, Hegson		MGA33, MGA34		Soils can be highly saline and alkaline, poorly drained, and difficult for vegetation to establish on.
		Hegson		MGA35		Challenging soil handling. Concerns would be admixing, compaction, and poor infiltration. Also, potential for hardpans and blowout areas with no topsoil.
	Sandy 1	Heartbreak, Kessler, Milk River	Low	MGA16	Low	
	Blowout 2	Dark Brown Solonetzic	Moderate	MGA17	Moderate	Hardpan may limit reclamation. Silver sagebrush is difficult to restore.

Table A-1 Ecological Range Site Reclamation Risk and Vegetation Restoration Risk Ratings for Ecodistricts in the Mixedgrass NSR continued...

Ecodistrict	Ecological Range Site	Soil Series	Reclamation Risk Rating for Range Site or Soil	Plant Community	Vegetation Restoration Risk Rating	Issues
Milk River Upland Continued	Thin Breaks 2	Purescape, Heartbreak, Hegson, Milk River	High	MGA20	High	Thin soils, erosion risk, challenging soil handling. Drought prone soils may limit revegetation potential.
	Thin Breaks	Purescape, Hegson, Orthic Dark Brown		MGA32		
		Rego Dark Brown		MGC2		
		Hegson, Milk River		MGC3, MGC7		
	Saline Lowlands 2	Purescape, Kessler, Milk River, Solonetz	High	MGA19	High	Salt enriched soils; potential for periodic water pooling; challenging soil handling. Soluble salts adversely affect plant growth.
Cypress Upland	Loamy 1	Marmaduke, Wisdom	High	MGA1	High	Plains rough fescue difficult to restore.
	Loamy	Wisdom, Tothill, Marmaduke, Plume	Moderate	MGA2	Low	Western porcupine grass seed is difficult to source
	Loamy	Wisdom, Tothill, Plume	Moderate	MGA3	Low	Needle-and-thread seed is difficult to source.
	Loamy 5	Wisdom, Tothill	Moderate	MGA4	Low	Needle-and-thread seed is difficult to source
	Loamy	Tothill	Low	MGA9	Low	

Table A-1 Ecological Range Site Reclamation Risk and Vegetation Restoration Risk Ratings for Ecodistricts in the Mixedgrass NSR continued...

Ecodistrict	Ecological Range Site	Soil Series	Reclamation Risk Rating for Range Site or Soil	Plant Community	Vegetation Restoration Risk Rating	Issues
Cypress Upland Continued	Loamy 4	Wisdom, Tothill, Plume, Woolchester	Moderate	MGA30	Low	Western porcupine grass seed is difficult to source.
	Blowout	Craigower, Tothill, Craigower, Wisdom, Glennbanner	High	MGA3, MGA9, MGC1	High	Hardpan may limit reclamation.
	Blowout 1	McAlpine	High	MGA5	High	Hardpan may limit reclamation.
	Shallow to Gravel	Marmaduke	High	MGA31	Moderate	Plains rough fescue difficult to restore.
	Gravel	McAlpine, Craigower	Moderate	MGA7	High	Soil handling and reclamation may be difficult.
	Thin Breaks 1	Wisdom, Tothill	High	MGA8	High	Thin soils, erosion risk, challenging soil handling. Drought prone soils may limit revegetation potential.
	Limy	Plume	High	MGA1	High	Thin soils prone to drought, erosion concerns. Plains rough fescue difficult to restore.
	Saline Lowlands 1	McAlpine, Craigower	High	MGA6	High	Salt enriched soils; potential for periodic water pooling; challenging soil handling. Soluble salts adversely affect plant growth.

Table A-1 Ecological Range Site Reclamation Risk and Vegetation Restoration Risk Ratings for Ecodistricts in the Mixedgrass NSR continued...

Ecodistrict	Ecological Range Site	Soil Series	Reclamation Risk Rating for Range Site or Soil	Plant Community	Vegetation Restoration Risk Rating	Issues
Lethbridge-Vulcan-Majorville-Vauxhall Plains	Loamy 3	Lethbridge, Readymade, Whitney	Low	MGA21	Low	Needle-and-thread seed is difficult to source.
	Loamy	Orthic Dark Brown	Low	MGA23	Low	Needle-and-thread seed is difficult to source. Limited seedbank for natural infill.
		Whitney, Lethbridge, Kessler		MGA24		
		Kessler, Lethbridge		MGA25, MGA27		
	Loamy	Lethbridge, Whitney, Kessler	Low	MGA26	Low	Limited seedbank for natural infill.
	Loamy	Readymade, Maleb	Low	MGA36	Low	Western porcupine grass seed is difficult to source.
	Loamy 7	Lethbridge, Readymade, Whitney, Cradduck	Low	MGC4	Low	
	Sandy 2	Kessler, Lethbridge	Low	MGA25	Low	
	Sandy	Kessler, Lethbridge	Low	MGA27	Low	
	Sandy 1 Little Bow	Carmangay, Kessler	Low	MGA28	Low	
	Sandy	Orthic Dark Brown	Low	MGC4, MGC5, MGC6	Low	

Table A-1 Ecological Range Site Reclamation Risk and Vegetation Restoration Risk Ratings for Ecodistricts in the Mixedgrass NSR continued...

Ecodistrict	Ecological Range Site	Soil Series	Reclamation Risk Rating for Range Site or Soil	Plant Community	Vegetation Restoration Risk Rating	Issues
Lethbridge-Vulcan-Majorville-Vauxhall Plains Continued	Sands 1 Little Bow	Ardenode, Heartbreak, Highwood	High	MGA28	High	Coarse textured soils; drought prone with erosion concerns.
	Saline Lowlands	Orthic Dark Brown	High	MGA29	High	Salt enriched soils; potential for periodic water pooling; challenging soil handling.
Blackfoot Plain	Limy (Li)	Chokio	High	Unconfirmed	High	Thin soils prone to drought, erosion concerns.
	Sandy (Sy)	Carmangay, Kessler	Low	MGA24	Low	
	Loamy (Lo)	Readymade, Coaldale, Lethbridge	Low	MGA22	Low	
Standard Plain	Clayey (Cy)	Coaldale	High	Unconfirmed	High	Clay soils are prone to compaction and destruction of soil structure (e.g., "puddling"). Structure is very difficult to restore.
		Purescape, Hegson, Rego Dark Brown	High	MGA34	High	Soils can be highly saline and alkaline, poorly drained, and difficult for vegetation to establish on. Challenging soil handling. Concerns would be admixing, compaction, and poor infiltration. Also, potential for hardpans and blowout areas with no topsoil.

Table A-1 Ecological Range Site Reclamation Risk and Vegetation Restoration Risk Ratings for Ecodistricts in the Mixedgrass NSR

Ecodistrict	Ecological Range Site	Soil Series	Reclamation Risk Rating for Range Site or Soil	Plant Community	Vegetation Restoration Risk Rating	Issues
Standard Plain Continued	Loamy (Lo)	Readymade, Coaldale, Lethbridge	High	MGA22	High	Presence of weedy species may limit reclamation
	Limy (Li)	Wilda	High	Unconfirmed	Moderate to High	Thin soils prone to drought, erosion concerns.
	Blowouts (Blo)	Minda	High	Unconfirmed	High	Hardpan may limit reclamation.
Sweetgrass Upland	Thin Breaks	Wisdom, Tothill	High	MGA8	High	Thin soils, erosion risk, challenging soil handling. Drought prone soils may limit revegetation potential.
		Purescape, Hegson	High	MGA32	High	
	Shallow to gravel	Marmaduke	High	MGA31	Moderate	Plains rough fescue difficult to restore
	Gravel	Marmaduke	High	MGA7	High	Reclamation may be difficult.

Table A-2 Reclamation and Restoration Risk Ratings for Ecological Range Sites Common to Multiple Ecodistricts

Ecological Range Site	Soil Series	Reclamation Risk Rating for Range Site or Soil	Plant Community	Vegetation Restoration Risk Rating	Issues
Overflow 1	Purescape, Whitney	Moderate	MGB2	Moderate	Disturbance may increase Kentucky bluegrass Invasion
Overflow 2	Craigower, Glenbanner		MGC2		
Overflow	Hegson, Milk River	Low	MGC7	Low	
Wetlands and Riparian Areas (All Lentic and Lotic site types)	N/A	High	All communities	High	Avoid all Lentic and Lotic site types
Clayey (Cy)	Coaldale	High	Unconfirmed	High	Clay soils are prone to compaction and destruction of soil structure (e.g., "puddling"). Structure is very difficult to restore.
Clayey	Orthic Regosol	High	MGA17	High	Soils can be highly saline and alkaline, poorly drained, and difficult for vegetation to establish on.
	Purescape, Hegson, Rego Dark Brown		MGA33, MGA34		Challenging soil handling. Concerns would be admixing, compaction, and poor infiltration. Also, potential for hardpans and blowout areas with no topsoil.
	Hegson		MGA35		

Table A-2 Reclamation and Restoration Risk Ratings for Ecological Range Sites Common to Multiple Ecodistricts continued...

Ecological Range Site	Soil Series	Reclamation Risk Rating for Range Site or Soil	Plant Community	Vegetation Restoration Risk Rating	Issues
Loamy 1	Marmaduke, Wisdom	Moderate	MGA1	High	Plains rough fescue is difficult to restore
Loamy	Wisdom, Tothill, Marmaduke, Plume	Moderate	MGA2	Low	Western porcupine grass seed is difficult to source
Loamy	Wisdom, Tothill, Plume	Moderate	MGA3	Low	Needle-and-thread seed is difficult to source
Loamy 5	Wisdom, Tothill	Moderate	MGA4	Low	Needle-and-thread seed is difficult to source.
Loamy	Tothill	Low	MGA9	Low	
Loamy 2	Lupen, Purescape, Wilda	Moderate	MGA10	Low	Needle-and-thread seed is difficult to source
Loamy	Lupen, Purescape, Wilda Purescape	Low	MGA11 MGA12, MGA13	Low	Disturbance may increase Kentucky bluegrass invasion.
Loamy 6	Purescape, Heartbreak, Lethbridge, Milk River	Low	MGA14	Low	Needle-and-thread seed is difficult to source.
Loamy 3	Lethbridge, Readymade, Whitney		MGA21		Needle-and-thread seed is difficult to source.
Loamy	Purescape, Hegson	Low	MGA17	Low	
Loamy	Readymade, Coaldale, Lethbridge	Low	MGA22	Low	Presence of weedy species may limit reclamation.

Table A-2 Reclamation and Restoration Risk Ratings for Ecological Range Sites Common to Multiple Ecodistricts continued...

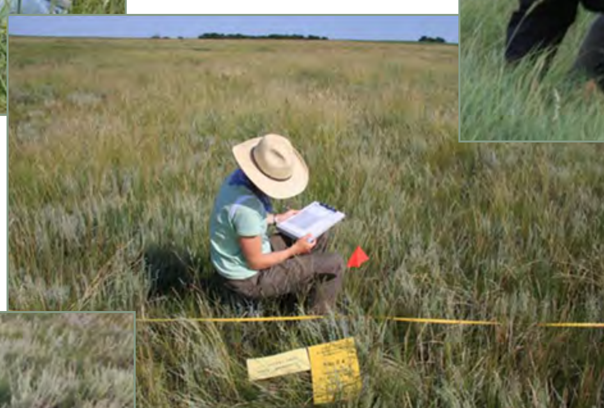
Ecological Range Site	Soil Series	Reclamation Risk Rating for Range Site or Soil	Plant Community	Vegetation Restoration Risk Rating	Issues
Loamy	Orthic Dark Brown Whitney, Lethbridge, Kessler Kessler, Lethbridge	Low	MGA23 MGA24 MGA25, MGA27	Low	Needle-and-thread seed is difficult to source. Limited seedbank for natural infill.
Loamy	Lethbridge, Whitney, Kessler	Low	MGA26	Low	Limited seedbank for natural infill.
Loamy 4	Wisdom, Tothill, Plume, Woolchester	Moderate	MGA30	Low	Western porcupine grass seed is difficult to source.
Loamy	Readymade, Maleb	Low	MGA36	Low	Western porcupine grass seed is difficult to source.
Loamy	Purescape, Hegson, Milk River	Low	MGA37	Low	Needle-and-thread seed is difficult to source.
Loamy 7	Lethbridge, Readymade, Whitney, Cradduck	Low	MGC4	Low	
Sandy 1	Heartbreak, Kessler, Milk River	Low	MGA16	Low	
Sandy (Sy)	Carmangay, Kessler	Low	MGA24	Moderate	
Sandy 2	Kessler, Lethbridge	Low	MGA25	Low	
Sandy	Kessler, Lethbridge	Low	MGA27	Low	
Sandy 1 Little Bow	Carmangay, Kessler	Low	MGA28	Low	

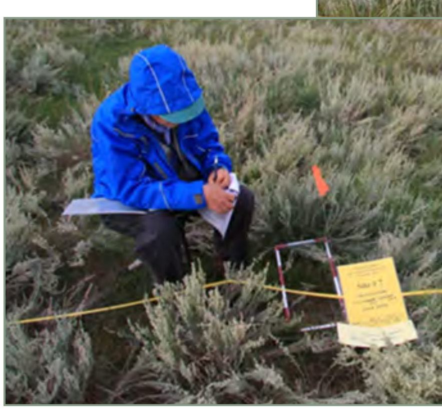
Table A-2 Reclamation and Restoration Risk Ratings for Ecological Range Sites Common to Multiple Ecodistricts continued...

Ecological Range Site	Soil Series	Reclamation Risk Rating for Range Site or Soil	Plant Community	Vegetation Restoration Risk Rating	Issues
Sandy	Orthic Dark Brown	Low	MGC4, MGC5, MGC6	Low	
Blowouts	Minda	High	Unconfirmed	High	Hardpan may limit reclamation.
Blowout	Craigower	High	MGA3	High	Hardpan may limit reclamation.
Blowout 1	McAlpine	High	MGA5	High	Hardpan may limit reclamation.
Blowout 2	Tothill,	Moderate	MGA9	Moderate	Hardpan may limit reclamation.
Blowout 2	Dark Brown Solonetzic	Moderate	MGA17	Moderate	Hardpan may limit reclamation. Silver sagebrush is difficult to restore.
Blowout	Craigower, Wisdom, Glennbanner	High	MGC1	High	Hardpan may limit reclamation.
Gravel	Marmaduke	High	MGA7	High	Reclamation may be difficult.
Limy	Wilda	High	Unconfirmed	Moderate	Thin soils prone to drought, erosion concerns.
Limy	Plume	High	MGA1	High	Thin soils prone to drought, erosion concerns. Plains rough fescue is difficult to restore.
Limy (Li)	Chokio	High	Unconfirmed	High	Thin soils prone to drought, erosion concerns.
Saline Lowlands 1	McAlpine, Craigower	High	MGA6	High	Salt enriched soils; potential for periodic water pooling; challenging soil handling. Soluble salts adversely affect plant growth.

Table A-2 Reclamation and Restoration Risk Ratings for Ecological Range Sites Common to Multiple Ecodistricts

Ecological Range Site	Soil Series	Reclamation Risk Rating for Range Site or Soil	Plant Community	Vegetation Restoration Risk Rating	Issues
Saline Lowlands 2	Purescape, Kessler, Milk River, Solonetz	High	MGA19	High	Salt enriched soils; potential for periodic water pooling; challenging soil handling. Soluble salts adversely affect plant growth.
Saline Lowlands	Orthic Dark Brown	High	MGA29	High	Salt enriched soils; potential for periodic water pooling; challenging soil handling. Soluble salts adversely affect plant growth.
Shallow to Gravel	Marmaduke	High	MGA31	Moderate	Plains rough fescue is difficult to restore.
Thin Breaks	Purescape, Hegson	High	MGA32	High	Thin soils, erosion risk, challenging soil handling. Drought prone soils may limit revegetation potential.
	Orthic Dark Brown	High	MGC2	High	
	Rego Dark Brown	High	MGC3	High	
	Hegson, Milk River	High	MGC7	High	
Thin Breaks 1	Wisdom, Tothill	High	MGA8	High	Thin soils, erosion risk, challenging soil handling. Drought prone soils may limit revegetation potential.
Thin Breaks 2	Purescape, Heartbreak, Hegson, Milk River	High	MGA20	High	Thin soils, erosion risk, challenging soil handling. Drought prone soils may limit revegetation potential.





Appendix B Target Recovering Plant Community Seed Mix Guidance

Introduction

Designing seed mixes for soil disturbances in native grassland not suited to natural recovery or assisted natural recovery in the Grassland Natural Region is as much an art as it is a science. The purpose of a native seed mix is to revegetate the disturbance with native species that will allow the process of succession to take place and establish a stable and resilient mid- to late seral plant community over time. Seed mix design needs to consider and include species that:

- Are adapted to the physical, textural, and chemical properties of the disturbed soils.
- Will provide cover quickly to reduce erosion potential.
- Will drive succession over time toward the desired species composition in the late seral target plant community.
- Are of different heights, root types, and growth strategies (e.g., C3 and C4 metabolism) to provide structural diversity and resilience to seasonal climate variation and herbivory.

Given the diversity of ecological range sites and successional plant community types that can be encountered within a relatively small area on the landscape, and the impracticality of designing specific mixes for the variety of plant communities on large projects, it is useful to establish which ecological range sites have similar site productivity and species in common. To develop descriptions of target recovering plant communities, ecological range sites in the NSR with common dominant native grass species are grouped, and the range of cover values for component native grass species are combined.

The following analysis of target recovering plant communities is based on the Mixedgrass Range Plant Community Guide, which describes common native grassland and common native shrubland plant community types. Government of Alberta Range Management Specialists provided the dataset used to develop the target recovering plant community descriptions. The combined plant community data in the analysis includes mid-seral, late seral and reference plant communities documented for each grouping of ecological range sites, to include plants that are drivers of succession at earlier stages in plant community development.

These groupings of ecological range sites with common dominant native grass species are referred to as target recovering plant communities. The proportions of each species are clearly not mature reference native plant communities, but rather composed of the dominant native grass species that are drivers or principal species in the successional process.

Each target plant community description provides the mean percent cover, the range of cover values expressed, and constancy of occurrence for each species in the dataset. The average combined percent cover of the native forb species and native shrub species, and exposed soil is also provided to illustrate these components of the target recovering plant community at a mid- to late-successional stage.

The resulting target recovering plant communities for each grouping of ecological range sites are presented in this appendix, accompanied by examples for seed mix composition.

The recommended native species will provide the initial vegetative cover to stabilize disturbed soils and facilitate the recovery of the plant community over time. Reference material used to develop the examples include:

- Results of the literature review conducted for this project (Miller et al. 2023).
- Findings of long-term monitoring case studies conducted for this project (Lancaster et al. 2012).
- *Common Plants of the Western Rangelands Volume 1: Grasses and Grass-like Species* (Tannas 2003).
- *Manual of Plant Species Suitability for Reclamation in Alberta 2nd Edition* (Hardy 1989).
- *A Guide to Using Native Plants on Disturbed Lands* (Gerling et al., 1996).
- *Native Plant Revegetation Guidelines for Alberta* (Native Plant Working Group 2001).
- *Revegetation Guidelines for Western Montana* (Goodwin et al. 2006).
- *Forage and Reclamation Grasses of the Northern Great Basin and Rocky Mountains* (Majerus 2009).
- *Revegetating with Native Grasses in the Northern Great Plains Professional's Manual* (Wark et al 2005).
- *Rebuilding Your Land with Native Grasses: A Producers Guide* (Gabruch et al 2011).
- *Plant Material Selection and Seed Mix Design for Native Grassland Restoration Projects* (Tannas Conservation Services Ltd. (2016).

Examples of native seed mixes, based on the target recovering plant community are given as percent pure live seed by weight and by seed count. Table B-1 lists approximate weights for each species. The value for each recommended species has been determined through an iterative process that converts the percent foliar cover anticipated in the recovering plant community, establishment vigour and the proportion of pure live seed required for each species in the seed mix.

It is important to note that this is only the first step in seed mix design and does not replace pre-site assessment.

Considerations that go into assigning proportions of a mix for each component species consider factors such as:

- when each species typically establishes on bare soil.
- limiting the proportion of persistent aggressive species. Some cultivars are known to be very aggressive such as green needle grass and prairie sandreed, also known as sand grass.
- adjusting for vigour of less competitive species such as June grass or slow-growing species such as plains rough fescue.
- seed size and weight (average number of seeds per kilogram).
- application rates and type of seeding equipment (broadcast, drill, no till drill).

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?

Plant species serve different purposes in a mix. Some establishing earlier and others late. Some have long lifespans and others short, serving a purpose during initial establishment but not persisting. Characteristics of grass seed commonly used in the Mixedgrass NSR are described in Table B-2.

When species substitutions are needed due to seed shortages, attention must be paid to the characteristics and role of each species in the mix and seed size (Tables B-1 and B-2). A rule of thumb is not to vary the relative proportions of component species in a mix by more than 5%.

More guidance for seed mix design is presented in Section 7: Native Plant Materials, which lists relevant publications for seed mix design.

Qualified practitioners with experience in native prairie restoration should be consulted for native seed mix design and any variances from designed proportions due to seed shortages.

Table B-1 Seed Weights of Grasses Commonly used in Restoration in the Mixedgrass NSR

Species Scientific Name	Common Name	Seeds/kg	Seeds/lb	Relative Seed Size
Bouteloua gracilis	blue grama	1,820,000	826,000	medium - small
Calamagrostis stricta	narrow reed grass	11,684,000	5,300,800	very small
Deschampsia cespitosa	tufted hair grass	5,510,000	2,500,000	small
Distichlis spicata	salt grass	1,150,000	522,000	medium
Elymus canadensis	Canada wildrye	254,000	115,000	large
Elymus lanceolatus	northern wheat grass	340,000	154,000	medium
Elymus trachycaulus ssp. subsecundus	slender wheatgrass	260,000	118,000	medium
Elymus trachycaulus ssp. trachycaulus	slender wheat grass	350,000	159,000	medium
Eriocoma hymenoides	Indian rice grass	518,000	235,000	medium
Festuca hallii	plains rough fescue	445,000	202,000	medium
Festuca idahoensis	Idaho fescue	990,000	449,000	medium
Festuca saximontana	Rocky Mountain fescue	1,498,000	680,000	medium
Hesperostipa comata	needle-and-thread	250,000	113,000	medium
Hesperostipa curtiseta	western porcupine grass	200,000	91,000	medium
Koeleria macrantha	June grass	5,100,000	2,313,000	small
Nassella viridula	green needle grass	400,000	181,000	medium
Pascopyrum smithii	western wheat grass	240,000	109,000	medium
Poa palustris	fowl bluegrass	6,179,550	2,803,000	small
Poa secunda ssp. juncifolia	alkali bluegrass	3,300,000	1,497,000	small
Poa secunda ssp. secunda	Sandberg bluegrass	2,040,000	926,000	small
Puccinellia nuttalliana	Nuttall's salt-meadow grass	6,140,000	2,785,000	small
Schizachyrium scoparium	little bluestem	530,000	240,000	medium
Sporobolus rigidus	prairie sandreed	603,000	274,000	medium

Table B-2 Characteristics of Grasses Commonly used in Restoration in the Mixedgrass

Scientific Name	Common Name	Metabolism	Structural Layer	Root Structure	Grazing Response *
Beckmannia syzigachne	slough grass	C3	tall	rhizomes	Decreaser
Bouteloua gracilis	blue grama	C4	Medium	rhizomes short	Increaser Type 2
Calamagrostis montanensis	plains reed grass	C3	medium	rhizomes	Increaser Type 1
Calamagrostis stricta	narrow reed grass	C3	tall	rhizomes	Increaser Type 1
Deschampsia cespitosa	tufted hair grass	C3	Tall	bunch	Decreaser
Distichlis spicata ssp. stricta	salt grass	C4	Medium	rhizomes	Increaser Type 1
Elymus canadensis	Canada wild rye	C3	Tall	rhizomes short	Decreaser
Elymus lanceolatus	northern wheat grass	C3	Tall	rhizomes short	Decreaser
Elymus trachycaulus ssp. subsecundus	awned wheatgrass	C3	Tall	bunch	Decreaser
Elymus trachycaulus ssp. trachycaulus	slender wheat grass	C3	Tall	bunch	Decreaser
Eriocoma hymenoides	Indian rice grass	C3	Tall	bunch	Decreaser
Festuca hallii	plains rough fescue	C3	Tall	rhizomes short	Decreaser
Festuca idahoensis	bluebunch fescue	C3	medium	bunch	Increaser Type 1
Festuca saximontana	Rocky Mountain fescue	C3	short	bunch	Increaser Type 1
Hesperostipa comata	needle-and-thread	C3	Medium	bunch	Decreaser
Hesperostipa curtiseta	western porcupine grass	C3	Tall	bunch	Decreaser
Koeleria macrantha	June grass	C3	Medium	bunch	Increaser Type 1
"Nassella viridula	green needle grass	C3	Tall	bunch	Decreaser
Pascopyrum smithii	western wheat grass	C3	tall	rhizomes	Decreaser
Poa palustris	fowl bluegrass	C3	tall	bunch	Decreaser
Poa secunda ssp. juncifolia	alkali bluegrass	C3	medium	bunch	Increaser Type 1
Poa secunda ssp. secunda	Sandberg bluegrass	C3	short	bunch	Increaser Type 2
Puccinellia nuttalliana	Nuttall's salt-meadow grass	C3	tall	bunch	Decreaser
Schizachyrium scoparium	little bluestem	C4	medium	bunch	Increaser Type 1
Sporobolus cryptandrus	sand dropseed	C4	tall	bunch	Decreaser
Sporobolus rigidus ssp. rigidus (Calamovilfa longifolia)	sand grass	C4	tall	rhizomes	Increaser Type 1

See the Glossary for definitions of grazing responses.
** Sources: Alberta Conservation Information Management System (ACIMS);*
2010 Reclamation Criteria for Wellsites and Associated Facilities for Native Grasslands (AEP 2013);
A Guide to Using Native Plants on Disturbed Lands (Gerling et al 1996).

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B1 Target Recovering Plant Community for the Cypress Upland Ecodistrict

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

B.1.1 Cypress Upland: Loamy, Shallow to Gravel, Gravel, and Thin Breaks Range Sites

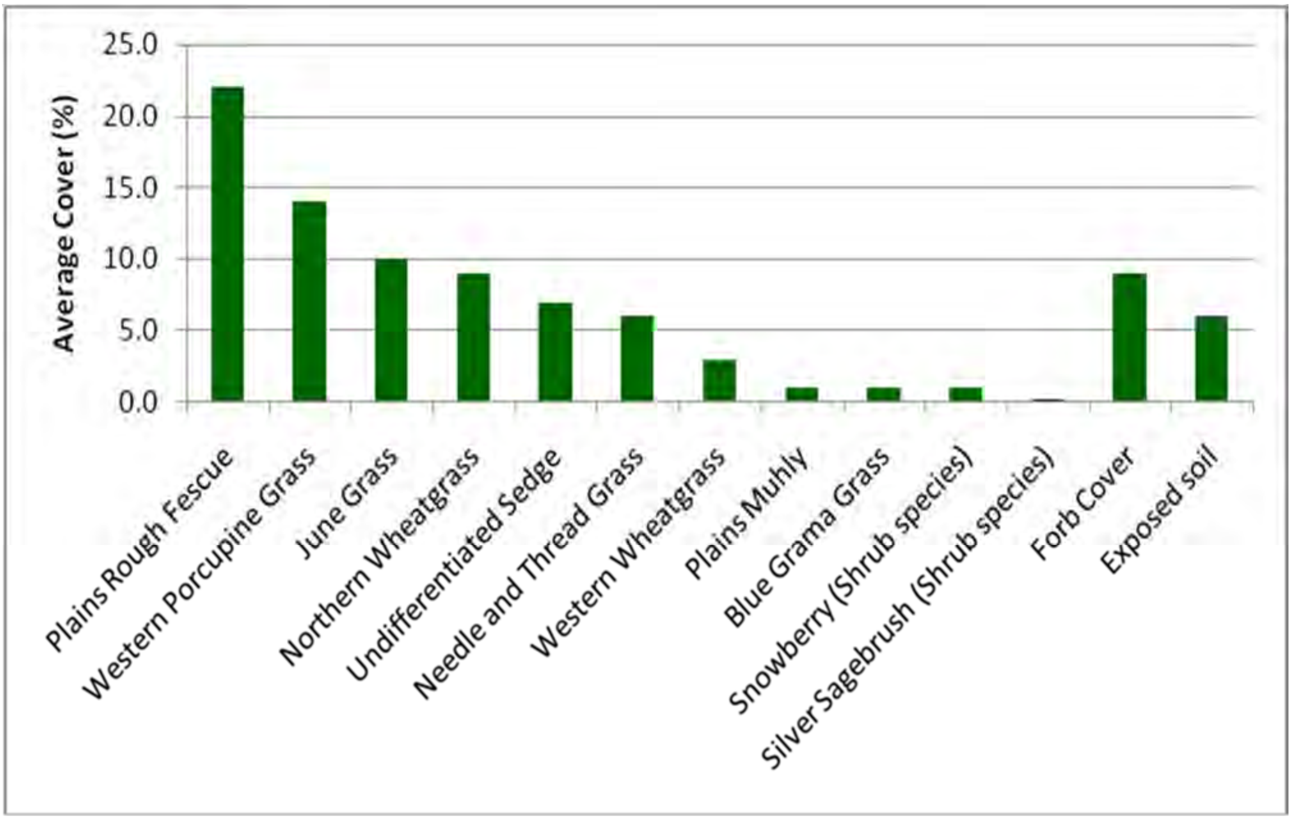
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Cypress Upland Ecodistrict in Table 11. The plant communities included in this cluster include MGA1, MGA2, MGA30, MGA31, MGA7 and MGA8.

This cluster generally applies to the mid to upper slope positions in the Cypress Upland Ecodistrict. Native grasslands are largely intact under the stewardship of large ranching operations. In this area plains rough fescue is a key indicator species common to Loamy, Shallow to Gravel, Gravel, and Thin Breaks ecological range sites. The cluster includes mid- and late seral stage and reference plant communities found on Loamy textured topsoils. Common dominant species include plains rough fescue, western porcupine grass, June grass and northern wheatgrass. The target recovering plant community is described in Table B-3 and Figure B-1.

Table B-3 Target Recovering Plant Community for Cypress Upland: Loamy, Shallow to Gravel, Gravel and Thin Breaks Range Sites

Species	Common Name	Seral Stage	Average % Cover	% Constancy
Festuca hallii	plains rough fescue	Late	22	71
Hesperostipa curtiseta	western porcupine grass	Late	14	91
Koeleria macrantha	June grass	Early - Mid	10	98
Elymus lanceolatus	northern wheatgrass	Late	9	74
Carex species	undifferentiated sedge	Early - Mid	7	97
Hesperostipa comata	needle-and-thread	Late	6	53
Pascopyrum smithii	western wheatgrass	Late	3	60
Muhlenbergia cuspidata	plains muhly	Late	1	3
Bouteloua gracilis	blue grama	Late	1	43
Symphoricarpos occidentalis	buckbrush (shrub)	Early - Mid	1	11
Artemisia cana	silver sagebrush (shrub)	Late	0.3	4
Average Total Vegetation Cover			**74**	
Average Forb Cover			**9**	
Average Moss and Lichen Cover			**40**	
Average Soil Exposure			**6**	

Figure B-1 Target Recovering Plant Community for Cypress Upland: Loamy, Shallow to Gravel, Gravel and Thin Breaks Range Sites



This information can 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 B-4 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 percent Pure Live Seed (PLS) by weight and by seed number.

Site assessment data including the pre-disturbance or adjacent plant community and associated range health are essential when fine tuning native seed mixes.

Table B-4 Example Seed Mix for Cypress Upland: Loamy, Shallow to Gravel and Gravel Range Sites

Scientific Name	Common Name	Proportion of Seed Mix by Weight of Pure Live Seed	Proportion of Seed Mix by Number of Pure Live Seeds
Festuca hallii	plains rough fescue	21.10%	25%
Hesperostipa curtiseta	western porcupine grass	37.60%	20%
Elymus trachycaulus ssp. Subsecundus	awned wheatgrass	21.70%	15%
Elymus lanceolatus	northern wheatgrass	8.80%	8%
Koeleria macrantha	June grass	1.50%	20%
Pascopyrum smithii	western wheatgrass	7.80%	5%
Bouteloua gracilis	blue grama	1.40%	7%

Example Seed Mix Notes:

- Awned wheatgrass will provide initial cover and is expected to disappear from the stand in about five years, providing space for infill of seeded species and encroachment from off site.
- Northern wheatgrass will stabilize the soils and provide structure in the stand.
- The proportion of plains rough fescue is less than what is required to compensate for the variability in the performance wild harvested seed, based on results of the long-term monitoring conducted for this project. However, seed availability is typically scarce, and once established it may increase over time through seed production. It is important to introduce the dominant late seral species to set a trajectory towards a target late seral plant community over time.
- The proportion of the western porcupine grass has been increased to compensate for the variability in viability of wild harvested seed.
- June grass will provide mid-height structure in the stand.
- Western wheatgrass will add diversity and mitigate risk if the wild-harvested seed mix components do not establish as planned.
- Blue grama is a warm season grass, unlike the other cool season grasses, and will add lower structure, resilience and diversity.

Substitutions: Sheep fescue is not a replacement for any native fescue species. It is non-native and invasive in native grassland. Green needle grass is not a substitute for western porcupine grass. Blue grama can be substituted for June grass or Sandberg bluegrass. Slender wheatgrass is a substitute for awned wheatgrass, but it can be aggressive, so keep proportions low.

When substitutions are needed, pay attention to the characteristics and role of each species in the mix and seed size (Tables B-1 and B-2). A rule of thumb is not to vary the relative proportion of component species <u>by seed number</u> in a mix by more than 5%.

B.1.2 Cypress Upland: Low Elevation Dry Loamy and Blowout Range Sites

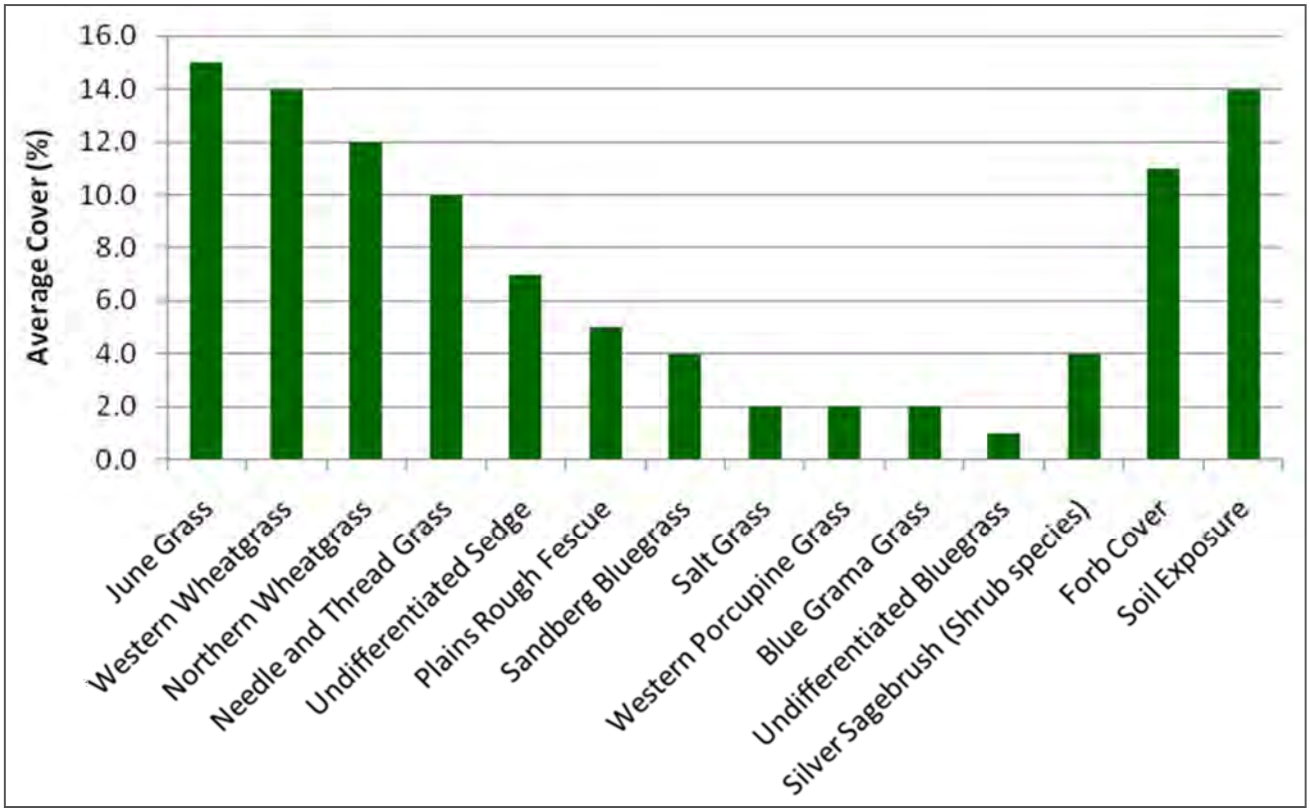
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Cypress Upland Ecodistrict in Table 11. The plant communities included in this grouping include: MGA4, MGA5, MGA9, and MGC1, which include mid- to late seral plant communities found at lower elevations in the Cypress Upland on lower slope, terrace, and level landform elements. The lower slopes tend to be more fragmented by cultivation. Drought tolerant June grass, northern and western wheatgrass and needle-and–thread are dominant. Plains rough fescue may be present at relatively low cover values. Soil exposure reflects the characteristics of dry Loamy to Blowout range sites and soils of the Solonetzic Order. The target recovering plant community is described in Table B-5 and Figure B-2.

Table B-5 Target Recovering Plant Community for Cypress Upland: Low Elevation Dry Loamy and Blowout Range Sites

Species	Common Name	Seral Stage	Average % Cover	% Constancy
Koeleria macrantha	June grass	Mid	15	100
Pascopyrum smithii	western wheatgrass	Late	14	100
Elymus lanceolatus	northern wheatgrass	Late	12	73
Hesperostipa comata	needle-and-thread	Late	10	45
Carex species	undifferentiated sedge	Early - Mid	7	82
Festuca hallii	plains rough fescue	Late	5	9
Poa secunda ssp. secunda	Sandberg bluegrass	Early - Mid	4	73
Distichlis spicata ssp. stricta	salt grass	Late	2	9
Hesperostipa curtiseta	western porcupine grass	Late	2	18
Bouteloua gracilis	blue grama	Late	2	73
Artemisia cana	silver sagebrush (shrub)	Late	4	73
Average Total Vegetation Cover			**61**	
Average Forb Cover			**12**	
Average Moss and Lichen Cover			**55**	
Average Soil Exposure			**14**	

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

Figure B-2 Target Recovering Plant Community for Cypress Upland: Low Elevation Dry Loamy and Blowout Range Sites



This information can 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 C-4 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 percent Pure Live Seed (PLS) by weight and by seed number.

Site assessment data including the pre-disturbance or adjacent plant community and associated range health are essential when fine tuning native seed mixes.

Table B-6 Example Seed Mix for Cypress Upland: Low Elevation Dry Loamy and Blowout Range Sites

Scientific Name	Common Name	Proportion of Seed Mix by Weight of Pure Live Seed	Proportion of Seed Mix by Number of Pure Live Seeds
Hesperostipa comata	needle-and-thread	32%	20%
Koeleria macrantha	June grass	2%	20%
Festuca hallii	plains rough fescue	14%	15%
Elymus lanceolatus	northern wheatgrass	18%	15%
Pascopyrum smithii	western wheatgrass	17%	10%
Poa secunda ssp. secunda	Sandberg bluegrass	2%	10%
Elymus trachycaulus ssp. subsecundus	awned wheatgrass	16%	10%

Example Seed Mix Notes:

- Awned wheatgrass will provide initial cover and is expected to disappear from the stand in about five years, providing space for infill of seeded species and encroachment from off site.
- Western and northern wheatgrass are colonizers of disturbances and drivers in the successional process on Blowout range sites in the Cypress Upland. Cultivars of western and northern wheatgrass are competitive.
- Needle-and-thread and plains rough fescue are recommended at higher rates to compensate for the variability in the performance wild harvested seed and slow establishment of rough fescue.
- June grass is an important mid-seral species and a lower structural component.
- Sandberg bluegrass is added for its drought tolerance and medium structure.

Substitutions: Sheep fescue is not a replacement for any native fescue species. It is non-native and invasive in native grassland. Green needle grass is not a substitute for western porcupine grass or needle-and-thread. Blue grama can be substituted for June grass or Sandberg bluegrass. Slender wheatgrass is a substitute for awned wheatgrass, but it can be aggressive, so keep proportions low.

When substitutions are needed due to seed shortages, pay attention to the characteristics and role of each species in the mix and seed size (Tables B-1 and B-2). A rule of thumb is not to vary the relative proportion of each species <u>by seed number</u> in a mix by more than 5%.

B.1.3 Cypress Upland: Saline Lowland Range Sites

The Range Plant Community Guide for the Mixedgrass lists MGA6 salt grass – Sedge – western wheatgrass as the late seral to reference plant community for Saline Lowland range sites in the Cypress Upland Ecodistrict. The target recovering plant community is described in Table B-3 and Figure B-1.

Table B-7 Target Recovering Plant Community for Cypress Upland: Saline Lowland Range Sites

Species	Common Name	Seral Stage	Average % Cover	% Constancy
Grasses and Sedges				
Carex species	undifferentiated sedge	Early - Mid	25	100
Distichlis spicata ssp. stricta	salt grass	Late	17	50
Pascopyrum smithii	western wheatgrass	Late	7	50
Poa species	undifferentiated bluegrass	Early - Mid	6	100
Festuca hallii	plains rough fescue	Late	6	50
Puccinellia nuttalliana	Nuttall's salt-meadow grass	Late	5	50
Koeleria macrantha	June grass	Early - Mid	3	50
Muhlenbergia species	undifferentiated muhly	Late	3	50
Sporobolus hookerianus	alkali cord grass	Late	3	50
Forbs				
Grindelia squarrosa	curly-cup gumweed	Early - Mid	1	50
Gutierrezia sarothrae	broomweed	Late	2	50
Antennaria species	undifferentiated everlastings	Early - Mid	1	50
Average Total Vegetation Cover			**57**	
Average Moss and Lichen Cover			**26**	
Average Soil Exposure			**19**	

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

This information can 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. Salt grass and western wheatgrass are drivers in the process of succession and adapted to the cyclic moisture conditions. Table C-6 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 percent Pure Live Seed (PLS) by weight and by seed number.

Site assessment data including range health are essential when fine tuning native seed mixes.

Table B-8 Example Seed Mix for Cypress Upland: Saline Lowland Range Sites

Scientific Name	Common Name	Proportion of Seed Mix by Weight of Pure Live Seed	Proportion of Seed Mix by Number of Pure Live Seeds
Pascopyrum smithii	western wheatgrass	78%	30%
Distichlis spicata	salt grass	14%	25%
Poa secunda ssp. secunda	Sandberg bluegrass	5%	20%
Puccinellia nuttalliana	Nuttall's salt-meadow grass	2%	15%
Koeleria macrantha	June grass	1%	10%

Example Seed Mix Notes:

- The rhizomatous root system of western wheatgrass is adapted to the shrink swell cycles of Clayey soils.
- Sandberg bluegrass is tolerant of salinity and drought, and will provide early cover.
- Nuttall’s salt-meadow grass and salt grass are adapted to moister microsites in Saline Lowlands.
- June grass will provide diversity by establishing in dryer niche areas within the site.

Substitutions: Alkali bluegrass (*Poa secunda ssp. juncifolia*) can be substituted for Sandberg bluegrass. Blue grama can be substituted for June grass or Sandberg bluegrass.

When substitutions are needed due to seed shortages, pay attention to the characteristics and role of each species in the mix and seed size (Tables B-1 and B-2). A rule of thumb is not to vary the relative proportion of each species <u>by seed number</u> in a mix by more than 5%.

B2 Target Recovering Plant Communities for the Sweetgrass and Milk River Upland Ecodistricts

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

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

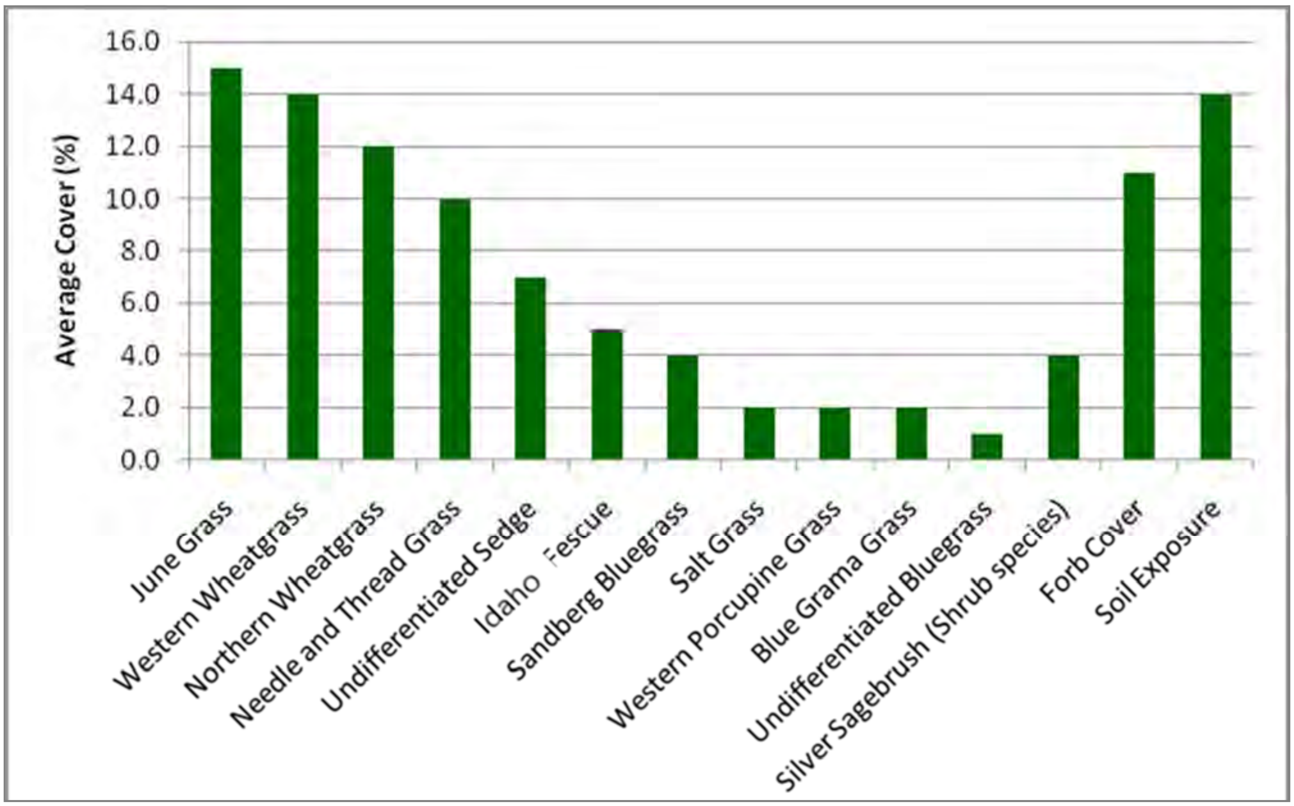
The Range Plant Community Guide for the Mixedgrass NSR lists plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11. The plant communities included in this cluster include MGB2, MGC7, and MGC2.

Table B-9 Target Recovering Plant Community for Sweetgrass and Milk River Upland: Overflow Range Sites

Species	Common Name	Seral Stage	Average % Cover	% Constancy
Nassella viridula	green needle grass	Late	11	100
Elymus lanceolatus	northern wheatgrass	Late	6	100
Pascopyrum smithii	western wheatgrass	Late	6	64
Carex species	undifferentiated sedge	Early - Mid	5	82
Festuca idahoensis	Idaho fescue	Early - Mid	4	27
Hesperostipa comata	needle-and-thread	Late	2	91
Koeleria macrantha	June grass	Early - Mid	2	73
Symphoricarpos occidentalis	buckbrush (shrub)	Early - Mid	15	100
Rosa woodsii	common wild rose (shrub)	Early - Mid	3	100
Average Total Vegetation Cover			**88**	
Average Forb Cover			**4**	
Average Moss and Lichen Cover			**2**	
Average Soil Exposure			**11**	

This cluster includes native plant communities found in areas subject to water spreading and sheet flow. Overflow sites are found on aprons, fans and draws where overland flow enhances site moisture conditions. Green needle grass, northern and western wheatgrasses are well adapted to these overflow range sites. Idaho fescue and needle-and-thread are also adapted to the fluctuations in moisture from dry to moist and back to dry. The soils and moisture conditions of these range sites increase the risk of invasion by non-native plants when the soils are disturbed. Invasive plant management (Appendix D) will be very important when restoring disturbances on Overflow range sites, including Kentucky bluegrass and Canada bluegrass.

Figure B-3 Target Recovering Plant Community for Sweetgrass and Milk River Upland: Over flow Range Sites



This information can 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 B-10 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 percent Pure Live Seed (PLS) by weight and by seed number.

Site assessment data including the pre-disturbance or adjacent plant community and associated range health are essential when fine tuning native seed mixes.

Table B-10 Example Seed Mix for Sweetgrass and Milk River Upland: Overflow Range Sites

Scientific Name	Common Name	Proportion of Seed Mix by Weight of Pure Live Seed	Proportion of Seed Mix by Number of Pure Live Seeds
Hesperostipa comata	needle-and-thread	33%	20%
Elymus lanceolatus	northern wheatgrass	24%	20%
Koeleria macrantha	June grass	2%	20%
Pascopyrum smithii	western wheatgrass	17%	10%
Poa secunda ssp. secunda	Sandberg bluegrass	2%	10%
Elymus trachycaulus ssp. subsecundus	awned wheatgrass	16%	10%
Nassella viridula	green needle grass	5%	5%
Bouteloua gracilis	blue grama	1%	5%

Example Seed Mix Notes:

- Green needle grass is an appropriate species to add to the seed mix for Overflow range sites, but not at more than 5% of the mix by seed number, due to the aggressive performance and very tall structure of the cultivars in the Mixedgrass NSR.
- Green needle grass, northern and western wheatgrass are available as native plant cultivars. The cultivars are aggressive and well adapted to overflow site conditions. They have been included to provide competition to site invasion by Kentucky bluegrass. However it is advisable to keep the percentages relatively low to avoid suppression of the other components of the seed mix.
- Needle-and-thread and blue grama are included as they are drought tolerant and well adapted to fluctuations in moisture conditions.
- June grass is common to these plant communities and adds lower structure to the stand.
- Blue grama is a warm season grass, unlike the other cool season grasses, and will add lower structure, resilience, diversity, and competition for Kentucky bluegrass.

Substitutions: Green needle grass is not a substitute for needle-and-thread or western porcupine grass. Blue grama can be substituted for June grass. If western porcupine grass or needle-and-thread are in short supply, Canada wild rye (*Elymus canadensis*) and/or Indian rice grass (*Eriocoma hymenoides*) could be added to the mix as both species provide tall structure and are decreasers, expected to disappear over time. Slender wheatgrass is a substitute for awned wheatgrass, but it can be aggressive, so keep proportions low. Idaho fescue seed sources are unreliable and are often non-native invasive sheep fescue (*Festuca ovina*).

When substitutions are needed due to seed shortages, pay attention to the characteristics and role of each species in the mix and seed size (Tables B-1 and B-2). A rule of thumb is not to vary the relative proportion of each species <u>by seed number</u> in a mix by more than 5%.

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

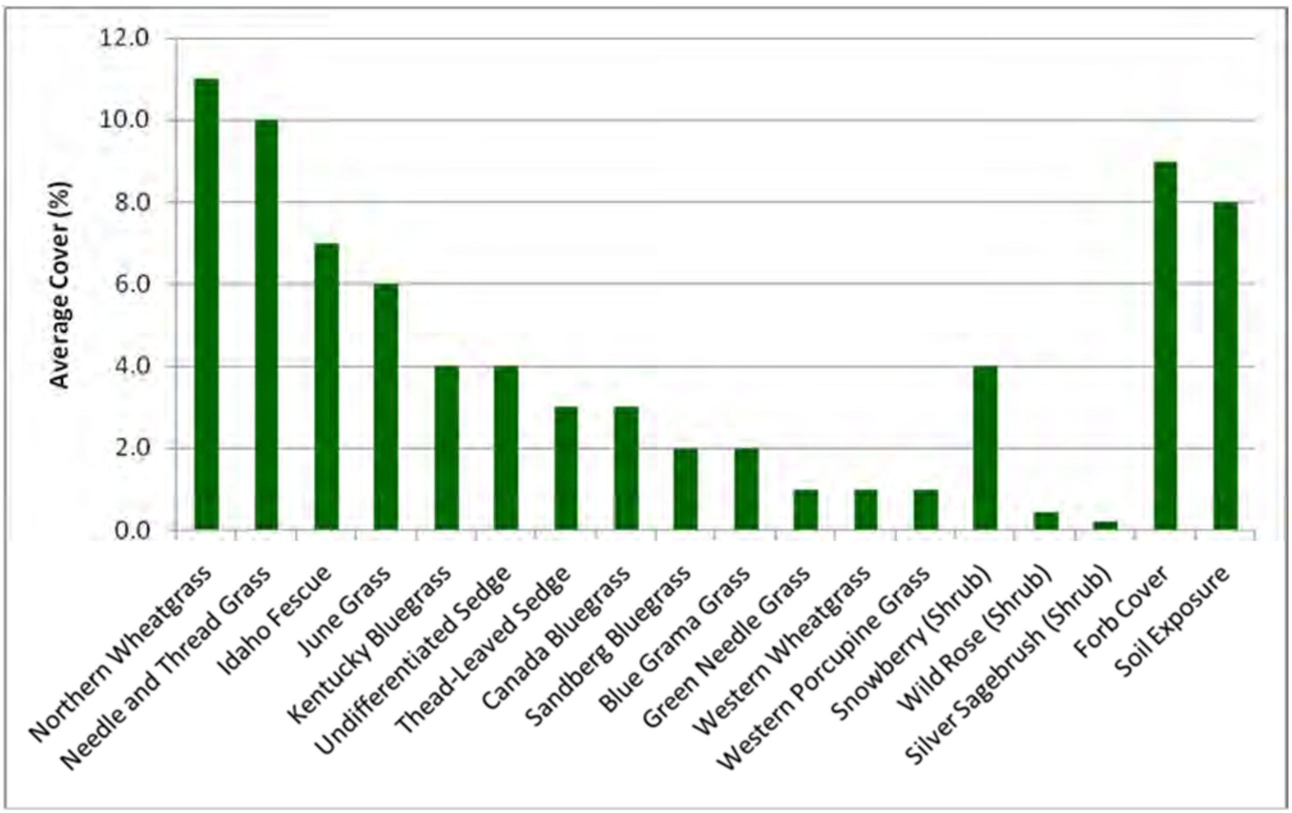
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11 (Adams et al. 2013). The plant communities included in this cluster include: MGA10, MGA11, MGA12, MGA13, MGB3, MGA20, MGC3, and MGA32.

Table B-11 Target Recovering Plant Community for Sweetgrass and Milk River Upland: Loamy and Thin Breaks Range Sites

Species	Common Name	Seral Stage	Average % Cover	% Constancy
Elymus lanceolatus	northern wheatgrass	Late	11	99
Hesperostipa comata	needle-and-thread	Late	10	82
Festuca idahoensis	Idaho fescue	Early - Mid	7	75
Koeleria macrantha	June grass	Early - Mid	6	97
Poa pratensis	Kentucky bluegrass	Early - Mid	4	46
Carex species	undifferentiated sedge	Early - Mid	4	96
Carex filifolia	thread-leaved sedge	Early - Mid	3	21
Poa compressa	Canada bluegrass	Early - Mid	3	1
Poa secunda ssp. secunda	Sandberg bluegrass	Early - Mid	2	22
Bouteloua gracilis	blue grama grass	Late	2	21
Nassella viridula	green needle grass	Late	1	44
Pascopyrum smithii	western wheatgrass	Late	1	2
Hesperostipa curtiseta	western porcupine grass	Late	1	37
Symphoricarpos occidentalis	snowberry (shrub)	Early - Mid	4	58
Rosa woodsii	Common wild rose (shrub)	Early - Mid	0.4	7
Artemisia cana	silver sagebrush (shrub)	Late	0.2	6
Average Total Vegetation Cover			**83**	
Average Forb Cover			**9**	
Average Moss and Lichen Cover			**13**	
Average Soil Exposure			**8**	

Dominant grass species in this cluster that drive the successional process include northern wheatgrass, needle-and-thread, Idaho fescue and June grass. Ecologically based invasive plant management (Appendix D) will be very important when restoring disturbances in this cluster. Kentucky bluegrass, an invasive non-native plant, is present in this cluster at an average mean cover of 4%. The plant community description for MGB2 (with Kentucky bluegrass cover ranging between 34-42%) illustrates the potential for this species to become dominant, resulting in a modified plant community.

Figure B-4 Target Recovering Plant Community for Sweetgrass and Milk River Upland: Loamy and Thin Breaks Range Sites



This information can be used to design a native seed mix based on the common dominant species in the cluster and the performance of each species in the recovery process. Table B-12 provides an example of the common dominant species recommended for inclusion in a native seed mix expressed as the portion required for each species in % Pure Live Seed by weight. An example for this cluster could include:

Table B-12 Example Seed Mix for Sweetgrass and Milk River Upland: Loamy and Thin Breaks Range Sites

Scientific Name	Common Name	Proportion of Seed Mix by Weight of Pure Live Seed	Proportion of Seed Mix by Number of Pure Live Seeds
Hesperostipa comata	needle-and-thread	39%	20%
Elymus lanceolatus	northern wheatgrass	29%	20%
Koeleria macrantha	June grass	2%	20%
Poa secunda ssp. secunda	Sandberg bluegrass	3%	15%
Bouteloua gracilis	blue grama	3%	10%
Elymus trachycaulus ssp. trachycaulus	slender wheatgrass	14%	10%
Elymus trachycaulus ssp. subsecundus	awned wheatgrass	9%	5%

Site assessment data including the pre-disturbance or adjacent plant community and associated range health are essential when fine tuning native seed mixes.

Example Seed Mix Notes:

- Slender wheatgrass and awned wheatgrass have been included to act as a nurse crops to provide initial vegetative cover on steep slopes and to provide competition to invasive non-native Kentucky bluegrass. However, it is advisable to keep the percentages relatively low to avoid suppression of the other components of the seed mix.
- Northern wheatgrass is a long-lived bunchgrass and will provide taller cover.
- June grass, Sandberg bluegrass and blue grama will provide lower structural layers and competition for this space with invasives Kentucky bluegrass and Canada bluegrass.
- Idaho fescue, also a lower structural layer and common in this community, has not been used in the mix due to the pervasive misidentification of seed for this species with seed of invasive non-native sheep fescue.
- Needle-and-thread, Sandberg bluegrass and blue grama are drought tolerant and well adapted to fluctuations in moisture conditions.
- Blue grama is a warm season grass, unlike the other cool season grasses, and will add resilience and diversity.

Substitutions: Green needle grass is not a substitute for needle-and-thread or western porcupine grass. Blue grama can be substituted for June grass. If needle-and-thread or western porcupine grass are in short supply, Canada wild rye (*Elymus canadensis*) could be added to the mix to provide initial tall structure and is expected to disappear over time. Awned wheatgrass is a substitute for slender wheatgrass. Idaho fescue seed lots should be tested by competent assessors prior to purchase by germinating and growing a sample of the seed lot to determine the accuracy of the seed identification.

When substitutions are needed due to seed shortages, pay attention to the characteristics and role of each species in the mix and seed size (Tables B-1 and B-2). A rule of thumb is not to vary the relative proportion of each species by seed number in a mix by more than 5%.

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

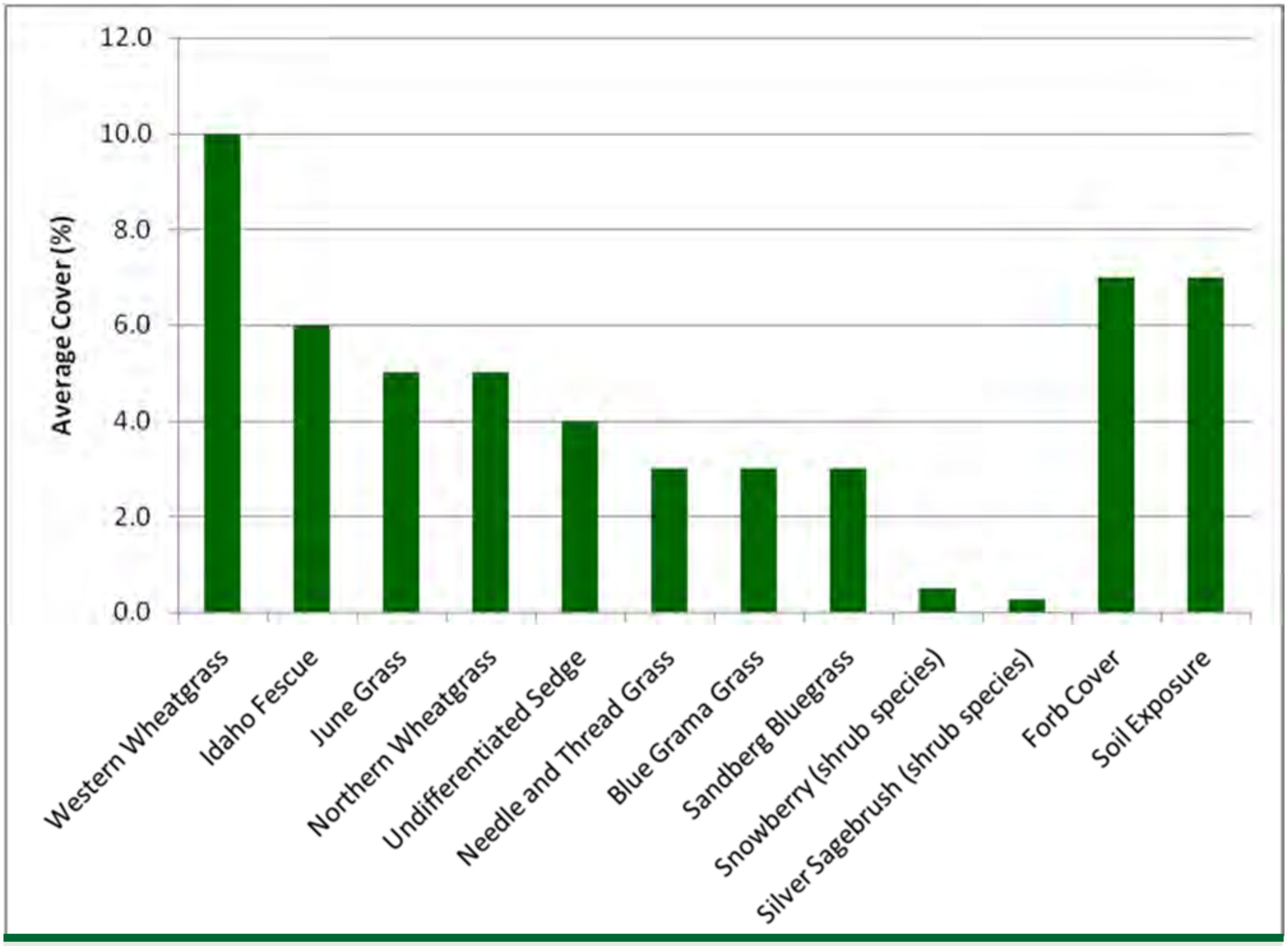
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11. The plant communities included in this cluster include: MGA33, MGA34, and MGA35.

Table B-13 Target Recovering Plant Community for Sweetgrass and Milk River Upland: Clayey and Blowout Range Sites

Species	Common Name	Seral Stage	Average % Cover	% Constancy
Pascopyrum smithii	western wheatgrass	Late	10	59
Festuca idahoensis	Idaho fescue	Early - Mid	6	59
Koeleria macrantha	June grass	Early - Mid	5	97
Elymus lanceolatus	northern wheatgrass	Late	5	68
Carex species	undifferentiated sedge	Early - Mid	4	100
Hesperostipa comata	needle-and-thread	Late	3	85
Bouteloua gracilis	blue grama	Late	3	68
Poa secunda ssp. secunda	Sandberg bluegrass	Early - Mid	3	32
Symphoricarpos occidentalis	buckbrush (shrub)	Early - Mid	0.5	18
Artemisia cana	silver sagebrush (shrub)	Late	0.3	6
Average Total Vegetation Cover			90	
Average Forb Cover			7	
Average Moss and Lichen Cover			12	
Average Soil Exposure			7	

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

Figure B-5 Target Recovering Plant Community for Sweetgrass and Milk River Upland: Clayey and Blowout Range Sites



Site assessment data including the pre-disturbance or adjacent plant community and associated range health are essential when fine tuning native seed mixes.

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

Table B-14 Example Seed Mix for Sweetgrass and Milk River Upland: Clayey and Blowout Range Sites

Scientific Name	Common Name	Proportion of Seed Mix by Weight of Pure Live Seed	Proportion of Seed Mix by Number of Pure Live Seeds
Koeleria macrantha	June grass	2%	20%
Pascopyrum smithii	western wheatgrass	32%	15%
Elymus lanceolatus	northern wheatgrass	23%	15%
Poa secunda ssp. secunda	Sandberg bluegrass	3%	15%
Bouteloua gracilis	blue grama	4%	15%
Hesperostipa comata	needle-and-thread	21%	10%
Elymus trachycaulus ssp. trachycaulus	slender wheatgrass	15%	10%

Example Seed Mix Notes:

- The rhizomatous root system of western wheatgrass is adapted to the shrink swell cycles of Clayey soils.
- Sandberg bluegrass and western wheatgrass are tolerant of salinity and drought.
- Slender wheatgrass will act as a nurse crops on these challenging soils. However, it is advisable to keep the percentages relatively low to avoid suppression of the other components of the seed mix.
- Northern wheatgrass and western wheatgrass are a long-lived and will provide taller cover.
- June grass, Sandberg bluegrass and blue grama will provide lower structural layers.
- Idaho fescue, also a lower structural layer and common in this community, has not been used in the mix due to the pervasive misidentification of seed for this species with seed of invasive non-native sheep fescue.
- Blue grama is a warm season grass, unlike the other cool season grasses, and will add resilience and diversity.

Substitutions: Green needle grass is not a substitute for needle-and-thread. Blue grama can be substituted for June grass. Idaho fescue seed lots should be tested by competent assessors prior to purchase by germinating and growing a sample of the seed lot to determine the accuracy of the seed identification.

When substitutions are needed due to seed shortages, pay attention to the characteristics and role of each species in the mix and seed size (Tables B-1 and B-2). A rule of thumb is not to vary the relative proportion of each species <u>by seed number</u> in a mix by more than 5%.

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

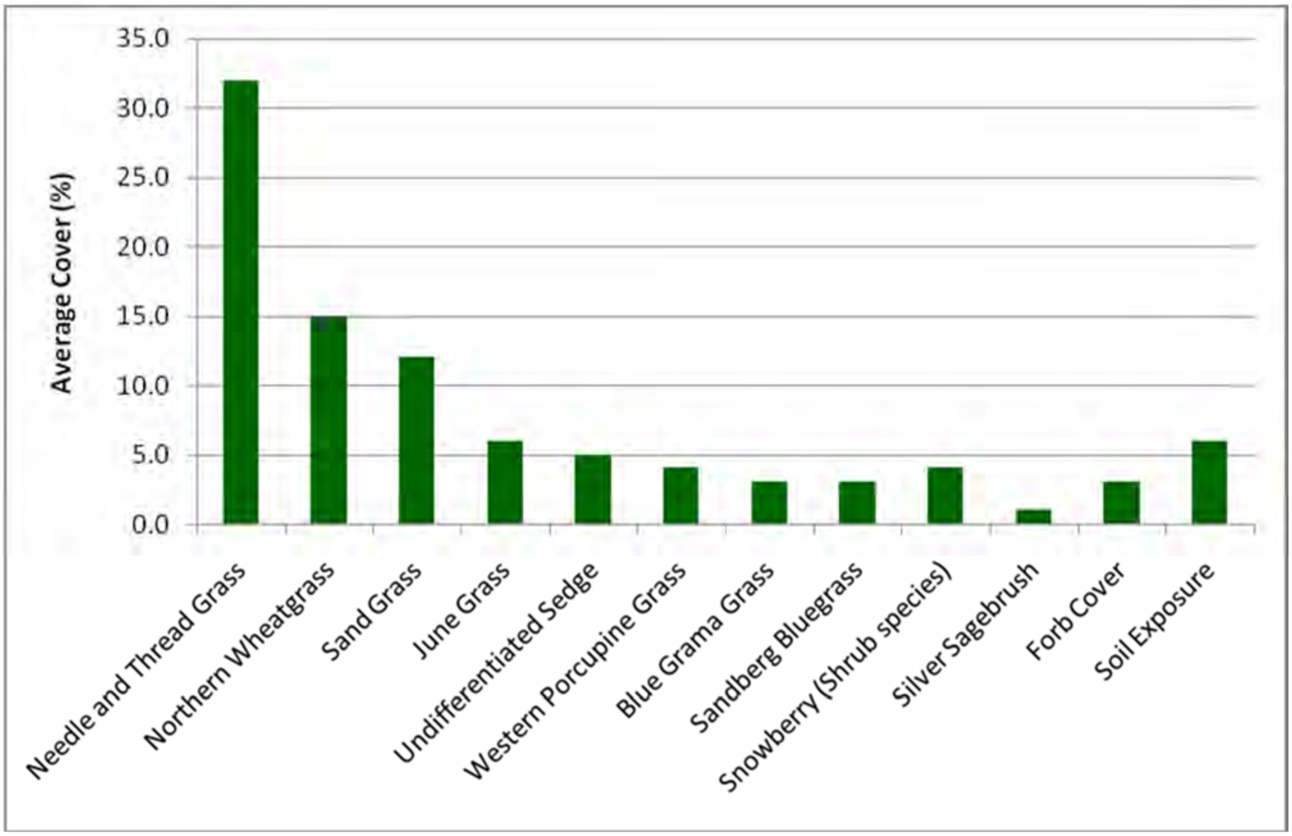
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11. The plant communities included in this cluster include: MGA16 and MGB4.

Table B-15 Target Recovering Plant Community for Sweetgrass and Milk River Upland: Sandy Range Sites

Species	Common Name	Seral Stage	Average % Cover	% Constancy
Hesperostipa comata	needle-and-thread	Late	32	
Elymus lanceolatus	northern wheatgrass	Late	15	
Sporobolus rigidus ssp. rigidus	prairie sandreed	Late	12	
Koeleria macrantha	June grass	Early - Mid	6	
Carex species	undifferentiated sedge	Early - Mid	5	
Hesperostipa curtiseta	western porcupine grass	Late	4	
Bouteloua gracilis	blue grama	Late	3	
Poa secunda ssp. secunda	Sandberg bluegrass	Early - Mid	3	
Symphoricarpos occidentalis	buckbrush (shrub)	Early - Mid	4	
Artemisia cana	silver sagebrush (shrub)	Late	1	
Average Total Vegetation Cover			**74**	
Average Forb Cover			**3**	
Average Moss and Lichen Cover			**24**	
Average Soil Exposure			**6**	

Dominant species in this cluster are needle-and-thread, northern wheatgrass and prairie sandreed. One of the communities in the analysis, MGB4, is a modified plant community dominated by smooth brome (*Bromus inermis*). If smooth brome is present in the pre-disturbance site assessment, then invasive plant management will be required (Appendix D).

Figure B-6 Target Recovering Plant Community for Sweetgrass and Milk River Upland: Sandy Range Sites



Site assessment data including the pre-disturbance or adjacent plant community and associated range health are essential when fine tuning native seed mixes.

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

Table B-16 Example Seed Mix for Sweetgrass and Milk River Upland: Sandy Range Sites

Scientific Name	Common Name	Proportion of Seed Mix by Weight of Pure Live Seed	Proportion of Seed Mix by Number of Pure Live Seeds
Hesperostipa comata	needle-and-thread	53%	30%
Eriocoma hymenoides	Indian ricegrass	13%	15%
Elymus lanceolatus	northern wheatgrass	13%	10%
Elymus trachycaulus ssp. trachycaulus	slender wheatgrass	13%	10%
Koeleria macrantha	June grass	1%	10%
Poa secunda ssp. secunda	Sandberg bluegrass	2%	10%
Bouteloua gracilis	blue grama	2%	10%
Sporobolus rigidus ssp. rigidus	prairie sandreed	4%	5%

Example Seed Mix Notes:

- The proportion of needle-and-thread is less than what is required to compensate for the variability in the performance wild harvested seed. However, seed availability is typically scarce, and once established it may increase over time through seed production. It is important to introduce the dominant late seral species to set a trajectory towards a target late seral plant community over time.
- Slender wheatgrass has been included to provide initial cover.
- Northern wheatgrass is a long-lived bunchgrass and will provide taller cover.
- June grass, Sandberg bluegrass and blue grama will provide lower structural layers.
- Needle-and-thread, Sandberg bluegrass, Indian ricegrass and blue grama are drought tolerant.
- Blue grama and prairie sandreed are warm season grasses.

Substitutions: If needle-and-thread is in short supply, Canada wild rye (*Elymus canadensis*) and/or Indian rice grass (*Eriocoma hymenoides*) could be added to the mix as both species provide tall structure and are decreasers, expected to disappear over time. Green needle grass is not a substitute for western porcupine grass or needle-and-thread. Blue grama can be substituted for June grass or Sandberg bluegrass. Prairie sandreed cultivars “Goshen” and “ND95” should be avoided as it is much taller than local populations.

When substitutions are needed due to seed shortages, pay attention to the characteristics and role of each species in the mix and seed size (Tables B-1 and B-2). A rule of thumb is not to vary the relative proportion of each species <u>by seed number</u> in a mix by more than 5%.

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

The Range Plant Community Guide for the Mixedgrass lists MGA19 salt grass – western wheatgrass - Sedge as the late seral to reference plant community for Saline Lowland range sites in the Milk River Upland Ecodistrict.

Table B-17 Target Recovering Plant Community for Sweetgrass and Milk River Upland: Saline Lowland Range Sites

Species	Common Name	Seral Stage	Average % Cover	% Constancy
Grasses and Sedges				
Distichlis spicata ssp. stricta	salt grass	Late	29	100
Pascopyrum smithii	western wheatgrass	Late	14	100
Carex species	undifferentiated sedge	Early - Mid	7	100
Hesperostipa comata	needle-and-thread	Late	6	100
Elymus lanceolatus	northern wheatgrass	Late	6	50
Poa pratensis	Kentucky bluegrass	Early - Mid	5	17
Nassella viridula	green needle grass	Late	4	50
Deschampsia cespitosa	tufted hair grass	Late	4	50
Koeleria macrantha	June grass	Early - Mid	3	100
Forbs				
Artemisia ludoviciana	prairie sage	Early - Mid	2	17
Pyrrocoma lanceolata	lance-leaved ironplant	Early - Mid	1	50
Shrubs				
Symphoricarpos occidentalis	buckbrush	Early - Mid	3	50
Average Total Vegetation Cover			76	
Average Moss and Lichen Cover			9	
Average Soil Exposure			15	

This range site and plant community is strongly influenced by discharge of groundwater and accumulation of salts, hence the dominance of salt grass and western wheatgrass. The site may show a cyclic response to variation in total annual precipitation. Vegetation canopy cover will decline and bare soil increase during dry cycles, with a very strong cover of salt grass and western wheatgrass during wet cycles. This community has a significant component of natural bare soil at about 15%.

If Kentucky bluegrass (invasive non-native plant) is identified in the pre-disturbance site assessment, ecologically based invasive plant management will be required (Appendix D).

This information can 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. salt grass and western wheatgrass are drivers in the process of succession and adapted to the cyclic moisture conditions.

Site assessment data including the pre-disturbance or adjacent plant community and associated range health are essential when fine tuning native seed mixes.

Table B-18 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 percent Pure Live Seed (PLS) by weight and by seed number.

Table B-18 Example Seed Mix for Sweetgrass and Milk River Upland: Saline Lowland Range Sites

Scientific Name	Common Name	Proportion of Seed Mix by Weight of Pure Live Seed	Proportion of Seed Mix by Number of Pure Live Seeds
Pascopyrum smithii	western wheatgrass	64%	30%
Distichlis spicata ssp. stricta	salt grass	11%	25%
Elymus lanceolatus	northern wheatgrass	22%	15%
Koeleria macrantha	June grass	1%	15%
Deschampsia cespitosa	tufted hair grass	1%	15%

Example Seed Mix Notes:

- Western wheatgrass and salt grass are drought tolerant and can tolerate salt laden soils and fluctuations in soil moisture.
- The rhizomatous root system of western wheatgrass is adapted to the shrink swell cycles of Clayey soils.
- Northern wheatgrass will provide initial cover and structure.
- Tufted hair grass and June grass will provide diversity by establishing in niche areas within the site.

Substitutions: Nuttall's salt-meadow grass can be substituted for tufted hairgrass.

When substitutions are needed due to seed shortages, pay attention to the characteristics and role of each species in the mix and seed size (Tables B-1 and B-2). A rule of thumb is not to vary the relative proportion of each species <u>by seed number</u> in a mix by more than 5%.

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

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

B.3.1 Lethbridge and Vulcan Plain Ecodistricts: Loamy Range Sites

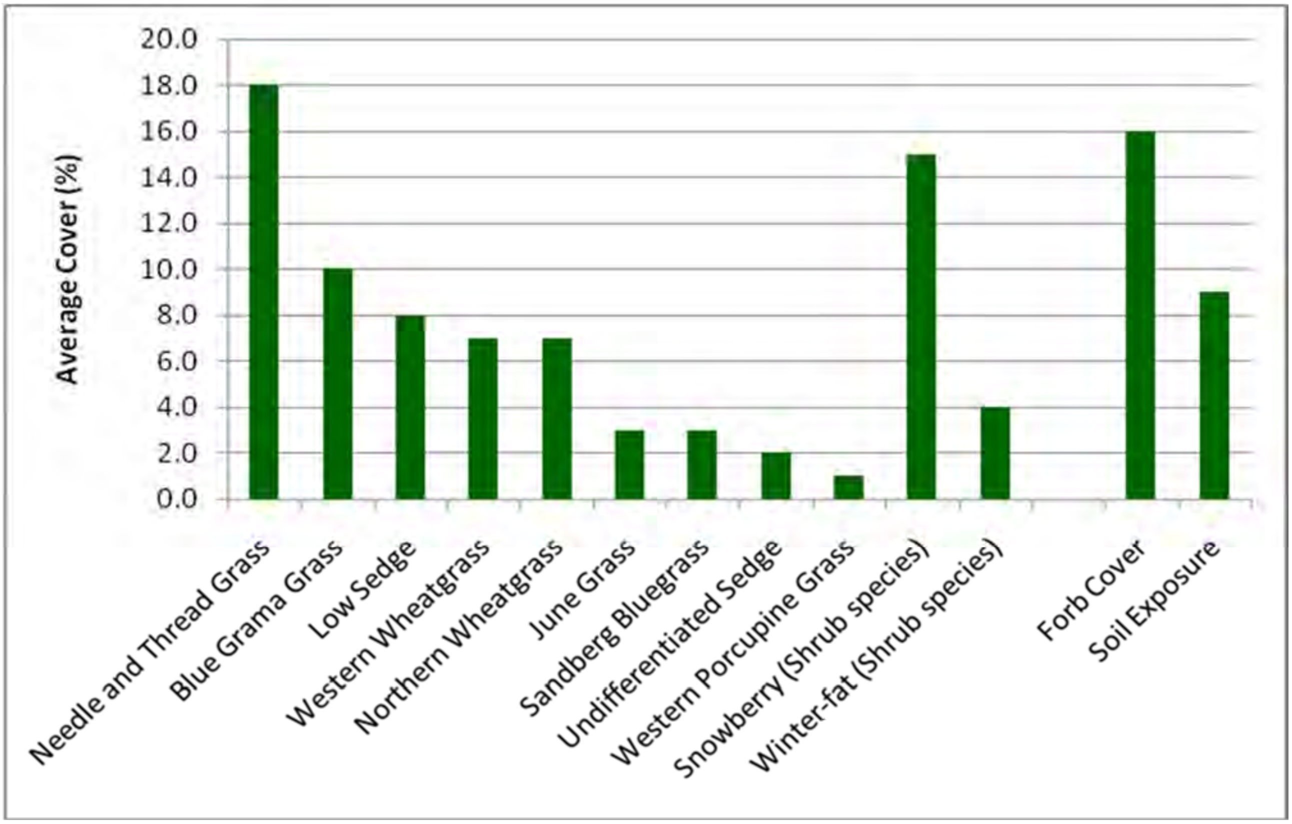
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11. The plant communities included in this cluster include: MGA21, MGA22, MGC4, MGC5, MGC6.

Table B-19 Target Recovering Plant Community for Lethbridge and Vulcan Plain: Loamy Range Sites

Species	Common Name	Seral Stage	Average % Cover	% Constancy
Hesperostipa comata	needle-and-thread	Late	18	96
Bouteloua gracilis	blue grama	Late	10	64
Carex duriuscula	low sedge	Early - Mid	8	77
Pascopyrum smithii	western wheatgrass	Late	7	22
Elymus lanceolatus	northern wheatgrass	Late	7	83
Koeleria macrantha	June grass	Early - Mid	3	42
Poa secunda ssp. secunda	Sandberg bluegrass	Early - Mid	3	25
Carex species	undifferentiated sedge	Early - Mid	2	21
Hesperostipa curtiseta	western porcupine grass	Late	1	3
Symphoricarpos occidentalis	buckbrush (shrub)	Early - Mid	15	69
Krascheninnikovia lanata	winter-fat (shrub)	Late	4	14
Average Total Vegetation Cover			**61**	
Average Forb Cover			**16**	
Average Moss and Lichen Cover			**11**	
Average Soil Exposure			**9**	

Needle-and-thread, blue grama grass, northern and western wheatgrass are important drivers in the successional process in this cluster. Buckbrush is an important shrub providing significant cover in open shrublands along the Little Bow drainage. The moist Loamy soils associated with this grouping are particularly sensitive to invasion by non-native plants like Kentucky bluegrass and Canada bluegrass. Topsoil disturbances will require invasive plant management (Appendix D).

Figure B-7 Target Recovering Plant Community for Lethbridge and Vulcan Plain: Loamy Range Sites



This information can 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 B-20 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 percent Pure Live Seed (PLS) by weight and by seed number.

Table B-20 Example Seed Mix for Lethbridge and Vulcan Plain: Loamy Range Sites

Scientific Name	Common Name	Proportion of Seed Mix by Weight of Pure Live Seed	Proportion of Seed Mix by Number of Pure Live Seeds
Bouteloua gracilis	blue grama	9%	30%
Hesperostipa comata	needle-and-thread	44%	20%
Koeleria macrantha	June grass	2%	15%
Elymus lanceolatus	northern wheatgrass	16%	10%
Elymus trachycaulus ssp. trachycaulus	slender wheatgrass	16%	10%
Poa secunda ssp. secunda	Sandberg bluegrass	2%	10%
Pascopyrum smithii	western wheatgrass	11%	5%

Ecologically based invasive plant management (Appendix D) will be required if invasive plants are detected in the pre-disturbance site assessment. The moist loamy soils provide the nutrient and moisture conditions suited to non-native plant invasion of disturbed soils.

Example Seed Mix Notes:

- Needle-and-thread can be seeded at greater than the target cover values to compensate for the variability in the performance wild harvested seed. However, if it forms a large percentage of the mix and fails, it can leave sites with insufficient cover. Needle-and-thread seed seed availability is typically scarce, and once established it may increase over time through seed production. It is important to introduce the dominant late seral species to set a trajectory towards a target late seral plant community over time.
- Slender, northern and western wheatgrasses are available as native plant cultivars. They can be quite competitive and should be seeded at low application rates.
- Slender wheatgrass is included to provide initial cover and competition to invasive plants and is expected to disappear from the stand in approximately five years.
- June grass and Sandberg bluegrass are early successional species in this mix and will provide lower structure in the stand.
- Blue grama is a warm season grass that is tolerant of grazing.

Substitutions: Green needle grass is not a substitute for needle-and-thread or western porcupine grass. If needle-and-thread or western porcupine grass are in short supply, Canada wild rye (*Elymus canadensis*) could be added to the mix to provide initial tall structure and is expected to disappear over time. June grass can be substituted for Sandberg bluegrass.

When substitutions are needed due to seed shortages, pay attention to the characteristics and role of each species in the mix and seed size (Tables B-1 and B-2). A rule of thumb is not to vary the relative proportion of each species <u>by seed number</u> in a mix by more than 5%.

B.3.2 Lethbridge and Vulcan Plain Ecodistricts: Sandy and Sands Range Sites

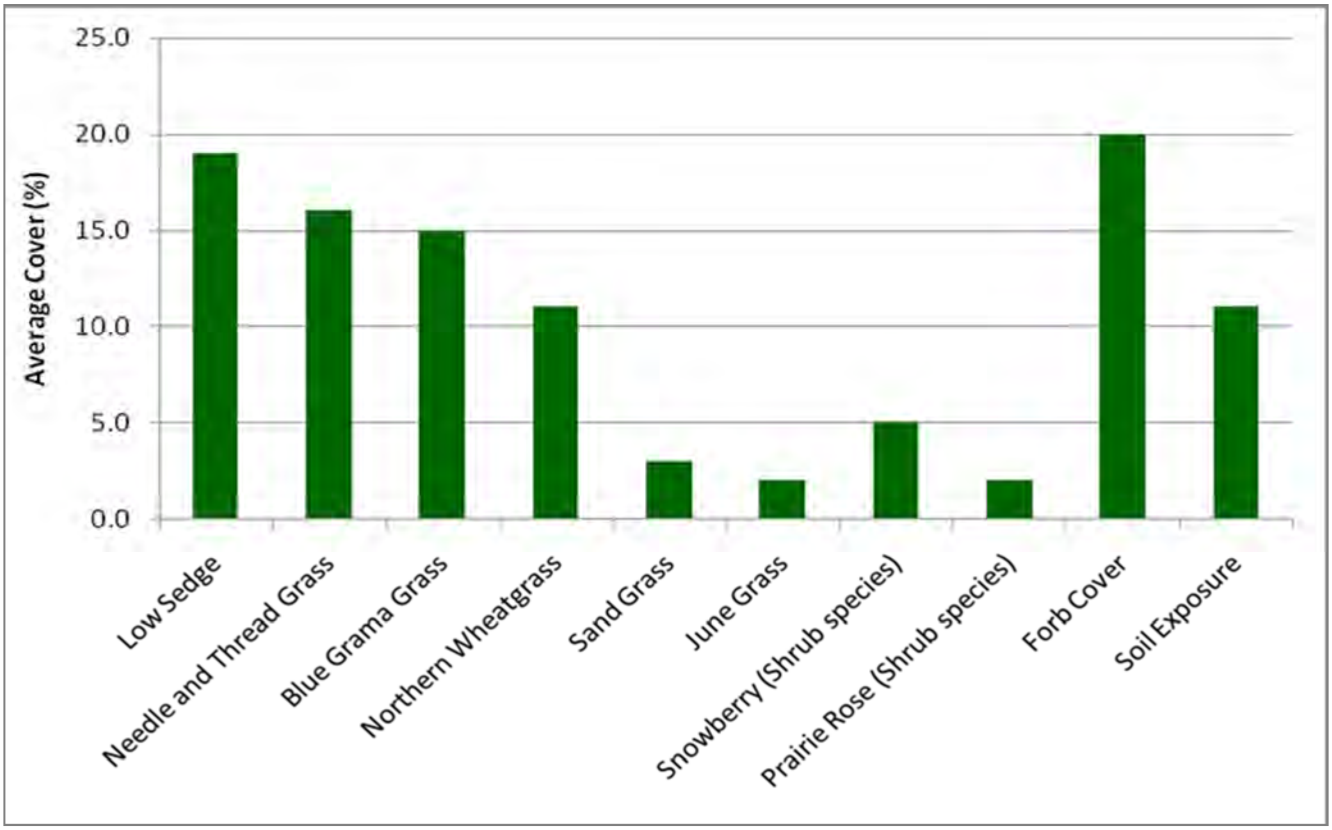
The Range Plant Community Guide for the Mixedgrass lists the plant communities by ecological range site for the Sweetgrass and Milk River Upland Ecodistricts in Table 11. The plant communities included in this cluster include: MGA21, MGA22, MGC4, MGC5, MGC6.

Table B-21 Target Recovering Plant Community for Lethbridge and Vulcan Plain: Sandy and Sands Range Sites

Species	Common Name	Seral Stage	Average % Cover	% Constancy
Carex duriuscula	low sedge	Early - Mid	19	100
Hesperostipa comata	needle-and-thread	Late	16	100
Bouteloua gracilis	blue grama	Late	15	90
Elymus lanceolatus	northern wheatgrass	Late	11	98
Sporobolus rigidus ssp. rigidus	prairie sandreed	Late	3	4
Koeleria macrantha	June grass	Early - Mid	2	65
Symphoricarpos occidentalis	buckbrush (shrub)	Early - Mid	5	56
Rosa arkansana	prairie rose (shrub)	Early - Mid	2	34
Average Total Vegetation Cover			**62**	
Average Forb Cover			**20**	
Average Moss and Lichen Cover			**3**	
Average Soil Exposure			**11**	

Low sedge is a significant species in the process of succession in this cluster. needle-and-thread, blue grama and northern wheatgrass are also prominent. The shrub component is also important with snowberry occurring at an average of 56% constancy. The forb component is also significant at an average of 20% and includes pasture sagewort (*Artemisia frigida*), prairie sagewort (*Artemisia ludoviciana*) and common yarrow (*Achillea millefolium*). If non-native invasive plants are detected in the pre-disturbance site assessment, ecologically based invasive plant management will be required (Appendix D).

Figure B-8 Target Recovering Plant Community for Lethbridge and Vulcan Plain:



This information can 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 B-22 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 percent Pure Live Seed (PLS) by weight and by seed number.

Site assessment data including the pre-disturbance or adjacent plant community and associated range health are essential when fine tuning native seed mixes.

Table B-22 Example Seed Mix for Lethbridge and Vulcan Plain: Sandy and Sands Range Sites

Scientific Name	Common Name	Proportion of Seed Mix by Weight of Pure Live Seed	Proportion of Seed Mix by Number of Pure Live Seeds
Bouteloua gracilis	blue grama	9%	30%
Hesperostipa comata	needle-and-thread	41%	20%
Eriocoma hymenoides	Indian ricegrass	15%	15%
Elymus lanceolatus	northern wheatgrass	15%	10%
Elymus trachycaulus ssp. trachycaulus	slender wheatgrass	15%	10%
Koeleria macrantha	June grass	1%	10%
Sporobolus rigidus ssp. rigidus	prairie sandreed	4%	5%

Example Seed Mix Notes:

- Needle-and-thread can be seeded at greater than the target cover values to compensate for the variability in the performance wild harvested seed. However, if it forms a large percentage of the mix and fails, it can leave sites with insufficient cover. Needle-and-thread seed availability is typically scarce, and once established it may increase over time through seed production. It is important to introduce the dominant late seral species to set a trajectory towards a target late seral plant community over time.
- Northern wheatgrass is a long-lived bunchgrass and will provide taller cover.
- June grass, Sandberg bluegrass and blue grama will provide lower structural layers.
- Needle-and-thread, Sandberg bluegrass, Indian ricegrass and blue grama are drought tolerant.
- Blue grama and prairie sandreed are warm season grasses.

Substitutions: If needle-and-thread is in short supply, Canada wild rye (*Elymus canadensis*) and/or Indian rice grass (*Eriocoma hymenoides*) could be added to the mix as both species provide tall structure and are decreasers, expected to disappear over time. Green needle grass is not a substitute for western porcupine grass or needle-and-thread. Blue grama can be substituted for June grass or Sandberg bluegrass. Prairie sandreed cultivars “Goshen” and “ND95” should be avoided as it is much taller than local populations.

When substitutions are needed due to seed shortages, pay attention to the characteristics and role of each species in the mix and seed size (Tables B-1 and B-2). A rule of thumb is not to vary the relative proportion of each species <u>by seed number</u> in a mix by more than 5%.

B.3.3 Lethbridge and Vulcan Plain Ecodistricts: Saline Lowlands Range Sites

The Range Plant Community Guide for the Mixedgrass lists MGA29 salt grass – foxtail Barley - western wheatgrass as the late seral to reference plant community for Saline Lowland range sites in the Lethbridge and Vulcan Plain Ecodistricts.

Table B-23 Target Recovering Plant Community for Lethbridge and Vulcan Plain: Saline Lowlands Range Sites

Species	Common Name	Seral Stage	Average % Cover	% Constancy
Grasses and Sedges				
Distichlis spicata ssp. stricta	salt grass	Late	34	100
Hordeum jubatum	foxtail barley	Early - Mid	11	90
Poa palustris	fowl bluegrass	Early - Mid	5	50
Pascopyrum smithii	western wheatgrass	Late	5	70
Carex praegracilis	graceful sedge	Early - Mid	3	30
Carex duriuscula	low sedge	Early - Mid	3	30
Juncus balticus	wire rush	Early - Mid	2	50
Poa arida	plains bluegrass	Early - Mid	2	40
Forbs				
Solidago Canadensis	Canada goldenrod	Early - Mid	4	30
Lepidium densiflorum	common pepper-grass	Early - Mid	3	60
Achillea millefolium	common yarrow	Early - Mid	2	60
Average Total Vegetation Cover			**59**	
Average Forb Cover			**1**	
Average Moss and Lichen Cover			**>1**	
Average Soil Exposure			**20**	

This range site and plant community is strongly influenced by discharge of groundwater and accumulation of salts, hence the dominance of salt grass and western wheatgrass. The site may show a cyclic response to variation in total annual precipitation, vegetation canopy cover will decline and bare soil increase during dry cycles, with a very strong cover of salt grass and western wheatgrass during wet cycles.

This community has a significant component of natural bare soil at about 20%.

Foxtail barley can withstand soil disturbance and can dominate the site, limiting infill and species diversity and slowing the process of succession.

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

Table B-24 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 percent Pure Live Seed (PLS) by weight and by seed number.

Site assessment data including the pre-disturbance or adjacent plant community and associated range health are essential when fine tuning native seed mixes.

Table B-24 Example Seed Mix for Lethbridge and Vulcan Plain: Saline Lowlands Range Sites

Scientific Name	Common Name	Proportion of Seed Mix by Weight of Pure Live Seed	Proportion of Seed Mix by Number of Pure Live Seeds
Distichlis spicata ssp. stricta	salt grass	19%	40%
Elymus trachycaulus ssp. trachycaulus	slender wheatgrass	32%	20%
Pascopyrum smithii	western wheatgrass	47%	20%
Poa palustris	fowl bluegrass	2%	20%

Example Seed Mix Notes:

- Western wheatgrass, fowl bluegrass and salt grass are drought tolerant and can tolerate salt laden soils and fluctuations in soil moisture.
- Slender wheatgrass is salt tolerant, will provide initial cover, competition to invasive plants and is expected to disappear from the stand in approximately five years, creating space for infill from the adjacent native plant community.

Substitutions: On wetter sites, Nuttall's salt-meadow grass can be substituted for salt grass. Alkali bluegrass can be substituted for fowl bluegrass.

When substitutions are needed due to seed shortages, pay attention to the characteristics and role of each species in the mix and seed size (Tables B-1 and B-2). A rule of thumb is not to vary the relative proportion of each species <u>by seed number</u> in a mix by more than 5%.

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

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

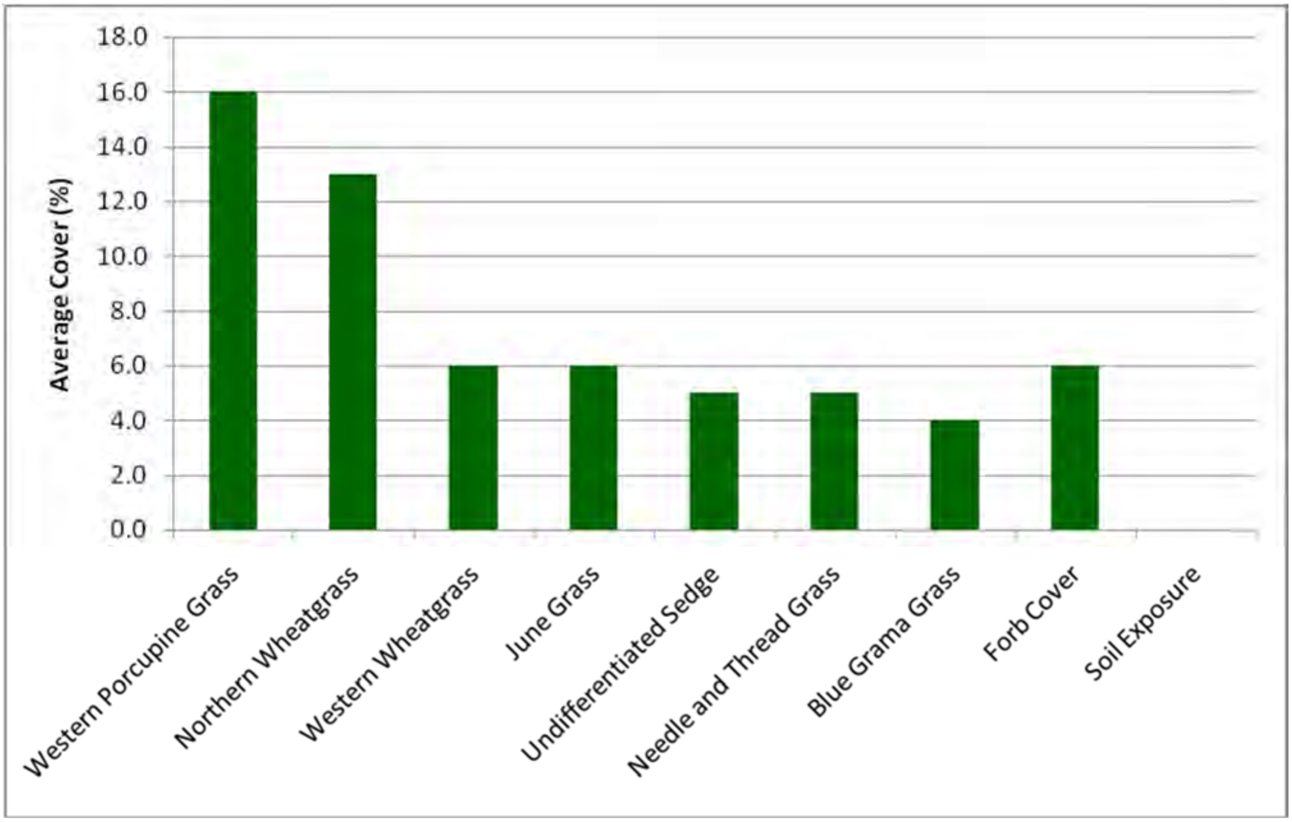
B.4.1 Majorville Upland Ecodistrict: Loamy Range Sites

Table B-25 Target Recovering Plant Community for Majorville Upland: Loamy Range Sites

Species	Common Name	Seral Stage	Average % Cover	% Constancy
Hesperostipa curtiseta	western porcupine grass	Late	16	100
Elymus lanceolatus	northern wheatgrass	Late	13	100
Pascopyrum smithii	western wheatgrass	Late	6	100
Koeleria macrantha	June grass	Early - Mid	6	100
Carex species	undifferentiated sedge	Early - Mid	5	100
Hesperostipa comata	needle-and-thread	Late	5	100
Bouteloua gracilis	blue grama	Late	4	100
Average Total Vegetation Cover			**96**	
Average Forb Cover			**6**	
Average Moss and Lichen Cover			**11**	
Average Soil Exposure			**0**	

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

Figure B-9 Target Recovering Plant Community for Majorville Upland: Loamy Range Sites



This information can 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 B-26 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 percent Pure Live Seed (PLS) by weight and by seed number.

Site assessment data including the pre-disturbance or adjacent plant community and associated range health are essential when fine tuning native seed mixes.

Table B-26 Example Seed Mix for Majorville Upland: Loamy Range Sites

Scientific Name	Common Name	Proportion of Seed Mix by Weight of Pure Live Seed	Proportion of Seed Mix by Number of Pure Live Seeds
Hesperostipa curtiseta	western porcupine grass	51%	30%
Hesperostipa comata	needle-and-thread	14%	10%
Elymus lanceolatus	northern wheatgrass	15%	15%
Elymus trachycaulus ssp. trachycaulus	slender wheatgrass	10%	10%
Pascopyrum smithii	western wheatgrass	7%	5%
Bouteloua gracilis	blue grama	2%	10%
Koeleria macrantha	June grass	1%	20%

Example Seed Mix Notes:

- The proportion of the western porcupine grass and needle-and-thread have been increased to compensate for the variability in viability of wild harvested seed.
- Slender wheatgrass is included to provide initial cover and competition to invasive plants and is expected to disappear from the stand in approximately five years.
- Slender, northern and western wheatgrasses are available as native plant cultivars. They can be quite competitive and should be seeded at low application rates.
- Northern and western wheatgrass will add tall structure and mitigate risk if the wild-harvested seed mix components do not establish as planned.
- June grass and blue grama will provide mid-height structure in the stand.
- Blue grama is a warm season grass, unlike the other cool season grasses, and will add diversity and resilience.

Substitutions: Green needle grass is not a substitute for western porcupine grass or needle-and-thread. Awned wheatgrass is a substitute for slender wheatgrass. Blue grama can be substituted for June grass.

When substitutions are needed due to seed shortages, pay attention to the characteristics and role of each species in the mix and seed size (Tables B-1 and B-2). A rule of thumb is not to vary the relative proportion of each species by seed number in a mix by more than 5%.

Appendix C Ecologically Based Invasive Plant Management (EBIPM)

Ecologically Based Invasive Plant Management (EBIPM) is an approach to rangeland invasive plant management which applies scientific principles and management experiences in a step-by-step plan (Figure C-1) (Rangelands SRM 2012).

Figure C-1 Step by Step Process of Ecologically Based Invasive Plant Management (EBIPM)

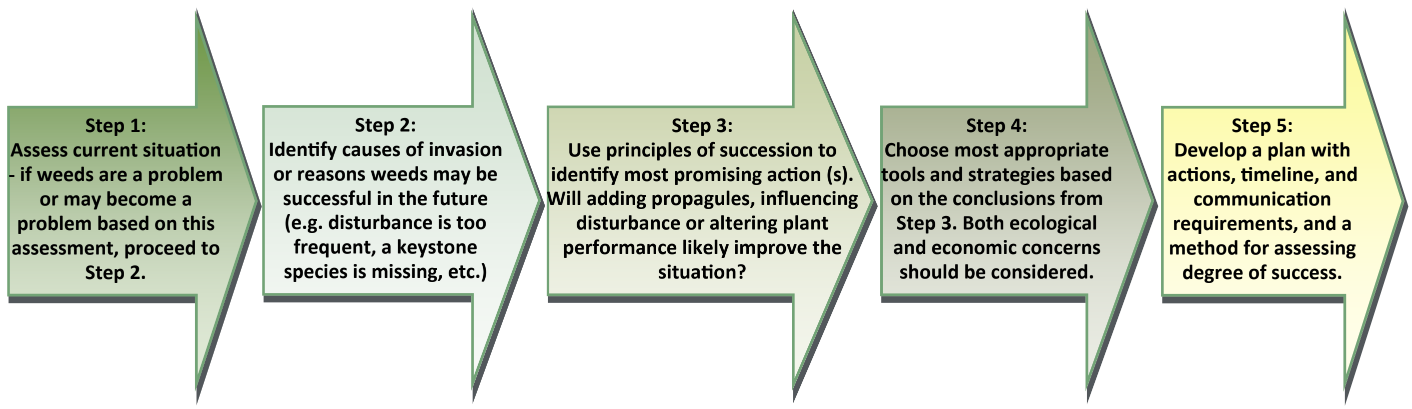


Image source: Svejcar and Boyd 2012

Prior to applying EBIPM, it is important to understand the history of the area, especially locating and evaluating historical cultivation. Cultivation has been practiced in southern Alberta since the 1880s. Long-term effects of cultivation include soil compaction, reduced native seedbanks, and changes in soil nutrients and fertility, all potential causes of invasive plant succession. Knowing if an area has been cultivated will help identify causes of plant community change and which ecological processes are in need of repair.

Step 1: Assess the Current Situation

Alberta Invasive Species Council (AISC) is an important source of information regarding new weeds of concern and methods of control. **Alberta Native Plant Council** (ANPC) also maintains a list of non-native plants, "Alberta Exotic Plants Wiki. The **Association of Agricultural Fieldmen** will identify the person responsible for the project area. Incorporating their local knowledge of weeds of concern and effective methods of control is very useful in vegetation management planning. The **United States Department of Agriculture** (USDA) **Agricultural Research Service** has conducted considerable research in the field of vegetation management. A 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.

The Noxious Weeds section of the *Rangeland Health Assessment* (Adams et al. 2016) is a useful tool for assessing noxious weeds and invasive plants. The Density Distribution Guide for Rating Noxious Weed infestations found in the field workbook will assist in describing the extent and scoring the severity of invasion as a start to planning the management process.

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

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

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

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

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

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

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

- Most invasive plants require more fertile or moist soil characteristics than native grasses. For example, smooth brome will thrive close to riparian areas.
- Special attention must be paid to areas that might promote growth of invasive plants while waiting for ideal native species germination conditions, i.e.: soil disturbance exposes buried seeds.

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

When invasive plant performance is controlled through herbicides, biological control, mowing, or other methods, niches are opened in the plant community allowing for native plant infill or for further weed invasion. Refer to *Section 4.2 - Understanding the Process of Succession* for more information on succession processes. Use Figure 4-1 and Table 4-1 to determine the current stage of the invasive plant community.

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

The use of a particular management tool for control of invasive plants often depends on the functional traits and life cycle of the target invasive plant or plants, as well as the functional traits and life cycle of the desirable plants within the community. Treatments are site-specific and typically involve more than one management approach. Potential management approaches include the following.

Livestock grazing can be one of the most useful approaches to keep rangelands in good condition and maintain optimum production. Livestock can remove excessive litter, recycle nutrients, stimulate tillering of perennial grasses, and reduce seedbanks of competitive annual plants.

- **Targeted grazing** uses livestock timing, frequency, intensity, and selectivity to apply herbivory pressure on target plant species or portions of the landscape to reach specific vegetation objectives. It can be a useful tool to manipulate plant cover in both mature plant communities and in areas recovering from disturbance. Although a simple concept, it is more complex in practice and relies on an understanding of several different interacting factors, including the interactions between plants and herbivores. The 2022 report *Targeted Grazing: Plant and Animal Interactions* by Michalsky et al., delves into the details of plant-herbivore interactions, and the various considerations that should be considered when developing a targeted grazing prescription in western Canada. It is available on the Grassland Restoration Forum website.
- **Applying herbicides** is a common strategy to control invasive species, especially for perennial weeds, and may require repeated application over a long-term control time. Biennial weed species are best controlled before flowering of mature plants and also again in the fall to control rosettes of new growth (summer and fall spraying in 1 year). Repeated application over a season and over several years may be required. Alberta Agriculture and Irrigation provides information on all registered herbicides (Alberta Agriculture and Rural Development 2021).
- **Mowing** is effective for annual species, if done prior to seed setting. If infestations are low, hand pulling of tap rooted species or spot herbicide applications may be effective.
- **Controlled burns** are a possibility for willow encroachment and weed invasions. However, they require municipality or provincial approval.
- Some native species can persist and compete with invasive species (Table 8.1). Increasing seeding rate of competitive native species may help but be careful of the seed rate of species that compete with other native species.

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

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

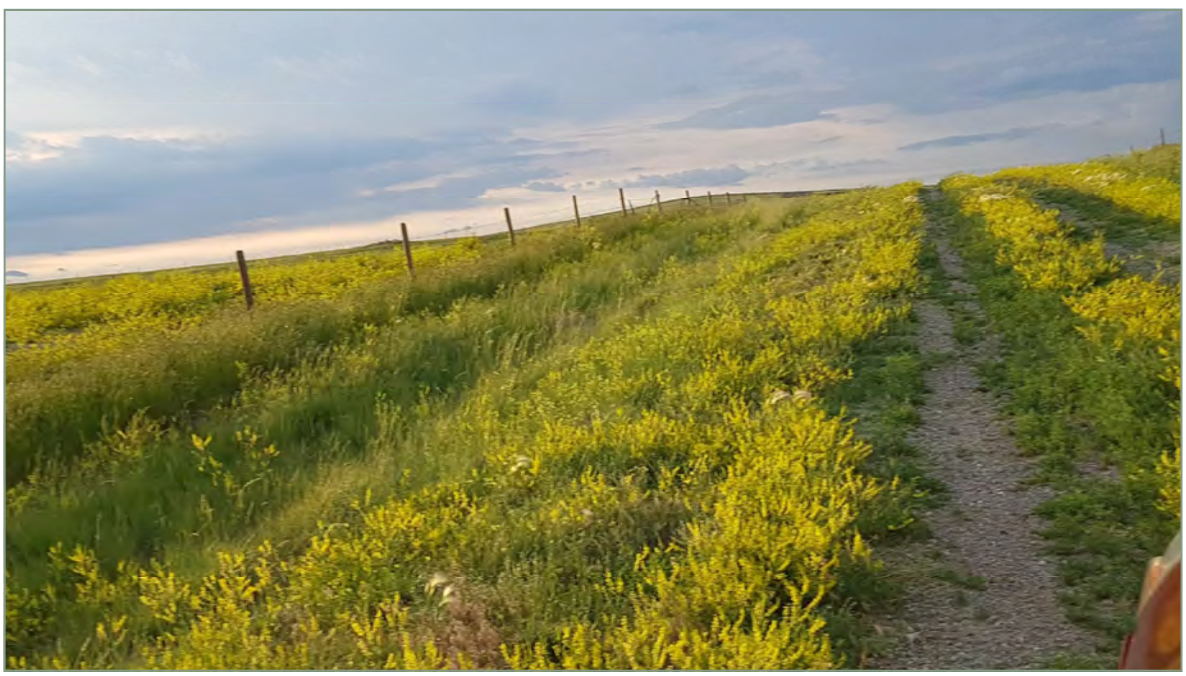
- Set measurable goals and objectives with the information obtained in Steps 1 to 4.
- Collect information on the proposed site and treatments on sites with similar climate, soils, and potential plant community to allow treatment alternatives design.
- Develop the adaptive management plan, defining the scale of the treatments, replication of sampling, study plot sizes, proper location of control areas, and protocols for data collection.
- Seek stakeholder input and incorporate stakeholder concerns.
- Adjust the plan to incorporate stakeholder comments. Widespread support for a management plan is key to its success.
- Implement the management plan, including a long-term perspective. The plan should be conducted for several years to be successful.
- Collect and analyse monitoring data, rigorously on a regular basis for several years.
- Draw conclusions. For instance, for a reclaimed wellsite, If vegetation passes the 2010 *Reclamation Criteria* (Alberta Environment and Parks 2013) apply for a Reclamation Certificate. If not, update the plan.

These steps should be repeated with each cycle, ultimately improving management, until the reclamation criteria are fulfilled.

Appendix D Monitoring Methods to Inform Adaptive Management

The purpose of monitoring is two-fold. In the first few years after disturbance, monitoring is a component of an adaptive management approach to maintaining a site to ensure that erosion, invasive species or grazing concerns do not inhibit revegetation by desirable species. In the long-term, monitoring is required to demonstrate a positive trajectory towards plant communities present prior to disturbance or towards a target native plant community.

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



Invasion of Yellow Sweetclover (Melilotus officinalis) onto Surface Disturbance

Reclaimed sites that are not monitored or managed can quickly deteriorate, resulting in costly mitigation or loss of restoration potential.

D.1 Set Measurable Goals and Objectives

The goal for restoration of native rangelands is to re-establish mature native plant communities on a disturbance that are suited to the ecological range site and equivalent in composition, structure and successional stage to the surrounding native grassland. The process of recovery evolves over time through initial establishment and through several successional stages as ecosystem processes re-develop, and species composition and structure matures (Kestrel Research Inc. and Gramineae Services Ltd. 2011).

The following sources provide information on site conditions, such as climate, soils, and the potential plant community to help establish restoration targets, methods and potential timeframes:

- The *2010 Reclamation Criteria for Wellsites and Associated Facilities for Native Grassland* (AEP 2013a) provide established methods that can be used as a baseline for monitoring and targets for defining successful recovery.
- Set goals for Range Health, referring to Adams et al. (2016).
- Refer to the relevant Range Plant Community Guides to determine what the potential plant communities might be.
- Alberta climate information is available on the Alberta Climate Information Service (ACIS) website, providing historical Alberta Climate Maps and Alberta Weather Station Data and Graphs (ACIS 2023). ACIS models climate information by extrapolating from multiple weather stations. Weather stations in the project site vicinity are easily found. Tracking precipitation and temperature for the duration of monitoring will provide important information about potential and actual recovery success.

The timeframe for recovery will vary depending on the size of the disturbance, recovery strategy used and site-specific conditions of the ecological range site where disturbance has occurred (climate, presence of invasive species, grazing pressure and range health). For example, if the surrounding area has a low range health score, the proposed site is located on a Blowout range site or has a slow-growing species such as silver sagebrush, recovery may be slow. Patience is required to allow natural successional processes to take place.

D.2 Establish a Monitoring and Adaptive Management Plan

Develop a Monitoring Plan

Key to the reclamation criteria is establishing permanent monitoring sites that compare the recovering disturbed site with adjacent undisturbed control sites. Information collected over time from these sites can be used to adjust treatments, as required. Planning steps include:

- Define replication of sampling, study plot sizes, proper location of control areas, and protocols for data collection.
- Establish the survey locations on lease and access and corresponding control points early in the establishment phase to assist the process of reclamation certification. Establish permanent photo reference points to capture the progress of restoration over time.

- Establish survey locations on pipelines to monitor the progress of restoration over time. Ensure that monitoring will include the diversity of different recovery strategies used for soil disturbances.
- Establish the frequency of monitoring events to allow timely and effective adaptive management and to track the process of succession towards the Target Recovering Plant Community over time.

Seek Stakeholder Input and Incorporate Stakeholder Concerns

Incorporating the experience and concerns of stakeholders is important to establishing a viable, cost effective and useful adaptive management and monitoring plan.

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

Time Frames for Assessing Recovery

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

General Monitoring Guidelines

General monitoring guidelines are described in Alberta Environmental Protection's *Principles for Minimizing Surface Disturbance in Native Grasslands - Principles, Guidelines and Tools for all Industrial Activity in Native Grasslands in Prairie and Parkland Landscapes of Alberta* (AEP 2016a) for all proposed disturbances.

- For wellsites, the *2010 Reclamation Criteria for Wellsites and Associated Facilities for Native Grassland 2013* (AEP 2013a) describe how to partition the disturbance for assessment, based on the disturbance size.
- Site visits should be targeted to efficiently gather the information needed to support an adaptive management plan. For example, the number of site visits during the first two growing seasons may depend on the invasive non-native plant risk factor.
- Completing Rangeland Health Assessments at the established off-site controls and on-site monitoring sites, using the standardized methods developed by Government of Alberta, can determine if the disturbed site is on a positive successional trajectory.

D.3 Monitoring and Adaptive Management Years 1-3

In the first few years after disturbance, monitoring is a component of an adaptive management approach to maintaining a site to ensure that erosion, invasive species, grazing concerns or other issues do not inhibit revegetation by desirable species.

Monitoring in Years 1-3

Vegetation establishment on disturbed topsoil should be monitored for seedling composition, rather than determining percent foliar cover of each species, for the first few years after disturbance when seedlings are small.

- Observations are typically collected for 10 to 15, quarter-square-metre subplots (known as "frames") and averaged. More subplots are recommended for sites with greater variability. For smaller topsoil disturbances such as a construction pad or well site, frames are placed randomly or along a transect. For a linear disturbance, such as a pipeline or transmission trench, set out 30-metre transects and place quarter-square-metre subplots every 2 to 3 m. Count the young plants for each species in each subplot and determine an average for the count. Compare the species composition on site to the seed mix. Low counts may require re-seeding (Hecker and Neufeld 2006). However, large areas of bare ground around and under seedlings is normal in the first three years and will potentially infill of native species from surrounding undisturbed areas.
- Conduct Range Health Assessments using the current manual (Adams et al. 2016, or more recent) within the first three growing seasons to identify possible problems on the disturbance that require remedial reclamation such as weed or non-native species issues (see EBIPM Section), soil issues or erosion issues.

Adaptive Management in Years 1-3

Early and regular monitoring provides information to assess and if necessary change management practices to mitigate any potential problems at the earliest opportunity. Particularly for invasive species, the best time to remove them is when they are few in number. Following are some beneficial adaptive management considerations early in the restoration process:

- Fencing to prevent grazing by livestock or wildlife can be useful in the first 2 to 3 (4) years to allow plant germination and establishment (see section 7.2 Grazing Management).
- A flush of annual weeds and native forb species during the first couple of growing seasons following soil disturbance is normal. These species provide microclimate niches for small grasses, such as June grass, which may be sheltered by annual weeds until they become established. Spraying these so-called weedy species and re-seeding the site may promote aggressive colonizers and reduce the potential for native species infill. If infestations of annual weeds are heavy, mowing before seed set can be used to reduce competition while retaining the erosion mitigation they provide.
- Prohibited Noxious and Noxious weeds must be removed, by hand-picking, herbicide application or other methods (see EBIPM in Appendix C).
- The longer the problems are allowed to go unattended the more difficult and costly it will be to achieve successful restoration.

D.4 Monitoring and Adaptive Management Years 3-5+

Regular monitoring as plant communities develop from early to more mature seral stages (see Table 4-1) provides the information to assess whether a positive trajectory towards restoration is occurring. More mature seral stages have greater range health and greater ability to perform ecological functions including: net primary production, maintenance of soil/site stability, capture and beneficial release of water, energy and nutrient cycling, and plant species functional diversity (Adams et al. 2013). Monitoring will provide the information to assess whether changes in management practices or invasive species control is required.

Monitoring after Year 3

As vegetation becomes established (years three and later on disturbed topsoil) estimating the foliar cover that each species contributes to the plant community and estimating the amount of bare soil becomes important as the recovering plant community matures.

- Document the recovering plant community using the methods described in the *Range Survey Manual for Alberta Rangelands* (AEP 2021).
- Conduct Range Health Assessments using the current manual (Adams et al. 2016, or more recent) to document redevelopment of ecological functions and identify possible problems on the disturbance that require remedial reclamation such as weed or non-native species issues (see EBIPM Section), soils or erosion issues.

Adaptive Management after Year 3

Common adaptive management considerations after year three to promote recovery are:

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

Draw Conclusions and Update the Plan

These steps should be repeated with each cycle, ultimately improving management, until a positive trajectory towards restoration is demonstrated.

- If vegetation passes the principles and benchmarks of the *2010 Reclamation Criteria for Wellsites and Associated Facilities for Native Grasslands* (AEP 2013a), the site is considered to be on a sustainable trajectory towards a mature native grassland plant community compatible with the surrounding area. These benchmarks are suitable for any disturbance on native grasslands but have been best identified for the oil and gas industry for wellsites in grasslands. If vegetation cover and composition do not meet these benchmarks, update the plan.
- Document the monitoring and maintenance program. Share successes and failures with colleagues through organizations such as the Canadian Land Reclamation Association and the Grassland Restoration Forum.

The *2010 Reclamation Criteria – Native Grasslands* (AEP 2013a) 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.

Grassland Restoration Forum

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