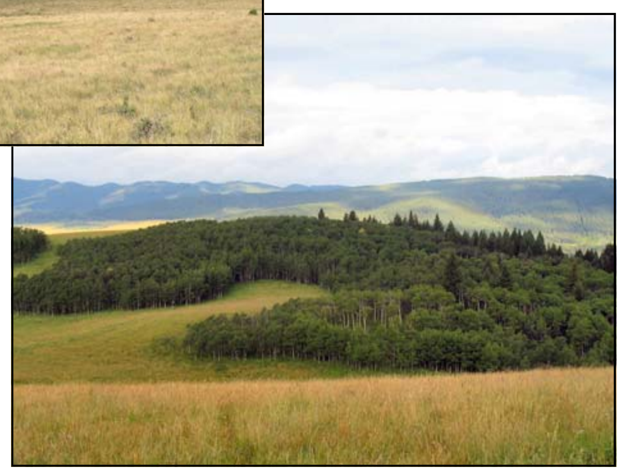
Revegetation Strategies for Public Lands: A Gap Analysis

April 2007



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Acknowledgements

One snowy day in late November of 2006, while visiting at my son's ranch in Saskatchewan, I received a phone call from Gerry Ehlert, asking if I would consider putting together a project team to conduct a gap analysis of the revegetation strategies implemented for industrial disturbances on Public Lands. We both agreed that such a project was very important and timely; given the increase in industrial activity, and the uncertainty surrounding current revegetation strategies. Putting down the phone I realized how daunting the project would be given the time frame required. However, there was a "catch calf" found at dawn to be sheltered from the cold, and my son and daughter-in-law were away in Regina attending Agribition. I packed up my year old grandson, and we brought the cow and calf up to the barn to ensure their needs were taken care of before Mother Nature got really ugly. You may ask why I digress with this story but to me it is important. It strengthened my resolve to take on this project. Mother cow and calf are doing very well and the neighbor's bull is a prize specimen of renowned fertility! The reader can draw their own conclusions.

Gramineae wishes to acknowledge the technical assistance provided by the following members of the project team: Ron McNeil of Landwise Inc., and Varge Craig of Alta Rangeland Services Ltd., for their assistance in conducting and documenting the SRD workshops, and for providing valuable assistance, direction and technical review during the preparation of the gap analysis; Ken Baker and Jane Lancaster of Kestrel Research for the compilation of a draft framework for a literature review of the Boreal Natural Region, and Peggy Desserud for the compilation of the literature review for the Grassland, Parkland, Foothills and Rocky Mountain Natural Regions. Finally, a special thanks to Donna Kubian of CorPirate Services. Donna provided invaluable computer support during the SRD workshops, taking notes and compiling minutes. Together we edited and produced the final report.

The compilation of information and the production of this report could not have been possible without the assistance of numerous individuals who are actively involved in the environmental stewardship of Alberta's Public Lands. The co-operation and technical assistance received from Sustainable Resource Development staff was exceptional and the hospitality received at each of the SRD regional offices was greatly appreciated. Thanks to Gerry Ehlert, Kevin Ball and John Begg for initiating and managing the contract. Thanks to Barry Cole, Pat Porter, Bruce Cairns, Darrin Britton, Brian Allan, Jeff Hartley, Don Livingston and Tracey Cove for organizing the SRD workshops. Special thanks to Barry Adams and Mike Alexander for providing guidance and technical assistance regarding the use of the Range Plant Community Guides during the gap analysis and to John Taggart and Jim Clark for bringing wildlife issues and the loss of habitat for Species at Risk into focus. Special thanks also to Lowell Calder for contributing his extensive experience as a Public Lands Officer.

Special thanks are extended to the stakeholders in the oil and gas industry, environmental consulting firms, the native seed industry, and research institutions such as the Universities and the Alberta Research Council who took the time to participate in the interview process. Your experience provided valuable insight regarding the issues faced within the current land use framework. The time frame was extremely compressed and I apologize to those stakeholders that I have missed.

The ***Prairie Conservation Forum*** provided guidance for this document through the ***Alberta Prairie Conservation Action Plan: 2006 to 2010.*** The action plan represents what can be accomplished when all levels of government (federal, provincial and municipal), industry, academia, and conservation groups work together with commitment and dedication, to draft and adopt an action plan for the conservation and enhancement of Alberta's native prairie and parkland ecosystems for future generations.

"A goal without a plan is just a wish." **Antoine de Saint-Exupery**

Executive Summary

This document has been prepared to provide Alberta Sustainable Resource Development (SRD) with a concise gap analysis of the current revegetation strategies implemented for industrial disturbances on Public Lands. Two reports are provided:

1. A gap analysis for the Grassland, Parkland, Rocky Mountain and Foothills Natural Regions;
2. A framework for a gap analysis of the Boreal Natural Region, to be completed under a separate contract in 2007.

Information was compiled through a literature review, workshops held with SRD staff at regional offices, and telephone interviews conducted with key representatives of the oil and gas industry, the native seed industry, research institutions, and environmental consulting firms.

The framework for the gap analysis was based on the *Natural Regions and Subregions of Alberta*, (Natural Regions Committee 2006). *The Alberta Prairie Conservation Action Plan 2006 to 2010* provided guidance through Alberta's commitment to the vision, guiding principles, and goals detailed in the action plan.

Each Natural Region and Subregion is characterized by the unique interaction of climate, physiography, vegetation, soils, wildlife and land use attributes (Natural Regions Committee, 2006). Therefore, the ecosystem response to man-made disturbance will be different in each Natural Region and Subregion. The gap analysis summarizes current land management challenges, existing revegetation strategies, and indicates where research is required to maintain ecological health and function.

THE METHODS USED TO COMPILE INFORMATION FOR THE GAP ANALYSIS INCLUDED:

A literature review was conducted to examine current and past research regarding the restoration potential of industrial disturbances in natural landscapes. The review focused on research relevant to the Grassland, Parkland, Foothills, and Rocky Mountain Natural Regions of Alberta. The literature search was conducted utilizing the internet and several search engines using key words to identify relevant papers. Recent publications from expert sources such as the Alberta Research Council, the SRD website and associated links were included.

Interviews were conducted to determine the revegetation strategies currently used on both a Natural Region and a Subregional basis. The purpose was to capture the local knowledge and experience of field based professionals who are required to: design and propose; review and approve; or implement revegetation strategies for industrial disturbances on Public Lands. An information package was emailed to each location with a list of proposed interview questions in advance of the interviews or workshops. The packages included a summary of the key recommendations by the Reclamation Criteria Advisory Group (RCAG 2006) for enhancing the "Reclamation Criteria for Wellsites and Associated Facilities" (1995 Update) to facilitate discussion. Minutes of each workshop or interview were compiled and filed for review and incorporation during the preparation of the gap analysis.

Interviews with SRD were conducted in a workshop format at SRD regional offices to facilitate efficiency as well as encourage involvement of as many SRD Land Use Officers, Rangeland Agrologists and SRD Fish and Wildlife biologists as possible.

Telephone interviews were conducted with key representatives of the oil and gas sector including: Conoco Phillips, EnCana, Talisman Energy, Husky Energy, Shell Canada, Trident Exploration and Compton Petroleum; native seed supply companies including Brett Young Seeds, Pick Seeds, and Eastern Slope Rangeland Seeds; environmental consultants firms including Tera Environmental Consulting, Rangeland Conservation Services, Ghostpine Environmental Consulting and Cheryl Bradley. The Base Environmental officers and rangeland agrologists from CFB Wainwright and CFB Suffield were contacted; the Alberta Research Council; and stewardship and conservation organizations including Cows and Fish.

The method used to identify key findings and gaps from the workshops and interviews conducted was to consolidate common themes expressed during the interview process. This allows gaps to be identified in an iterative manner designed to promote further consultation and information exchange between all stakeholders.

Common themes that emerged during the interview process include:

- The workshops conducted with SRD staff indicated the need for a re-evaluation of existing land use strategies, improved communication and information sharing, as well as additional training and qualification requirements within industry to improve the success of existing revegetation strategies on Public Lands. SRD staff stressed the need to apply the science of cumulative effects monitoring in everyday decision making. Currently, staff is required to make routine approvals without understanding the current level of land use footprint in the area under consideration.

- The interviews conducted with industry indicated a willingness to address and improve existing revegetation strategies. A number of innovative revegetation trials are currently underway to improve revegetation and restoration success. Industry has also contributed funding for the research and development of the native plant cultivars that are currently in production. Industry has developed innovative pipeline construction equipment, improved drilling technology, and developed minimal disturbance methods of constructing access and leases to reduce the impact of development on the landscape.

- Interviews conducted with research institutions such as the Alberta Research Council along with native seed sales and production companies denoted an industry that is market driven. The industry has recently struggled to keep native seed in production, largely due to a lack of supply and demand. Sourcing the most suitable native seed for projects takes time, and with the rapid growth of development activities this important step is, unfortunately, often *not* considered a priority by industry.

- Interviews with conservation stakeholders advised proceeding with caution, while enhancing the information base and relying on science-based decision making when evaluating current revegetation strategies.

KEY FINDINGS AND GAPS IDENTIFIED SPECIFIC TO ALL NATURAL REGIONS AND SUBREGIONS INCLUDE:

Establish and consolidate terms of reference.

Standardized terminology to assist stakeholders in goal setting A significant gap identified refers to the need to establish standardized terminology when discussing revegetation strategies that are clearly understood and agreed to by all stakeholders. The interview process indicated terms such as “natural recovery”, and “ecosystem health, function and operability” currently have multiple meanings depending on the context in which they are used. Clearly defined terms will assist SRD and stakeholders in setting goals for revegetation strategies.

Documentation and acceptance of Best Management Practices The interview process indicated a lack of agreement by SRD and stakeholders regarding the success of currently implemented practices and procedures for revegetating industrial disturbances. Establishing Best Management Practices could provide a mechanism for agreement regarding revegetation strategies. No single strategy will be appropriate on a Natural Region basis given the diversity of soils, landforms, native plant communities and wildlife habitat requirements.

Organize and consolidate information requirements Consensus during the interviews indicated the Public Lands Operational Handbook requires modification to be more useful. Similarly, Energy Utility Board (EUB), Alberta Environment and SRD Information Letters, Directives, Codes of Practice and similar related materials are not readily available in a user friendly manner. They are located on numerous websites with no comprehensive, single location via the internet. It is recommended that a central repository for information be established that is readily accessible by all stakeholders.

Enhance land use management

Three gaps were identified to facilitate enhanced land use management:

Identification of land areas highly sensitive to disturbance. There are sites within each of the Natural Subregions where the impact of industrial disturbance and the success of current revegetation strategies are unknown. Key indicators can be used to determine these sites based on the Natural Subregion, soils, landform, moisture / nutrient regimes, and the reference native plant communities adapted to the site. For example, topsoil depth, physical properties and nutrient regime can determine erosion risk or the potential for non-native species invasion following disturbance. To illustrate how these areas could be identified, areas are listed by Natural Subregion in the form of Draft Prediction Confidence Tables, which are based on the Range Plant Community Guides developed by the SRD Rangeland Management Branch. Examples are provided in draft as Appendix B. It should be noted that further consultation with SRD and stakeholders is required to complete these tables.

As well, there are currently areas where the mineral rights have been sold with no clear scientific evidence that the associated surface disturbance to the soils and native plant communities can be successfully restored. Areas of particular concern include: the Central Parkland, Northern Fescue, Foothills Fescue, Foothills Parkland and Montane Natural Subregions. The ability of the native plant communities to recover from the decreased well spacing allowed by the EUB in the Dry Mixedgrass and the Mixedgrass Natural Subregions is also unknown and is of serious concern to SRD and stakeholders.

Stakeholder participants indicated the process by which mineral leases are sold for energy development requires re-examination within the Sustainable Resource and Environmental Management (SREM) Land Use Framework.

Monitoring and research regarding revegetation pathways. The literature review and the interview process indicated a lack of consensus and knowledge regarding potential revegetation successional pathways. The need for continued monitoring and research was identified as a priority.

Re-evaluation of planning and decision documents. Consensus during the interview process indicated existing Integrated Resource Management Plans (IRP, Green Zone), Land Management Plans (LMP White Zone) and Regional Integrated Decisions (RID) require revision to accurately reflect current landscape conditions and the impact of man-made development activity on the landscape. Biophysical data needs to be updated to reflect current wildlife habitat use. The following recommendations were compiled from the interview process:

1. Protective Notations (PNT) require review and update. PNTs should embrace ecological integrity rather than simply support bio-diversity.
2. Regional cumulative effects assessments are required to monitor the impact of multiple use activities on the landscape over time. Thresholds need to be established to determine the acceptable level of multiple and sustainable use within each regional landscape.
3. Representative areas are required within each Natural Subregion where development activity is not permitted. These areas could provide the baseline for scientific monitoring of man made disturbance related activity - within comparable ecosystems - on ecosystem function and change over time. These areas should have Protective Notations placed on them and the mineral rights withdrawn by the Department of Energy.

Provide training and develop qualifications

Qualification process for the submission of Environmental Field Reports (EFR), Area Operating Agreements (AOA) and Environmental Assessments (EA). At present there is no qualification requirement for consultants. A combination of qualified individuals is often required to accurately assess the sensitivity to development activity. The following recommendations were compiled from the interviews:

1. Develop qualification requirements for consultants who submit EFRs and AOAs.
2. Include in the qualification requirements field based experience in construction related activities specific to the development.
3. Implement a mentoring program to ensure field based experience is passed on to new consultants.
4. Develop specific methods for using Range Health Assessment and the Range Plant Community Guides when conducting assessments for proposed industrial activity in native rangeland. Also establish qualification requirements, provide additional training and certification.

Raise awareness of the importance of wetland and riparian function. Maintaining the ecological health and function of riparian zones adjacent to all classes of watercourses and wetlands is of major concern to SRD and stakeholders. The following recommendations were compiled from the interview process:

1. Establish education programs to increase industry awareness of the importance of riparian zones and their function within the landscape.
2. Establish qualifications and training requirements for the identification and assessment of riparian zones.
3. Further research is required to determine the impact of industrial disturbance related activities within riparian zones. This includes impact to ground and surface water resources, the uncertainty of restoration success, and the resulting impact to riparian habitat for all species.

Raise awareness of the importance of rare plants and habitat requirements for Species at Risk. Guidelines have been established for sourcing available information and conducting the field surveys. However, where avoidance is not possible, there are no clear guidelines for acceptable mitigation options. Also there are no requirements for monitoring, nor any standardized science-based methods of evaluating the success of the mitigation implemented. The following recommendations were compiled during the interview process:

1. Available information on mitigation that has been implemented for Species at Risk (rare plants, rare plant communities or designated wildlife species) requires consolidation and review.
2. Acceptable mitigation options need to be clearly defined for Species at Risk.
3. Monitoring is required to further evaluate and determine suitable mitigation options for Species at Risk.
4. Standardized, science-based methods of evaluating mitigation strategies are required.

Standardize methods of field-based, pre-disturbance assessments. There currently is no standardized pre-disturbance assessment process. This makes it difficult to consistently assess proposed revegetation strategies, as information describing the pre-disturbance status of the landscape is either missing or inadequate. Generally, there is not enough information included in the reports to make adequate decisions. The following recommendations were compiled during the interview process:

1. The EFR template should be modified to reflect the biophysical issues associated with each Natural Subregion as well as the size and type of disturbance related activity.
2. A standardized method of field based assessment is required that is specific to each Natural Subregion. The Alberta Vegetation Inventory and the Grassland Vegetation Inventory with linkage to AGRASID, the Range Plant Community Guides, and the Range Health Assessment protocol could provide a standardized method of assessment.
3. Standardized assessments could be attached to the disposition file through the Geographic Land Information Management & Planning System (GLIMPS) to improve the SRD audit process.

Risk assessment as a tool to priorize erosion and sediment control plans. Concerns regarding erosion and sediment control were expressed by stakeholders during the interview process. Sediment and erosion control are known to be important factors in achieving revegetation success. The following recommendations were compiled during the interview process:

1. To determine the appropriate revegetation strategy, a risk assessment should be conducted to determine site specific erosion potential and the potential for sediment to enter water bodies.
2. Where erosion concerns exist, site specific erosion and sediment control plans should be developed and implemented.
3. Monitoring should be conducted to evaluate the effectiveness of the method implemented and the information forwarded to a central information repository so that it is readily available for review by stakeholders.

To seed or not to seed, that is the great debate.

Define where the use of natural recovery is appropriate. Natural recovery is the term used when a disturbed site is reclaimed with no intervention. Natural recovery relies on the process of native plant succession to re-colonize the disturbance. Success or failure can depend on many factors.

There was considerable discussion during the interview process regarding the use of native seed on reclaimed disturbances. Consensus indicated that natural recovery is the preferred revegetation strategy by both industry and SRD. However, consensus also indicated the use of natural recovery is not appropriate for all types of disturbances, nor is it appropriate in all Natural Regions and Subregions. The literature review supported this assumption.

Thin soils and the hot dry climate of the Dry Mixedgrass Natural Subregion favors native plant recovery and encroachment following disturbance. However, in highly fragmented landscapes such as the Central Parkland Natural Subregion, non-native invasive species present in the surrounding landscape can seriously affect restoration success if natural recovery is used. Non-native species invasion also a serious concern in the Foothills Fescue, Foothills Parkland and Montane Natural Subregions, where fertile soils and higher moisture regimes favor the growth non-native species following disturbance. The size of the disturbance and the site erosion potential were also identified as key factors affecting the success of natural recovery. The following recommendations were compiled from the interview process:

1. Clear guidelines are required indicating where natural recovery is appropriate. The guidelines must consider the size and type of disturbance, the surrounding plant community and the potential for natural encroachment to occur, topographic constraints and site erosion potential, site moisture regime, existing land use, and the presence of weeds and non-native invasive species in the surrounding landscape.
2. Justification for the use of natural recovery must be clearly documented in the EFR.

Assisted natural recovery, through the use of non-persistent cover crops that provide initial soil stabilization while allowing natural encroachment to occur, was also a subject of considerable interest to industry during the interview process. It was recommended that this is an area that requires further research and monitoring.

Define the appropriate use of native seed as a revegetation strategy. There are currently four types of commercially available native seed used in revegetation strategies:

- Wild harvested seed is defined as native species collected from native plant communities at seed set. Examples include Western porcupine grass or Foothills rough fescue. Germination potential and unreliable seed set are two problems associated with the use of wild harvested seed. Currently Foothills rough fescue seed is only available through wild harvest collection.

- A native cultivar is a plant variety which has undergone genetic selection by plant breeders, has been registered by a certifying agency and propagated under specific guidelines to maintain its genetic integrity. Ag Canada has developed numerous species that are commonly used for revegetation in natural landscapes. These species perform reliably, however they are generally less variable genetically and phenotypically than native populations.

- An ecovar™ is an ecological variety (TM Ducks Unlimited) of a native plant species selected to produce a population containing maximum genetic variability. Ecovars™ retain much more genetic variety than do cultivars, and theoretically will be more adaptable to environmental changes as a result.

- The term "source identified" native plant cultivar describes native seed produced commercially from wild collections from specific geographic areas. This is the type of native seed developed by the Alberta Research Council. The genetic uniqueness of "source identified" native plant cultivars can be maintained by completely renewing the breeder plots every two generations with newly collected wild seed (Woosaree, personal communication, 2007).

Concerns with the purity of native seed, source identification, lack of suitable species, and germination potential were expressed by SRD and stakeholders during the interview process. As well, concerns regarding the ability of some native plant cultivars to spread off-site, or affect the genetic integrity of native species in the surrounding landscape, have been expressed by conservation groups.

The literature review identifies gaps in current knowledge and indicates ongoing research and monitoring projects into the use of sod transplants, and nursery grown seedling transplants for sensitive plant communities such as rough fescue grasslands. Industry is also currently funding further development of "source identified" native plant cultivars, experimenting with the use of non-persistent cover crops to control erosion where appropriate native seed is not currently available, and funding trials to reduce the impact of non-native species invasion on disturbed sites. Trials are also underway regarding the use of locally wild harvested Foothills rough fescue seed on disturbances. Recommendations from the gap analysis include:

1. Guidelines for the use of native seed should be revised to reflect more recent research findings. Guidelines are required for each Natural Subregion. The guidelines must consider the size and type of disturbance, the surrounding plant community and the potential for natural encroachment to occur. Topographic constraints and site erosion potential, moisture regime, existing land use, and the presence of weeds and non-native invasive species in the surrounding landscape are all factors that need to be considered in the revised guidelines.

2. Where native seed compatible with the surrounding native plant community is not available, a staged approach to revegetation with the use of non-persistent cover crops may be appropriate depending on the site. Sod salvage, nursery grown seedling transplants or the use of wild harvested hay as a mulch and seed source may be appropriate revegetation strategies for specific development activities.

KEY FINDINGS AND GAPS IDENTIFIED SPECIFIC TO THE NATURAL REGIONS AND SUBREGIONS INCLUDE:

Section 4.3 describes the current revegetation strategy implemented in each Natural Subregion on Public Lands. The interview process, combined with the literature review, identify the areas where further monitoring and research is required to improve or validate current revegetation strategies. Each Natural Subregion offers unique challenges for achieving restoration success.

DRAFT ACTION PLAN:

The Draft Action Plan (Section 5.0) provides recommendations resulting from the Gap Analysis and the interview process. It includes a summary of recommended monitoring trials and research initiatives that could increase information sharing, the knowledge base by Natural Subregion, and lead to consensus among stakeholders. Options for managing and funding research projects are also provided.

Priorities for the development of the action plan include:

1. Posting this report on the Integrated Land Management (ILM) web page to facilitate a wide review of the document by all stakeholders;
2. Finalizing the Boreal Gap Analysis and posting the report for review on the ILM web page;
3. Presenting this report to SREM to respond to requests for clarification.
4. Presenting this report at workshops held with SRD staff and industry representatives at key locations where there is uncertainty regarding the outcome of current revegetation strategies. It is recommended that these workshops be arranged and conducted early in the 3rd quarter of 2007. Similar workshops are recommended following the completion of the Boreal Gap Analysis;
5. Continued SRD participation in the Southern Foothills Study;
6. Providing leadership and active participation in the establishment of regional cumulative effects assessments to facilitate the application of science-based cumulative effects monitoring in everyday decision making;
7. Completion and refinement of the Draft Prediction Confidence Tables in consultation with SRD, representatives of industry, and stakeholders;
8. Continued participation with stakeholders in the development of Best Management Practices specific to the Natural Subregions;
9. Establishing priorities and funding for research initiatives with the research institutions and proceeding with the chosen priorities in 2007 and;
10. Establishing a central repository for information sharing between all stakeholders.

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Abbreviations

AEP .... Alberta Environmental Protection
AGRASID .... Agricultural Region of Alberta Soil Inventory Database
AOA .... Area Operating Agreement
AOP .... Area Operating Plan
ARC .... Alberta Research Council
ATV .... All-Terrain vehicle
BMP .... Best Management Practices
C .... Celsius
CAPP .... Canadian Association of Petroleum Producers
CFB .... Canadian Forces Base
Cm .... Centimetre
DNA .... Deoxyribo Nucleic Acid
EFR .... Environmental Field Report
EUB .... Energy Utilities Board
GLIMPS .... Geographic Land Information Management & Planning System
GSH .... Great Sand Hills
GVI .... Grassland Vegetation Inventory
Ha .... Hectare
IL .... Information Letter
ILM .... Integrated Land Management
IRP .... Integrated Resource Plan
Kg .... Kilogram
KVA .... Kilovolt Ampere
LMP .... Land Management Plan
m .... metre
MD .... Municipal District
MSL .... Mineral Surface Lease
NEOS .... Alberta Cooperative Library Consortium
NGO .... Non-Governmental Organization
PCAP .... Prairie Conservation Action Plan
PCF .... Prairie Conservation Forum
PFRA .... Prairie Farm Rehabilitation Administration
PNT .... Protective Notation
RCAG .... Reclamation Criteria for Advisory Group
RID .... Regionally Integrated Decision
RoW .... Pipeline Right-of-Way
RRTAC .... Reclamation Research Technical Advisory Committee
SARA .... Species at Risk Act
SASCI .... Southern Alberta Sustainable Community Initiative
So .... subsoil
SRD .... Alberta Sustainable Resource Development
SREM .... Sustainable Resource and Environmental Management
Sp. .... Species
TCPL .... Trans Canada Pipeline
TM .... Registered Trademark

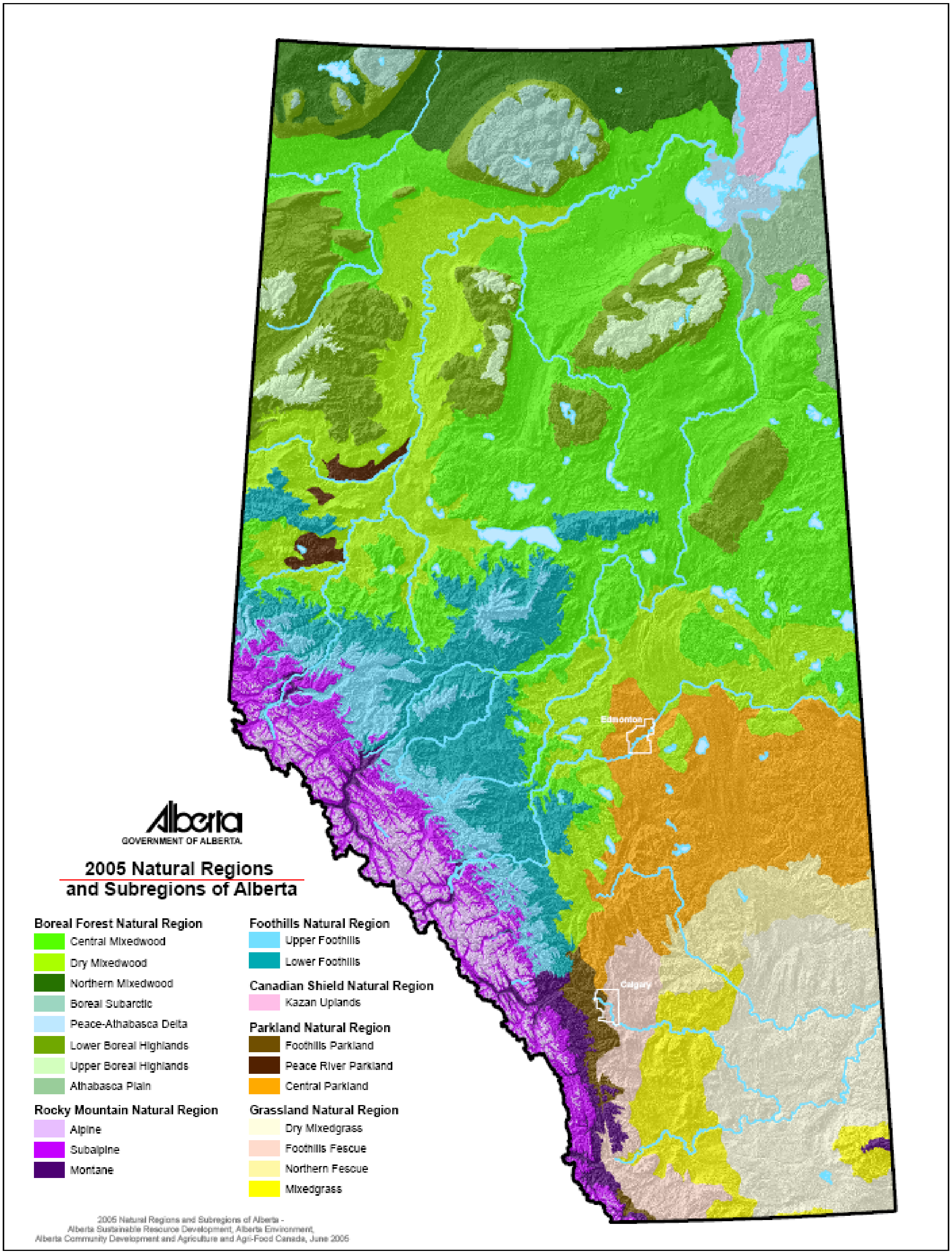
1 Introduction and Scope of Work

Gramineae Services Ltd. (Gramineae) was contracted by Alberta Sustainable Resource Development (SRD) in early 2007, to conduct a Gap Analysis regarding revegetation strategies appropriate for industrial disturbances on Public Lands in Alberta. Project is part of the Reclamation Stream Team's work plan regarding Integrated Land Management (see about ILM in http://www.srd.gov.ab.ca/land/u_ILM_powerpoint.html). The scope of work includes:

- Conducting a literature review to determine current knowledge of revegetation strategies applicable to the Natural Regions of Alberta;
- Conducting interviews with SRD Land Use Specialists, Forestry Land Management Officers, Rangeland Management Branch, and Fish and Wildlife in each Natural region to supply information to assist in the gap analysis;
- Contacting the University of Calgary, the University of Alberta and the Alberta Research Council to summarize current research relevant to the project;
- Contacting and interviewing key industry stakeholders such as the Canadian Association of Petroleum Producers, and a selected group of key petroleum producers to assist in the gap analysis;
- Contacting and interviewing environmental consultants, reclamation consultants, reclamation contractors to gather their input for the gap analysis;
- Contacting companies who grow and supply native seed in Alberta, to gather their input for the gap analysis;
- Documenting the present revegetation strategies used to reclaim disturbed lands in Alberta, eg. traditional/conventional and natural recovery methods and techniques for disturbed native forests and grasslands;
- Documenting on a ecosystem basis the key successes and failures relative to the goal of reclaiming disturbed lands back to healthy and functioning native grassland and forest ecosystems;
- Developing a revegetation strategy framework for native grasslands and forests for SRD to consider and build into its present policy, standards/guidelines/conditions, and practices dealing with the revegetation of disturbed lands.

Gramineae assembled a team of individuals with a variety of experience to complete the scope of work within the time frame allotted.

Figure 1. Natural Regions & Subregions of Alberta



2 Literature Review

2.1 Introduction

In a global context, grasslands are considered to be the world's single most threatened ecosystem and are a conservation priority in North America (Samson and Knopf 1996). Over time, Alberta's native prairie and parkland landscapes have been and are continuing to be transformed by agricultural, industrial, commercial, recreational, and residential/urban development. (Native Prairie Guidelines Working Group 2002). Revegetation practices have evolved over time, starting with little revegetation prior to the 1970s, to implementing agricultural practices, e.g. planting agronomic species, in the 1970s and 1980s, and with attempts to restore pre-disturbance habitat commencing in the late 1980s and 1990s.

This literature review examines current and past research into revegetation of disturbances, focusing on the Grassland, Parkland, Foothills, Montane and Subalpine Natural Regions of Alberta. The literature search was conducted utilizing the internet and several search engines utilizing key words to identify relevant papers. Papers from expert sources were also included, e.g. the Alberta Research Council.

Key words utilized in literature search included: revegetation, reclamation, natural recovery, seeding, transplants, combined with Alberta grassland, parkland, foothills, montane and subalpine natural regions

Search Engines Utilized: Google Scholar, University of Alberta Libraries, NEOS Libraries Catalogue, Lexus Nexus, Canadian Theses Portal

Other Information Sources: SRD web sites and other linkages; The Alberta Research Council

2.2 Seeding

2.2.1 Wild Harvested Seed

One of the greatest obstacles to using native species or changing revegetation practices is the limited range and volume of commercially available native seed (Sutton 1975, Woosaree et al. 2001). Wilson (Wilson 2002) identified three major constraints to prairie restoration; lack of seed, among-year variability in establishment, and the persistence of introduced, non-native perennial species.

Wild harvested seed presents particular difficulties including uncertainty of the seed maturity dates, variable field conditions, the location of the seed source being not compatible with the reclamation site, the knowledge of the collector, hand-collection methods, and storage methods (Smreciu et al. 2003). For example, rough fescue is an erratic seed setter and the conditions required for seed set are unknown (Johnston and MacDonald 1967, Willms and Quinton 1995, Bradley et al. 2002). Several years or even decades may pass between seeding (Johnston and MacDonald 1967, Romo et al. 1991), making reliable seed collection difficult if not impossible. Clark (1998) observed decreased production of seeded native grasses, in the black soil zone (fescue prairie) of Saskatchewan and Alberta, relative to other soil zones, although the mechanism behind this decreased production is not clear.

Another problem with native seed is seed storage. Walker (Page 2004) observed that Foothills rough fescue *(Festuca campestris)* seeds collected and stored are only viable for three years. In contrast, Tannas (Page 2004) noted that native seed could be stored for longer periods of time but was very sensitive to environmental conditions, adding that proper seed storage is critical for success. Romo et al. (1991) observed that when moisture is held constant that most of the decline in germination of plains rough fescue *(Festuca hallii)* was accounted for by seed age.

Unreliable germination of wild-harvested seed poses an additional problem. In an analysis the germination of wild-seed collection of 45 native species from the Central Parkland region, Woosaree and James (2004) found poor germination in the majority of species, possibly due to timing of harvest, resulting in collection of un-ripened seeds. Sometimes germination in controlled environments, e.g. a greenhouse, is not reflected in field conditions. For example, while rough fescue has been shown to germinate readily in greenhouse conditions (Johnston and MacDonald 1967, Romo et al. 1991, Desserud 2007), field establishment is unreliable (Pahl and Smreciu 1999).

2.2.2 Native Grass Hay

A variant of wild seed harvesting is cutting hay from native grassland to use as a mulch and seed source. Straw has long been used as a mulch or erosion control mechanism; however, using hay as a seed source is less well known. Hay was used as a seed source in the Central Great Plains after the drought years of the 1930s yet few reports of using hay as a seed source have been published after the 1940s (Reis and Hofman 1983).

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

In a plains rough fescue hay experiment in the Rumsey Natural area in 2006, hay cutting was timed for rough fescue seeding, an event that occurred in 2006, but had not occurred for at least five previous years (Desserud 2007). The hay was sprayed upon a newly disturbed pipeline right-of-way (RoW) and its growth will be monitored. Seedling emergence from the hay, in greenhouse conditions, was predominately rough fescue, followed by Kentucky bluegrass and June grass. If the objective of hay cutting is rough fescue, this technique would be viable only in those years when rough fescue seeded, an unpredictable event (Johnston and MacDonald 1967, Romo et al. 1991).

2.2.3 Cultivars and Ecovars™

One solution to seed availability is the cultivation of commercially viable seed from native seed sources to produce a cultivar. A cultivar is a plant variety which has undergone genetic restriction through selection by plant breeders, and which has been registered by a certifying agency (Ferdinandez et al. 2005). Cultivars for several native grasses are available in Canada and are widely used in the reclamation industry, e.g. western wheat grass (*Agropyron smithii*), slender wheatgrass (*Agropyron trachycaulum*), green needle grass (*Stipa viridula*) and alpine bluegrass (*Poa alpina*) (Joyce 1994, Pahl and Smreciu 1999).

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

Cultivated rhizomatous wheatgrasses, e.g. western wheatgrass, in particular, may be particularly persistent and could pose problems in native species restoration. Hammermeister (2001) concluded the cultivars of native wheatgrasses common in seed mixes out compete other typically more dominant native species, e.g. rough fescue (*Festuca hallii*), in early seral stages. His analysis was conducted on a reclaimed pipeline in the Mixedgrass subregion. Hammermeister's conclusion may be substantiated by Elsinger's findings in an analysis of natural gas wellsites in the Rumsey Natural Area, located in the Central Parkland and Northern Fescue regions. She found that approximately half of the well sites, in rough fescue (*Festuca hallii*) grassland, were dominated by western wheat grass (*Agropyron smithii*) and northern wheatgrass (*Agropyron dasystachyum*), persisting for many years following reclamation seeding (Elsinger 2006). As part of commercially available seed mix, these species most likely were cultivars.

Adams (pers. com. 2006) feels that concerns about wheatgrass competition are exaggerated. When viewed over sufficient time (10 to 15 years), as soils regain stable organic matter and the soil processes typical of native grassland re-establish, wheatgrass cover declines and other species, including native forbs, begin to recolonize the disturbance.

An ecovar™ is an ecological variety (coined by Ducks Unlimited) of a native plant species selected to produce a population containing maximum genetic variability (Woosaree 2000). Ecovars™ retain much more genetic variety than do cultivars, and theoretically will be more adaptable to environmental changes as a result. The result of a third type of native plant cultivation is termed "ecotype". An ecotype is generally defined as a distinct genotype within a species, resulting from adaptation to local environmental conditions, and that can interbreed with other ecotypes of the same species (Hufford and Mazer 2003).

Some successful native plant cultivars that have been grown by the Alberta Research Council include native mountain species grown to seed in a Central Parkland location (Vegreville, Alberta) (Woosaree et al. 2001). These included spike trisetum (*Trisetum spicatum*), rocky mountain fescue (*Festuca saximontana*) and alpine fescue (*Festuca brachyphylla*). Seeds from these cultivars are targeted for reclamation projects in Montane and Sub-alpine settings, in national and provincial parks. Despite their production in a subregion which differs from their original source, the genetic uniqueness of native plant cultivars can be maintained by completely renewing the breeder plots every two generations with newly collected wild seed (Woosaree, personal communication, 2007).

Other species successfully bred by Woosaree and James (2006) include those suitable for Mixedgrass prairie sandy soils, e.g. *Elymus canadensis* , *Agropyron subsecundum*, *Bromus anomalous*, *Oryzopsis hymenoides* and *Bouteloua gracilis*. Woosaree (2007a) has developed native plant cultivars of species that may be suitable for revegetation in the Foothills Fescue and Foothills Parkland subregions. Germination of wild-harvested seed was good, with most having over 70% germination rate, with only 2 with 5 % or less (Table 1 – Results of Germination Trials of Seeds Obtained from the Foothills Subregions). Woosaree (2007a) also established plots of plains rough fescue (*Festuca hallii*) which will be evaluated in 2007.

Table 1. Results of Germination Trials of Seeds Obtained from the Foothills Subregions (Woosaree 2007a)

Scientific name	Common Name	Average Germination %
Festuca idahoensis	Idaho fescue	98
Glycyrrhiza lepidota	Wild licorice	0
Gaillardia aristata	Brown-eyed Susan	80
Linum lewisii	Wild Blue Flax	84
Agropyron smithii	Western wheatgrass	99
Potentilla pensylvanica	Prairie Cinquefoil	79
Solidago canadensis	Canada Goldenrod	73
Petalostemon purpureum	Purple prairie clover	5
Antenaria nitida	Pussytoes	39
Liatris punctata	Wild liatris	75
Ratibita columnifera	Prairie coneflower	91

The difficulty in vegetating contaminated soils prompted Woosaree (2007a) to evaluate species to germinate, grow and degrade in salt-hydrocarbon contaminated soils. He ranked the ability of plants to grow successfully in contaminated soils from 1 to 5, with 5 being excellent vigor. Species ranking were:

1) *Puccinellia nuttalliana* 2.8
2) *Deschampsia caespitosa a* 2.8
3) *Aster ericoides* 2.6
4) *Agropyron repens* 2.5
5) *Rumex occidentalis* 2.4
6) *Agropyron subsecundum* 1.7
7) *Triglochin maritima* 1.7
8) *Achillea millefolium* 1.6
9) *Atriplex patula* 0.8
10) *Carex sp.* 0.7
11) *Distichlis stricta* 0.2

Following a review of ecovar™ and cultivar literature and information, Downing (2004, p. 12) cautioned "Native cultivar or ecovar™ suitability in one natural subregion does not necessarily imply suitability in another. A monitoring strategy that considers site characteristics, restoration techniques (e.g., seeding rates), cultural practices (e.g. grazing, windbreaks, stubble planting), and genetic attributes of the cultivars or ecovars™ should be implemented to assess the positive and negative impacts of their use both within and outside the subregions for which they were produced".

2.2.4 Seed Mixes

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

In a Northern Fescue grassland experiment, Woosaree and James (2004) compared the recovery of rough fescue (*Festuca hallii*) with three seed mixes: 1) *Festuca hallii* and *Agropyron trachycaulum*; 2) *Festuca hallii* and five other native grasses; and 3) a mix of eighteen native grasses and forbs. After five years, the slender wheat grass had started to die-back and be replaced by forbs. The rough fescue was present, but not dominant, though after eight years, it had started to increase, especially in the simple mix with only slender wheat grass. Woosaree and James (2004) concluded the reduced canopy cover afforded by forbs, from the highly diverse seed mix, as well as slender wheat grass replacement, allowed slow-growing rough fescue to increase over time. For rough fescue they concluded a time period of five years may be too short to observe plant community changes as they started to see an increase in rough fescue only by year eight and nine (Woosaree et al. 2004).

In a comparison of a commercially available seed mix and wild-harvested seed, in sandy soils in the Central Parkland, Woosaree (2007b) described greater diversity in the wild-harvested mix, as well as greater germination, especially of late seral species. In the commercial mix, *Stipa spartea, Festuca hallii* and *Calamovilfa longifolia* failed to emerge, possibly as a result of seed age, dormancy or not being adapted to the area as the origins of the seeds were not indigenous (Woosaree 2007b).

Hard-coated seeds, e.g. many *Stipa* species, such as green needle grass or western porcupine grass, may not germinate in the first year unless scarified (Nurnberg 1994). Without seed treatment they should be seeded with non-competitive, early establishers such as slender wheat grass, or forbs such as yarrow to give them a competitive edge after germination in the second year (Nurnberg 1994).

Pitchford (2000), in a Central Parkland seeding experiment, concluded that seed mix diversity did not necessarily promote species richness in the resulting ground cover. She also found that colonization of the seeded plots from external seed sources changed the expected species composition. Conversely, in a Northern Fescue grassland, a more diverse seed mix resulted in more diverse ground cover (Woosaree et al. 2004).

2.2.5 Seeding Rates

Recommendations for seed mixes for the Dry Mixedgrass subregion include using 20% or less rhizomatous wheatgrasses, e.g. Western or Northern wheatgrass; increase the percentage of slender wheatgrass, as it is quick to establish, but not long-lived; use a more diverse seed mix and incorporate native species, e.g. blue grama and June grass; and, use broadcast seeding, which allows the incorporation of small seeds (Gill Environmental Consulting 1996). The author of this report when interviewed, (Hawkes pers com 2007), indicated that the long term persistence of rhizomatous wheatgrasses may have been overstated. Experience has shown that the rhizomatous wheatgrasses have been observed to decrease in abundance and competitive ability after a longer period of time (+15 years).

Seeding rates for native grass seed used in the reclamation projects of this review are in the order of 10 kg/ha (Table 2 – Selection of Seeding Rates for Projects in this Review). Sinton et al. (1996) recommend a rate of 8 – l1 kg/ha for drilled seeds, cautioning that rates will vary depending on the size and weight of the seed. Some researchers consider this rate to be too high and that it may inhibit the invasion of native plants onto disturbed sites (Hammermeister and Naeth 1996).

Table 2. Selection of Seeding Rates for Projects in this Review

Note: (all were drill seeders)

Source	Description and Region	kg/ha
Hammermeister and Naeth 1996	Various well sites in Dry Mixed Grass	6.6 – 10.7
Sinton et al. 1996	Native Plants on Disturbed Sites guide	8-11
Sinton 2001	Oil and gas reclamation recommendations	10-12
Woosaree et al. 2004	Wellsite in Northern Fescue	12-18
Woosaree and James 2006	Well site in Northern Fescue	9.9
Woosaree and James 2006	Well site in Northern Fescue	16
Woosaree 2007b	Pipeline in Central Parkland	10

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

2.2.6 Season of Seeding

The best season in which to seed native grasses depends on the species. Generally cool-season grasses (C3), e.g. most wheatgrasses, rough fescue, June grass benefit from spring or early spring seeding. Warm-season grasses (C4), e.g. blue grama (*Bouteloua gracilis*) benefit from warmer soils in late spring and early summer. *Stipa* species, e.g. western porcupine grass or needle and thread, prefer late summer or fall seeding (Pahl and Smreciu 1999). Nurnberg (1994) found hard-coated seeds such as *Stipa* species, may not germinate in the first year unless scarified, which may be the reason for requiring a winter season following seeding.

Spring seeding preferences are probably related to higher spring moisture which would favour germination (Grilz 1992). Romo et al. (1991) found plains rough fescue to be particularly sensitive to moisture requirements and that water stress overrides temperature stress and narrows the conditions at which germination will occur. In a Central Parkland native forb reclamation experiment, Aruchuk (2001) concluded spring seeding increased native forb establishment over fall seeding and that spring forb transplants had higher first year and second year survival than fall transplants. Pitchford (2000) found higher density of seeded grasses in the first year if seeded in the spring, especially for *Agropyron dasystachyum, A. trachycaulum, Koeleria macrantha,and Stipa viridula*. She found less difference between spring and fall seeding for most forbs.

Soil temperature also plays a role in native seed germination. A higher rate of germination in plains rough fescue can be expected when seedbed temperatures are increasing and temperatures near 15° C appear to be most favourable for germination (Grilz 1992). Optimal growth and re-growth following defoliation for *Festuca hallii* appears to be at levels near 17° C or below and 12° C for *Festuca campestris*, with reduced growth above that temperature (King et al. 1998). *Festuca hallii* has a faster tillering rate at higher temperatures than *Festuca campestris*, possibly a result of rhizome development, which may represent an adaptation to opportunistic growth following summer storms (King et al. 1998). Summer dormancy appears to be triggered by moisture stress, since in an experiment, where water was non-limiting, *Festuca hallii* did not enter dormancy, even at 27°C (King et al. 1998). As a result, in areas with moist summer periods, *Festuca hallii* may mature later in the summer, even up to the latter part of July (Pavlick and Looman 1984).

2.3 Transplants

Transplant research for grasslands has focused on bunch grasses, with the goal of giving these slow-growing species a head-start in establishment. In a Montane transplant project in southern B.C., Page and Bork (2005) had success with bluebunch wheatgrass (*Agropyron spicata*) and Richardson's needlegrass (*Stipa richardsonii*) transplants from seedlings grown in plugs and pots. Best (2001) achieved success with rough fescue (*Festuca hallii*) transplants, from fifteen cm diameter cores cut from healthy rough fescue plants. The cores were transplanted in Elk Island, in the Central Parkland. Although the survival rate was high, the major factors that caused some of the transplants to fail were elk grazing and competition from Kentucky bluegrass.

The size of the transplant may have an effect on initial survival. Page and Bork (2005) found larger transplants such as pots survive better in the initial years than plugs. This effect may be short lived once plugs become established (Davies et al. 1999). Other factors affecting transplants may be spacing, i.e. the effect of competition, and nutrients. Davies et al. (1999) found plugs of various species, in a British grassland, transplanted closer than 30 cm apart, fared less well than those planted farther apart.

The season of the transplant may also be a factor, though this effect is species specific. In a Montane transplant project in southern B.C., Page and Bork (2005) found bluebunch wheatgrass (*Agropyron spicatum*) had better survival with fall transplanting, while Richardson's needlegrass (*Stipa richardsonii*) fared better with spring transplanting.

Transplants may allow better recovery of reclaimed areas in harsh, slow-growing environments, such as the Subalpine. Campbell and Scotter (1975) found good survival, one year later, of several Subalpine species, e.g. meadow spirea (*Lutetkea pectinata*), transplanted from plugs cut from the local area. The plugs were planted in the mid-summer, watered and fertilized. The site was the Mount Revelstoke National Park and survival was best in areas protected from human trampling.

Tannas (Tannas 2007 #5450 /d) has had preliminary success with transplanting rough fescue (*Festuca campestris*) cuttings from mature plants in the Foothills Fescue subregion. He attributed the success to the large root mass contained in the cuttings allowing ample energy for re-growth and high soil moisture conditions accompanying the spring planting. Plants were watered at planting. Without watering, survival rates fell from 86% survival to 55%, but planting time may also have affected this so direct comparison is not really possible. Greenhouse plugs are also being tested for the possibility of being more economically viable as a planting method. Preliminary results will be available in the fall of 2007 (Tannas 2007 #5450).

Another technique is transplanting sod cut from grassland. Sod transplants of Foothills rough fescue (*Festuca campestris*) resulted in successful reclamation of a developed site in Calgary (Foothills Fescue subregion) (Revel 1993). Five centimetre deep sod was cut with commercial sod cutters. The site was prepared by tilling and 1/4" of topsoil was added. Initial growth was slow as the roots became established and the site appeared to be returning to an early seral stage. Ten years later the site appeared to be healthy and species composition within the range of a late-seral Foothills rough fescue plant community (Revel, Faculty of Environmental Design, University of Calgary, pers. comm., 2005).

The species composition of the site prior to disturbance is an important factor when considering sod transplanting. Petherbridge (2000) had initial success with rough fescue (*Festuca hallii*) sod salvage three years following a pipeline restoration in the Central Parkland region of southeastern Alberta; however, he cautioned that the site initially contained many invasive species that these could proliferate through sod salvage (Petherbridge 2000 #3010). Following five years of monitoring, (AXYS 2003b page 52) confirmed this observation at one of Petherbridge's sites, reporting that the sod salvage was reverting to an early seral stage with shallow-rooting species such as Kentucky bluegrass and wheat grasses.

In another site, in the Mixedgrass sub-region, Petherbridge (Petherbridge 2000 #3010 /d) reported better success, resulting in similar rough fescue (*Festuca hallii*) density on the sod salvage site and the undisturbed native grassland. He noted that the species composition of the sod salvage areas more closely resembled undisturbed grassland than seeded areas (Petherbridge 2000 #3010).

The size of the area to be reclaimed is another factor in the potential success of sod salvage. The expense of collecting, storing and transplanting sod for large areas may prohibit its use; therefore the technique may be better suited to smaller scale projects, e.g. on portions of a pipeline, or for a 1 ha well site (Petherbridge 2000 #3010).

2.4 Plant Competition

2.4.1 Competition among Native and Non-Native Species

Reclamation efforts often must contend with the presence of non-native agronomic grasses, either on the original site, adjacent to it, introduced by grazing cattle or other human activity, including past reclamation practices. Some of these species are well adapted to the thick black or brown soils found in the western and central grasslands, e.g. smooth brome (*Bromus inermis*), crested wheatgrass (*Agropyron cristatum*), timothy (*Phleum pratense*) and Kentucky bluegrass (*Poa prantensis*).

In a survey of 1,686 grasslands in the Central Parkland, Holcroft and Weestra (2003) found 34.5% were dominantly non-native, and 42% of the rough fescue grasslands in the survey contained invasive non-native plants. In the southwestern foothills with predominately black Chernozem soils, crested wheatgrass, Kentucky bluegrass and smooth brome have been found on reclaimed natural gas well sites and in adjacent areas (Bradley et al. 2002, Alexander 2004). An assessment of coal-bed methane sites in Wyoming found higher abundance of non-native species on the disturbed sites than in adjacent native grassland (Bergquist et al. 2004).

In an assessment of a 25 year-old pipeline in the Central Parkland, Parker (2005) found that *Bromus inermis* persisted where it had been introduced on the RoW and that it had invaded into adjacent native pastures to levels between 5% and 25% of the cover. In the Foothills Fescue subregion, Osterman (1994) reported significant differences between the species composition of a pipeline RoW and adjacent undisturbed grassland eleven to twelve years following the disturbance. In the Foothills Fescue and Montane subregions, Desserud (2006) concluded seeded species such as sheep fescue (*Festuca ovina*) could persist and become dominant, even after ten or fifteen years.

Attempts to reduce or eradicate non-native grasses in native grasslands have met with little success, since some non-native species are too aggressive to be completely eliminated once established. Brown (1997) failed to eliminate smooth brome from rough fescue grassland with fire, mowing and glyphosate treatments. She had limited success with grazing; however, while the smooth brome was reduced, Kentucky bluegrass appeared to take its place and increased correspondingly. A 6-year regime of annual cropping with glyphosate applied in the first year failed to eliminate agronomic grasses like Kentucky bluegrass from sites adjoining native Foothills fescue grassland (Adams, Ehlert, et al. 2005 #690)

Wilson and Pärtel (2003) reduced considerably the cover of crested wheatgrass (*Agropyron cristatum*) and correspondingly increased blue grama (*Bouteloua gracilis*) cover. They achieved this with a combination of herbicide over four years, followed by clipping for three years. The experimental plots returned to near-native cover after seven years; nevertheless, crested wheatgrass persisted at reduced levels and its seed bank content remained unchanged (Wilson and M. Pärtel 2003, Brussard et al. 1996). Ambrose and Wilson (2003) found similar persistence of crested wheatgrass seedbank in the Mixedgrass prairie. In an experiment where crested wheatgrass was treated with herbicide over a four year period, it continued to emerge from the seedbank with consistent numbers. In contrast, blue grama (*Bouteloua gracilis*) showed little seed bank emergence. Stromberg and Kephart (1996) found one successful restoration technique to reduce competition for native seedlings, was mowing annuals before their seeds mature.

Bakker et al. (2003) found differences in the response of crested wheatgrass to management techniques based on summer precipitation, in the Dry Mixedgrass prairie. They recommended that management should focus on controlling crested wheatgrass during dry years and on introducing native species during wet years.

Following an assessment of seeded pipeline recovery in the Dry Mixedgrass region, Hammermeister (2001) concluded that native wheatgrass cultivars dominated plant community development and suppressed establishment of other species. He hypothesized that species characteristics rather than species diversity was more important in seed mix selection. For example, the aggressive nature of Northern and Slender wheat grasses (*Agropyron dasystachyum* and *A. trachycaulum*) would allow them to out-compete other, perhaps slower growing species, such as rough fescue (Hammermeister 2001). In another Dry Mixedgrass reclamation project, Soulodre (2001) concluded that the wheatgrass communities resulting from seeding would likely continue in that state. In a seed mix experiment in the Central Parkland, Bush (1998) also discovered that *Agropyron trachycaulum*, *A. smithii* and *A. subsecundum* were extremely well adapted and competitive. Assessing the same plots two years later, Howat (1998) found that while *Agropyron trachycaulum* and *A. smithii* remained, *A. subsecundum* had declined, and *Festuca hallii* had started to appear.

The extent of competition between desirable native species is less well known. In a test of competition between woody and grass species in the Dry Mixedgrass prairie, in Saskatchewan, Peltzer and Köch (2001) found that proximity of blue grama (*Bouteloua gracilis*) and wolf willow (*Eleagnus commutata*) reduced the survivorship of both, while proximity to neighbours of the same species did not. They hypothesized that grasses and woody species compete between themselves.

Lamb (1998) reported persistence of non-native agronomic grasses ten years following reclamation in a Subalpine region. While the agronomic grasses continued to dominate a linear disturbance, there was no evidence of invasion into neighbouring forested stands, and similarly, no invasion of woody species onto the disturbance (Lamb 1998).

2.4.2 Weeds

Weed control practices are well described by Alberta government guides and enforced by regulating agencies; therefore, this review will not delve into detail regarding weed control. A few studies are presented that give interesting perspectives.

Bush (1998) discovered that competitive weeds can influence community development in the first year of reclamation. In a seed mix experiment in the Central Parkland, bindweed (*Polygonum convolvulus*) altered the community by out-competing most seeded species in the first year. By the second year, the bindweed had virtually disappeared, and the seeded plants that had survived grew with little competition. Nonetheless, many of the original seeded species did not survive, possibly due to competition with the bindweed, resulting in a lower diversity in the second year (Bush 1998). Woosaree and James (2006) found similar abundance of annual weeds, e.g. Russian pigweed (*Axyris amaranthoides*) and stinkweed (*Cleomella*) where their cover reached up to 31% in the first year following seeding. They concluded these weeds were not a concern since they were annuals and would soon be replaced by perennial grasses (Woosaree and James 2006).

Herbicide application to weedy species and introduced graminoids increased native grassland production and native grass density in two studies (Wilson and Gerry 1995, Masters et al. 1996). Rice (1998) had success controlling the invasion of spotted knapweed (*Centaurea maculosa*) into a Montane fescue grassland in Montana. The dominant species were bluebunch wheat grass (*Agropyron spicatum*), rough fescue (*Festuca campestris*) and Idaho fescue (*Festuca idahoensis*), and occasionally big sagebrush (*Artemesia tridentata*). Application of herbicides (picloram , clopyralid, and a mixture of clopyralid plus 2,4-D) resulted in a considerable and lasting decrease in spotted knapweed, a temporary decrease in native forbs, which recovered within two to three years, and an increase in the native bunch grasses. Conversely, mowing, not spraying is recommended for weed control in the Dry Mixedgrass subregion, due to the invasive nature of herbicide spraying, e.g. it will kill native forbs as well (Gill Environmental Consulting 1996).

2.5 Soil Management Techniques

A diverse vegetation mix is unlikely to develop rapidly unless strategies to initiate diversity are incorporated in the reclamation planning. Such strategies include seedbed preparation, controlling soil erosion, enhancing the soil chemical and physical properties and improving the nutrient cycle (Woosaree and James 2006).

2.5.1 Handling Topsoil

Most of the literature on handling topsoil deals with the effects on the chemical, physical and microbial properties of the soil, and only a few were found with relation to resulting plant growth. Two topsoil stripping techniques were compared in sandy soils in the Central Parkland: a conventional strip of the upper 10-15 cm (the entire A horizon) and a double strip, where the top 5 cm was stripped first and piled separately from the remaining A horizon. In both cases, the subsoil was stripped and stored separately from the A horizon (Wruck 2004). Wruck (2004) concluded that the two topsoil techniques made no difference in resulting native vegetation cover following two recovery techniques: seeding and natural recovery.

Topsoil handling and storage can affect the potential success of natural recovery. Iverson and Wali (Iverson and M. K. Wali 1982) found that seed bank density in four-year-old stored topsoil was considerably less than that in adjacent undisturbed prairie in North Dakota. The seeds of some species, e.g. *Artemesia frigida* did persist up to four years in stored topsoil; however most other did not.

A pipeline reclamation experiment, in the Dry Mixedgrass subregion, tested the results of two topsoil stripping techniques: no stripping and stripping, in combination with seeding and natural recovery. Petherbridge (Petherbridge 2000 #3010 /d) concluded the no-strip technique resulted in a smaller initial disturbance and conserved more of the original native plant cover than the conventional topsoil stripping technique. Conversely, the seedbank of the stripped area contained more species than the no-strip area, possibly a result of admixing of B horizon soil in the non-strip area, which would reduce the overall seed presence in the seedbank (Petherbridge 2000 #3010). Another no-strip technique resulted in a successful grassland restoration, through natural recovery, involving a no-strip and directly ploughed-in small diameter (< 15 cm) pipeline in the Mixedgrass subregion (Adams, Castelli, et al. 1996 #1720).

2.5.2 Irrigation

Because grassland species are adapted to relatively dry conditions, irrigation may not be required. Nurnberg (1994) recommended irrigation in the first year, in the Mixedgrass prairie, for some species e.g. rough fescue (*Festuca hallii*), but found it made little difference with other native species. In fact, he found continual irrigation into the second year reduced the growth and productivity of some, e.g. northern and slender wheat grasses.

In more harsh environments, irrigation may assist new growth. Campbell and Scotter (1975) watered plugs transplanted from Subalpine species and found good survival, one year later. Woosaree and James (2006) attributed the use of straw mulch to conserve moisture for the success of a well site revegetation in the Mixedgrass region during a year of severe drought (2002).

Tannas (Tannas 2007 #5450 /d) attributed partial success of transplanting rough fescue (*Festuca campestris*) cuttings from mature plants in the Foothills Fescue subregion to watering at the time of transplanting, and subsequent high soil moisture conditions in the accompanying spring season. Without watering survival rates fell from 86% survival to 55%.

2.5.3 Soil Amendments

The addition of fertilizer in grassland reclamation may be beneficial in poor growing conditions and harsh climates, for example at high altitudes or in poor soils. In a Montane pipeline reclamation project in 1977, the results of top-dressing, fertilizer, seeding methods and plant materials were assessed in both field and greenhouse trials (Wishart 1983). The results showed that top-dressing and mulching were not beneficial for revegetation and different seeding methods made no difference. Wishart (1989) concluded that simple broadcast seeding, with no fertilizer, was the best overall treatment. He did allow that fertilizer could be applied if rapid plant growth was required for erosion control. In a Subalpine reclamation project, Campbell and Scotter (1975) found transplanted plugs from Subalpine species benefited from an application of fertilizer. Fyles et al. (1985) concluded that fertilizer aided first year seeded growth in a sub-alpine reclaimed coal mine; however, after six years, a similar but unfertilized site had recovered to species similar to undisturbed grassland. They hypothesized that natural nitrogen in the substrate might have contributed to that development (Fyles et al. 1985).

Cohen-Fernández (2007) had preliminary greenhouse results in a limestone quarry reclamation experiment from the Subalpine region. In testing five subalpine-tolerant species, slender wheatgrass (*Agropyron trachycaulum*), hairy wild rye (*Elymus innovatus*), alpine blue grass (*Poa alpina*), rocky mountain fescue (*Festuca saximontana*), spike trisetum (*Trisetum spicatum*), she found that fertilized treatments produced significantly more biomass than unfertilized treatments and that the best performing amendments were biosolids, clean fill, top soil and beef manure compost. Pure sulphur also favoured one species: spike trisetum. The amendments were applied to crushed limestone, a substrate not normally suitable for revegetation. Further greenhouse experiments and field trials will be conducted in the next two years.

In another Subalpine region experiment, Smyth (1997) had good results with recovery of coal mine spoil following a fertilizer application. He compared amended and un-amended coal mine spoil as well as native topsoil from an adjacent area. Both the fertilized spoil and native soil had the best recovery of a grass/forb/sedge mix of local wild-harvested seed.

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

2.5.4 Soil Nutrient Depletion

Even as late as the 1980s, reclamation practices mirrored agricultural methods. For example, Lloyd (1981) recommended crested wheat grass, among native grasses as a preferred species, and suggested fertilizer would probably be required, especially in Mixedgrass Prairie. More recently, the ability of many native species to out-compete introduced species in nutrient-poor soils has been recognized. While soil impoverishment, e.g. through mulching with uncomposted wood products, may be unwanted for the landscape or agricultural industry (Harris et al. 1999), it may provide a potential reclamation path for native grasses.

Nitrogen is a key element in grassland ecosystems, because of its capacity to limit primary and secondary production (Dormaar et al. 1990). Classen and Marler (1998) demonstrated that invasive annuals, e.g. *Bromus* species were favoured over native perennials at higher nitrogen levels. Additionally, Wilson and Gerry (1995) found native seedling density decreased with increasing nitrogen. Several researchers have manipulated soil nitrogen levels through the addition of carbon sources, e.g. sugar, straw or sawdust, promoting nitrogen uptake by microbial action and affecting plant response. Blumenthal et al. (1995) found that carbon addition facilitated prairie species establishment over the course of the experiment, increasing total prairie biomass over a two-year period, whereas nitrogen addition reduced total prairie biomass in both years. A reverse affect was found for weeds. The nitrogen content of blue grama (*Bouteloua gracilis*) roots increased while that of *Festuca campestris* decreased in an assessment following soil decomposition (Dormaar and Willms 1993).

Several Tall Grass prairie experiments might have implications for Alberta reclamation. For example, Morgan (1994) saw a decline in non-prairie species after adding sugar and sawdust to soil. Addition of water and nitrogen in a Mixedgrass prairie regime resulted in diminution of the dominant grasses, e.g. needle and thread (*Stipa comata*) and an increase in weedy species (Lauenroth et al. 1978). Ewing (2002) successfully transplanted Idaho fescue (*Festuca idahoensis*) seedlings in a Washington State prairie experiment in coastal grassland. He discovered that Idaho fescue seedlings thrived in nitrogen deficient soil while weeds prospered and Idaho fescue suffered when mulched and fertilized.

Ewing (2002) found greater long-term (e.g. 3-year) survival for Idaho fescue (*Festuca idahoensis)* transplanted plugs in herbicide-treated plots. Newman et al. (2003) found an increase in photosynthesis in *Festuca arundinacea* in high nitrogen conditions in plants infected with an endophyte; conversely, similar photosynthesis rates were observed in low nitrogen levels with both infected and un-infected plants. McIneney (2003) found reduced tillering and root growth of rough fescue (*Festuca campestris*) under high nitrogen conditions, in a Montane site.

The rate of amendment application is important. Davis and Wilson (1997) reported the death of all plants with added sugar to a similar treatment. Conversely, while finding a decrease in one weedy species following carbon enrichment, Seastedt et al. (1996) and Reever Morghan and Seasdedt (1999) reported no change in a native bunchgrass. Similarly, Cione et al. (2002) found little effect in native shrub establishment with mulch-treated and nitrogen-reduced soil. These researchers attributed the lack of response to a low application rate or incomplete incorporation of the amendment into the soil.

2.6 Effects of Grazing

Animal herbivory, in particular cattle and wild ungulates, is a factor in grassland reclamation. Most grassland restoration projects should be protected from grazing, especially for the first few years until the perennial grasses become well established.

In a rough fescue (*Festuca hallii*) transplant experiment, in the Central Parkland, the transplants subjected to elk grazing faired poorly compared to those excluded from grazing. Cattle are known to congregate on disturbed sites, probably attracted by the young growth, and may adversely affect the establishment of native grasses (Naeth 1985, Integrated Environments Ltd. 1991 and Desserud 2006). Range exclosures in the Montane have shown that rough fescue grassland can recover if protected from grazing, if the original species composition has not been altered by agronomics such as Kentucky bluegrass (Alexander 2004).

Grazing rotation regimes may contribute to the success or failure of reclaimed native grassland. For example, rough fescue (*Festuca hallii* and *Festuca campestris*) is suited to late summer, autumn and winter grazing (Horton 1992, Dormaar and Willms 1990, Willms and Fraser 1992). Spring grazing can severely impact rough fescue vigor (Mclean and Wikeem 1985, Moisey 2003).

The response to seasonal grazing may vary with natural subregion. Willms et al. (1986) found that litter removal as a result of dormant season grazing benefited rough fescue in the Foothills Fescue and Central Parkland regions, but had a detrimental effect in the Mixedgrass Prairie region. They attributed this to the water-holding capacity of litter, which when absent might reduce growth in the dry Mixedgrass Prairie, and conversely might stimulate tiller growth in moister regions. Molinar et al. (2001) found a similar positive response to native grass growth with increased litter in drier grasslands.

Long-term grazing can alter the species composition of grassland. Slogan (1997) documented the changes in species composition in rough fescue grassland in Riding Mountain National Park in Manitoba over an eighteen year period, from 1995 to 1973. He discovered a decline in the abundance of plains rough fescue (*Festuca hallii*), a large increase in Kentucky bluegrass, and the presence of smooth brome (*Bromus inermis*), which was not present in 1973. The smooth brome was probably a direct result of cattle grazing (Slogan 1997).

Two other studies came to an opposite conclusion regarding the influence of grazing. In the Dry Mixedgrass, Soulodre (2001) found that populations of seeded needle-and-thread (*Stipa comata*) and western wheatgrass (*Agropyron smithii*) had no differences following grazing after a one year period. Osterman (2001) also concluded that grazing on a pipeline RoW did not change the species composition, after assessing ten year or older pipelines in the Foothills Fescue subregion.

2.7 Natural Recovery

The earliest examples of natural recovery in Alberta, whereby a disturbed site is reclaimed with no intervention, are the results of cultivated land abandoned and left to recover naturally. Coupland (Coupland 1961 #1730 /d) observed that the rate of plant community succession back to native Mixedgrass or Dry Mixedgrass prairie cover would depend on the size of the cultivated area, the distance to the supply of native seed stock and the degree of aridity of the years following abandonment. Succession back to a community dominated of late-seral perennial grasses might develop within 20 years (Adams, Poulin-Klien, et al. 2004 #3380, Adams, Poiulin-Klein, et al. 2005 #3390). Even so, the recovery may not result in a full return to pre-disturbance conditions. A pasture abandoned in 1932, near Lethbridge, Alberta (Mixedgrass subregion), had reverted to a needle and thread (*Stipa comata*) community by 1992, whereas adjacent never-cultivated areas were dominated by blue grama (*Bouteloua gracilis*) (Adams, Poulin-Klien, et al. 2004 #3380).

Natural recovery has been in and out of favour in reclamation practices. Prior to the advent of environmental management, e.g. pre-1970, disturbed sites were usually left alone, mainly from a lack of understanding of the consequences of environmental damage. Desserud (2006) assessed the recovery of a pipeline, in the Foothills Fescue region, constructed in the 1960s with no re-seeding or topsoil handling. The RoW contained considerable gravel, large rocks and bare ground, even after forty years. Natural recovery was occurring at one location; nevertheless, ground cover and species diversity was lower than an adjacent, more recent pipeline (Desserud 2006).

From the 1970s to recent times, intervention became more and more pronounced, with evolving construction and reclamation techniques, until the past few years, when natural recovery became an accepted technique (Naeth 2006). On the positive side, natural recovery could result in an effective, though potentially slow native prairie recovery, with reduced revegetation costs and weed management. Conversely, the length of time may delay the issuance of a reclamation certificate and expose the site to erosion and weeds (Hammermeister and Naeth 1996).

Six natural recovery trials were established on the Express Pipeline in southern Alberta to evaluate the ability of the RoW to naturally revegetate without active reseeding, relying on the existing seed bank and natural encroachment, for seed material (AXYS Environmental Consulting Ltd. 2003b). Sites were located in the Aspen Parkland on northern fescue grassland, in the Montane on mountain rough fescue grassland and in the Dry Mixedgrass on sandy and on solonetzic soils. Disturbances between 10 m and 30 m wide and 30m long, on sandy soils, solonetzic soils, wetlands solonetzic soils and brown chernozems in the montane and parkland, were selected for the natural recovery trials. Reclamation techniques employed included straw crimping, straw crimping knolls and imprinting. Six sample sites were established in each of the natural recovery trials representing each of the reclamation techniques. The sites were monitored over five years, during years 1, 2, 3, and 5 post-construction.

A number of factors affect potential success of natural recovery of RoWs from disturbance such as soil type, seed production on the site, range condition, proximity to undesirable vegetation species, length of soil storage, seasonal timing of soil replacement, exposure of the site to wind and pasture management.

Natural establishment of vegetation on the disturbed, unseeded soils of the RoW varied in different natural sub-regions (AXYS Environmental Consulting Ltd. 2003b). Trials on sandy soils were the most successful, with vegetation cover 10 percent greater on the unseeded sites than on seeded sites five years after construction. Native vegetation on sandy soils showed the greatest ability to recover quickly from short-term disturbance. Vegetation recovery from the seed or propagule bank resulted in 71 percent cover after five years while seeded soils resulted in a cover of 61 percent. More species were represented on the natural recovery sites than on the seeded sites.

On solonetzic soils in the Dry Mixedgrass subregion, natural recovery is slow with an average of only 49 percent vegetation cover present on unseeded soils. Seeded soils support marginally more vegetation (52 percent cover). Nine species were represented on unseeded sites and ten species were present on seeded sites. Over the five years post-construction, the bare patches have persisted on many of the Dry Mixedgrass solonetzic soil sites, both on seeded and unseeded sites.

Natural recovery in the fescue transition grasslands is extremely slow. Very few colonizing annual species established, leaving soils vulnerable to wind and water erosion. However, very few weeds are present in the large tracts of undisturbed rangeland in the Cypress Hills. Cover values after five years average only 34 percent although species diversity is high. Cover on seeded soils was roughly double this figure at 66 percent cover.

Non-vascular vegetation, including moss, lichen and prairie selaginella, contributes significantly to the ground cover in undisturbed grassland. Cover values are typically greatest in Dry Mixedgrass subregion solonetzic soils (average 37 percent cover) followed by fescue transition soils (average 33 percent cover). These components are less prominent in sandy soils and on the few parkland sites sampled. For all regions, on both natural recovery and seeded soils, recovery of moss and lichen (including prairie selaginella) is not noticeable five years after disturbance. The recovery period for these species is expected to be about 25 years.

Natural recovery will be influenced by the species composition of adjacent grassland and by the topography of the site. In a seeding and natural recovery experiment on a wellsite in the Northern Fescue region (Neutral Hills, Alberta) a natural recovery site was affected by its position, low on a slope with a mesic moisture regime, and the proximity of non-native species in the adjacent grassland. The resulting cover, ten years following reclamation, was predominately smooth brome (*Bromus inermis*) with smaller amounts of Kentucky Bluegrass (*Poa pratensis*), both favouring moist locations (Fitzpatrick 2005).

In the same Northern Fescue experiment, ten years recovery of one seeded block was predominately rough fescue (*Festuca hallii*), with other native species such as porcupine grass (*Stipa spartea*), fringe sage (*Artemisia frigida*), and slender wheatgrass (*Agropyron trachycaulum*) making up the majority of the rest of the species. A third block also had rough fescue and slender wheatgrass but also many undesirable forbs, e.g. Canada thistle (*Cirsium arvense*) (Fitzpatrick 2005), an invasive species of concern.

A natural recovery site was established in 1999 on a section of pipeline on a sloping open aspen parkland area in the foothills west of Cochrane (AXYS Environmental Consulting Ltd. 2003a). The area has been grazed for many years and a number of introduced species have established in the rough fescue grassland and aspen patches on the lower slopes and floor of the valley. Black Chernozemic soils were replaced after construction and branches scattered on a 2m wide ditch area to discourage cattle from creating a path or idling. After disturbance, vegetation cover increased from 0% to 50% cover in one year and to 84% cover in two years, arising entirely from the existing seed and propagule bank. The most prominent species on the RoW in 2000 and 2001 were Kentucky bluegrass and dandelion, with cover values of 22% and 11% respectively in 2002. Off-RoW, in the undisturbed vegetation in this relatively sheltered area, the dominant species is also Kentucky bluegrass. Dandelions are present in the undisturbed areas as well, forming 4% of the ground cover. Rough fescue and a variety of forbs are also re-establishing on disturbed soils on this site. This response illustrates the importance of site condition when selecting revegetation strategies. While natural recovery techniques were successful in re-establishing vegetation cover, they did not result in a community of native species, although native species form part of the cover.

Naeth et al. (1997) monitored a pipeline RoW and adjacent native grassland, in the Central Parkland, one year after construction (in 1988). Forb production was initially greater on the disturbed treatments than the control in the first year, then declined over the next three years. Forbs are frequently pioneer species and will increase following a disturbance, and then decrease as long-lived perennials become established (Naeth et al. 1997). Over the same period grass production increased, although the species differed between the disturbed and undisturbed areas. Rough fescue (*Festuca hallii*) had reduced cover in the disturbed areas, while Kentucky bluegrass (*Poa pratensis*) increased over four years (in 1991), to the same level as the control. Slender wheatgrass (*Agropyron trachycaulum*) was dominant on the disturbed areas and non-existent in the control (Naeth et al. 1997).

Subalpine, high-elevation sites are characterized by moderate to high stress conditions, e.g. a short growing season, high exposure and poorly developed soils. Zabinski and Cole (2000) concluded environmental conditions in the subalpine limit seed germination and growth, which could affect both natural recovery and revegetation results. The poor conditions in subalpine areas imply revegetation might take considerable time. This is borne out by Van ham’s (1998) assessment of a wellsite and roads on Plateau Mountain, Alberta, forty-two years after construction. She found good natural recovery of the disturbed sites, with similar species composition and richness to adjacent undisturbed areas.

In natural recovery, early seral species, such as pasture sage (*Artemesia frigida*), may appear and may not be desirable (Woosaree and James 2006). Early seral forbs that are the first to colonize a disturbed site are often species considered to be weeds. Woosaree and James (2006) found annual weeds such as Russian pigweed (*Axyris amaranthoides*) and stinkweed (*Cleomella*) cover reached up to 31% in the first year following seeding and was even higher in natural recovery areas. They concluded these weeds were not a concern since they were annuals and would soon be replaced by perennial grasses (Woosaree and James 2006). Arychuk (2001), in the Central Parkland, also found that early seed bank species emerging in disturbed sites were weedy species, e.g. lambsquarters (*Chenopodium album*), or Canada thistle (*Cirsium arvense*).

Monitoring of a pipeline reclamation project in sandy soils in the Central Parkland showed a succession of species from early seral forbs to mid and late seral species over five years. In year one, the site was dominated by sages (*Artemisia frigida* and *Artemisia ludoviciana*) and in years two and three the two sage species still remain dominant. By year five there was a decrease in the sages and several naturally occurring native species appeared on the site, including: *Festuca saximontana, Rosa woodsii, Ratibida columnifera, Heterotheca villosa, Petalostemon candidum, Arctostaphylos uva-ursi, Opuntia polyacantha* and various *Carex* spp. (Woosaree 2007b).

Natural recovery can work on small-scale disturbances, but it may take a much longer time to reach the climax plant community (Woosaree and James 2006). Soulodre (2001) concluded that natural recovery in the Dry Mixedgrass prairie would slowly progress toward a pre-disturbance community in a long as 50 years.

In the Montane and Sub-Alpine regions of the Castle Wilderness Area, Sheppard et al. (2002) recommended natural recovery for old cut-blocks, although they cautioned that complete recovery of these areas was probably not possible. They concluded that time and plant growth would gradually break up compacted soils and that most were already partially re-vegetated with native species.

A restoration project in 1991 near the Oldman River Dam in the Foothills Fescue subregion involved spreading soil from nearby native grassland on the site. A cover crop of oats was planted in the first year, and removed. Three years after the application, the amount of native species had increased from 11 to 29, and the number of exotic species was low (Smreciu and Yakimchuk 1994).

2.8 Assisted Natural Recovery

Two different revegetation techniques were used to revegetate a 1.0-1.5m wide pipeline ditch disturbance on the southern slopes of the Cypress Hills (AXYS Environmental Consulting Ltd. in association with: Kestrel Research Inc. and Gramineae Services Ltd. 2002). The project was situated in rough fescue grasslands in good to excellent range condition. The two approaches to reclamation seeding; cover cropping with an annual rye/flax mix, or using a native seed mix, produced similar cover values during the first year. During the second year of growth, the native seed treatment provided more vegetation cover than the annual rye/flax treatment (including non-seeded colonizers for both treatments). In the third year, cover values were still somewhat higher in sites seeded with native seed, with 41% cover versus 35% average cover on the rye/flax mix sites. However, the sample size is relatively small and variation was considerable between plots. The number of native species re-colonizing the disturbed soils from rhizomes, the seed bank or in-blown seed is similar for both treatments. For both treatments, the composition of native species is largely consistent with vegetation composition in undisturbed areas. Both treatments provided the same initial amount of cover or erosion protection during the first year. However, there was less vegetation cover on the rye/flax sites the second year, leaving soils more exposed to erosion. Both treatments have allowed for natural successional processes to occur. Rough fescue seedlings have established on both reclamation treatments despite drought conditions in the first two years after seeding. There has been no introduction of genetic variability using the annual rye/flax mix, as there are using native seed cultivars and non-local wild-harvested seed.

For old cut-blocks in the Montane and Sub-Alpine regions of the Castle Wilderness Area, Sheppard et al. (2002) recommended assisting natural recovery by breaking up compacted soils, using natural re-seeding of trees, and careful re-introduction of micro-organisms and animal species.

2.9 Rumsey Regionally Integrated Decision

The provincial guidelines for management of the Rumsey Natural Area could serve as an example for other sensitive areas, e.g. the southern Foothills. The Rumsey Parkland South Regionally Integrated Decision (RID) established a general framework for all forms of land use and development in the Block, including oil and gas, grazing, and recreational uses. The overall goal of the RID is "to preserve and protect the Rumsey Aspen Parkland ecosystem while allowing for responsible use of its resources" ((RID) Alberta Agriculture Food and Rural Development and Public Land Services 1993, p. 1). In terms of oil and gas development, excerpts of RID guidelines pertaining to vegetation reclamation of disturbances are:

1. General

    - Sites of rare and sensitive flora will be avoided
    - Cleared areas must be re-seeded using the seed of native grasses common to the area or as directed by the Public Lands officer who may allow natural revegetation by encroachment of native vegetation

2. Wellsites and pipelines:

    - The size and shape of the drilling site will minimize surface impact
    - The amount of clearing will be only to accommodate the actual rig and sump tanks. Presumably if drilling is conducted in the winter, the need for a larger clearing to satisfy fire safety standards is eliminated
    - Revegetate with specified Rumsey Parkland Mixture
    - Major pipelines will be routed to avoid crossing the Parkland
    - Strip and pile topsoil separately from any woody material and subsoil (so) that it can be distributed evenly over the disturbed area when operations are completed
    - Vehicle traffic is restricted to the right-of-way

The RID describes three revegetation methods, following topsoil replacement. The first, for disturbances of 4.6 m or less, allows for natural recovery of native species, with weed control and reduced grazing impact as the only two requirements. The second involves using mulch containing native seed from a similar area in close proximity of the disturbance, with grazing prohibited for at least three years. The final method entails seeding the reclaimed area with a prescribed seed mix, in this case, the Rumsey Seed Mixture.

2.10 The Alberta Prairie Conservation Forum

The Alberta Prairie Conservation Forum (PCF) is a large voluntary coalition of stakeholder groups whose members are interested in the conservation of native prairie and parkland environments in Alberta, Canada. Members include government agencies, e.g. Agriculture and Agri-Food Canada, PFRA, Alberta Agriculture, Food and Rural Development, Alberta Sustainable Resource Development, Alberta Environment, Eastern Irrigation District; non-governmental organizations, e.g. Alberta Native Plant Council, Alberta Wilderness Association, Ducks Unlimited Canada; universities; oil and gas companies, e.g. Shell Canada, Encana Corporarion; and many other interested parties, e.g. Canadian Forces Base – Suffield (Department of National Defence), Grasslands Naturalists, Ann and Sandy Cross Conservation Area.

The most recent Prairie Conservation Action Plan developed by the PCF has been revised and updated to provide a new, practical, five-year strategy that addresses both existing and new prairie conservation challenges. Pertinent components of the 2006 – 2010 PCF Action Plan are summarized as follows (Prairie Conservation Forum 2006 #5440).

Objective 1.1: Describe Alberta's native prairie and parkland landscapes by promoting, conducting, compiling and analyzing relevant research.

Actions:

1.1.1 Create a detailed grassland vegetative inventory of native and non-native species in the Grassland Natural Region.

1.1.2 Conduct a fifteen-year change analysis of the entire reconnaissance level inventory of the Grassland Natural Region including fine-scale analyses for selected sites.

1.1.3 Encourage efforts to characterize the suite of ecological goods and services provided by different landscape and land use types.

1.1.4 Monitor the network of sites in the Dry Mixedgrass, Mixedgrass, Northern Fescue, Foothills Fescue, and Parkland areas to improve our understanding about species and ecosystems.

Objective 1.3: Conduct research into key priority areas.

Actions:

1.3.1 Establish a research program on prairie ecology at a post-secondary institution in Alberta.

1.3.2 Conduct research into landscape management and multi-species approaches that sustain biodiversity.

1.3.3 Conduct research into minimal disturbance techniques on native prairie, and methods of restoring the ecological structure and function of disturbed sites.

1.3.4 Promote economic research into the value (s) of native prairie and parkland vegetation, watersheds, landscapes, airsheds, etc.

1.3.5 Develop a means to simulate cumulative effects on the prairie landscape that assesses past changes and predicts outcomes for biodiversity conservation, to be completed in the current PCAP (2006-2010).

Objective 2.1: Develop and implement policies and programs and advise on laws and regulations that encourage the conservation and restoration of Alberta's native prairies and parklands.

Actions:

2.1.1 Advise appropriate provincial agencies and municipal bodies of laws, regulations, policies, programs and activities that may be detrimental to the sustainability of Alberta's native prairies and parklands.

2.1.2 Develop clear and coherent strategies, policies and landscape level planning mechanisms that conserve and restore Alberta's native prairies and parklands.

2.1.3 Update Alberta's Wildlife Policy to incorporate the conservation of Alberta's native prairies and parklands.

2.1.4 Identify improvements that could be made to the energy disposition and licensing process that would improve public involvement and reduce the cumulative environmental effects of the energy industry on prairie and parkland ecosystems.

2.1.5 Promote policies preventing the cultivation of native prairie and parkland habitats on Alberta's Public Lands.

Objective 2.2: Support land use management practices and protective mechanisms that sustain diverse ecosystems and restore species at risk populations across the whole prairie and parkland landscape.

Actions:

2.2.1 Implement the wide use of range and riparian health assessments to enhance the level of stewardship on native prairie landscapes.

2.2.2 Encourage cooperative initiatives among agencies, NGOs and landholders; develop benchmarks for improved management and land use practices through biophysical and range inventories.

2.2.3 Implement cooperative conservation initiatives delivered by land and resource managers, landholders, industry and the public.

2.2.4 In consultation with interested and affected parties, develop and implement recovery plans at a landscape level for the highest priority landscape in each of the prairie and parkland subregions. This would include species reintroductions as required.

2.2.5 Expand riparian management programs, e.g. Cows and Fish, in the prairies and parklands.

2.2.6 Expand PCF membership to include more of the bodies responsible for making decisions affecting prairie ecosystems.

2.2.7 Identify appropriate models and practices for sustainable recreational activities and tourism on native prairie and parkland.

Objective 2.3: Protect significant, representative, and sensitive prairie and parkland ecosystems.

Actions:

2.3.1 Develop land use plans, designate parks and protected areas, and promote other mechanisms, e.g. conservation easements, to protect environmentally significant native prairie and parkland landscapes and connecting corridors on public and private lands.

2.3.2 Within five years of designating parks and protected areas, undertake biophysical inventories, develop management plans that protect ecosystem integrity, and establish monitoring programs.

2.3.3 Strengthen the inter-provincial cooperation of prairie and parkland protection in the Dilberry/Manitou Lakes area, the Middle Sand Hills/Great Sand Hills, and the Cypress/Milk River southwest pastures complex.

Objective 2.4: Restore degraded prairie ecosystems.

Actions:

2.4.1 Support management practices that help restore ecosystem functions, connectivity and biodiversity in degraded native prairies and parklands.

2.4.2 Use native plant species in weed-free, non-invasive seed mixes, for restoration within native prairie ecosystems and, where opportunity exists, on tame pastures and former croplands.

2.4.3 Support soil conservation practices on tilled agricultural lands.

2.4.4 Assess the implementation of the EUB Information Letter (IL) Guidelines for Minimizing Surface Disturbance on Native Prairie.

2.11 Current Regulations and Policy

The following are excerpts from Alberta government laws, regulations, guides and publications, relating to revegetation following oil and gas disturbance. They are sorted in order of jurisdiction.

2.11.1 The Environmental Protection and Enhancement Act

(RSA 2000 2000)

Definitions in the Act:

> "conservation" means, … the planning, management and implementation of an activity with the objective of protecting the essential physical, chemical and biological characteristics of the environment against degradation;
>
> "reclamation" means any or all of the following: …
>
> (iii) the stabilization, contouring, maintenance, conditioning or reconstruction of the surface of land

Part 6, section 137:

An operator must

(a) conserve specified land,

(b) reclaim specified land,

2.11.2 EUB Directive 56 Section 7.9.13 Environmental Requirements

(Alberta Energy and Utilities Board 2005)

> "The applicant is expected to assess each well site and access road and to develop plans to conserve, reclaim, and mitigate the effects of its activities"
>
> "If native prairie is present, the applicant is expected to follow the principals detailed in EUB IL 2002-01: Principles for Minimizing Surface Disturbance in Native Prairie and Parkland Areas"

2.11.3 EUB IL 2002-01: Principles for Minimizing Surface Disturbance in Native Prairie and Parkland Areas

(Alberta Energy and Utilities Board 2002)

IL 2002-1 section 1: "Industry should avoid disturbing native prairie. This can often be done by using existing access or non-native cover areas."

IL 2002-1 section 2: “If avoidance is not possible, disturbance should be minimized to whatever degree is absolutely necessary for a project to be constructed or operated safely and successfully.”

IL 2002-1 section 4: “Reduce overall effects. The area and intensity of the overall footprint, including other phases of the project, should be minimized.”

IL 2002-1 section 11: “Disturbances must be reclaimed to an equivalent land capability. This would be a comparable native prairie or parkland landscape… The goal is to restore prairie ecosystem function as quickly as possible and to allow for the eventual restoration of the full range of biological structure and diversity.”

IL 2002-1 section 13: “Native plants should be used in reclamation plans where appropriate.

2.11.4 Petroleum Industry Activity in Native Prairie and Parkland Areas: Guidelines for Minimizing Surface Disturbance

(Native Prairie Guidelines Working Group 2002)

> “Revegetation programs that maximize the re-establishment of native species (trees, shrubs, forbs, grasses, etc.) should be used.”
>
> “The use of nonnative species should only be considered where justified by site-specific conditions or reclamation needs. For example, using a nonpersistent, nonnative seed mix may be appropriate on a steep, erosive slope where the principal objective is to establish a vegetation cover to facilitate erosion control.”
>
> “Plant distribution should simulate off-site occurrence as much as possible. For example, shrubs may be planted in clumps, depending on the site plan.”
>
> “Under certain circumstances, natural recovery (no seeding) may be appropriate, giving consideration to topography, soils, moisture, range condition and grazing pressure, weed sources, and construction timing.”
>
> “The condition of the prairie around the site should be good (lots of seed) and the potential for erosion low. Further information regarding natural recovery may be found in the educational document: Oil and Gas: A Lighter Footprint (Sinton 2001).”
>
> “For prescribed seed mixes, there should be no substitutions without prior consultation with the appropriate regulatory agency and landowner/occupant. To ensure species compatibility and identify the presence of problem species, the company must obtain a copy of the certificate of seed analysis for each seed lot (prior to mixing) (Weed Control Act). If a problem species is identified, the seed lot may not be suitable for use.”

2.11.5 Oil and Gas: A Lighter Footprint

(Sinton 2001)

"The goal of revegetation on prairie is to re-establish sound ecological function and eventually restore the original range of variability in biological structure and diversity."

"Determining seeding rates (the number of seeds per unit area) is not an exact science due to the tremendous variability from species to species in seed size and shape, performance, and differences in seeding and growing conditions. Drill seeded rates of 10 to 12 kg/ha are more than adequate to provide an adequate vegetation cover on most sites."

"Natural recovery (no seeding) is an appropriate option in some situations. It can be used where the disturbance is small and located away from problem weed sources. The condition of the prairie around the site should be good (lots of seed) and potential for erosion low."

"[Sod salvage may be appropriate if] prairie sod [is] in good condition and thick enough to stay intact when it is cut." "Although the sod salvage technique is time consuming and expensive, it can be useful in specific situations where keeping the original vegetation is very important and the construction schedule allows for it."

2.11.6 Native Plant Revegetation Guidelines for Alberta

(Native Plant Working Group 2000).

"The use of appropriate plant materials for revegetating natural ecosystems is critical for the successful establishment of a native plant cover. Native species should be selected based on their consistency and compatibility with pre-disturbance plant communities within the Natural Subregion. The use of early successional species or native species that can survive in the altered conditions can be considered in areas where late successional species may be difficult to establish. The use of a particular species should also be technically feasible, economically viable, socially acceptable and consistent with site conditions and approved end land use."

Site preparation, e.g. weed control, seed bed preparation, create microsites

"The way that native plant materials are seeded or planted has to consider project goals, intended end land use, previous experiences with proposed methods and specific requirements of the species being used."

"Effective management of planted native stands is required to ensure that the vegetation is sustainable. Examples of management strategies may include: controlling unwanted plant species, interim protection of establishing plants and the removal of excess litter or dead plant material."

3 Interviews and Data Collection

Interviews were conducted to determine the revegetation strategies currently used on a Natural Region and Subregional basis. The purpose was to capture the local knowledge and experience of field based professionals who are required to design and propose, review and approve, or implement revegetation strategies for industrial disturbances on Public Lands.

3.1 Interviews Conducted with Sustainable Resource Development

The interviews were conducted in a workshop format at the SRD regional offices. A letter of introduction was forwarded to each regional Land Management Officer describing the project. The letter requested a suitable date when a workshop could be conducted with as many SRD Land Use Officers, Rangeland Agrologists and SRD Fish and Wildlife biolologists as possible, to make efficient use of SRD staff time and to eliminate unnecessary travel. SRD staff was very helpful in arranging staff time, central locations and facilitating key SRD contacts to improve the efficiency of the interview process.

In advance of the workshops, an information package was emailed to each location with a list of proposed interview questions and a summary of the key recommendations by the Reclamation Criteria Advisory Group (RCAG 2006) for enhancing the "Reclamation Criteria for Wellsites and Associated Facilities" (1995 Update) to facilitate discussion. The workshops were conducted in the following regional locations:

Medicine Hat	Feb. 7/07
Lethbridge	Feb. 8/07
Blairmore	Feb. 21/07
Calgary Bearspaw	Feb. 22/07
Red Deer	Feb. 23/07
Rocky Mountain House	March 22/07
Grande Prairie	March 19/07 (interview conducted via conference call as travel to location was not possible).

Each workshop was conducted with multiple members of the Gramineae team to ensure accurate recording of the issues associated with the gap analysis. At the beginning of each workshop, a brief presentation was given to inform the participants of the purpose of the gap analysis. This was followed by a Power Point presentation prepared by Ron McNeil of LandWise Inc., a member of RCAG, designed to inform participants regarding:

- What agencies, industry representatives and stakeholders are represented in RCAG;
- Why changes to the Reclamation Criteria for Wellsites and Associated Facilities (1995 Update) are necessary and timely;
- What overarching principles are guiding RCAG;
- What recommendations have been agreed to so far by RCAG, and;
- What those recommendations will mean for industry regarding pre-disturbance site assessments and the revegetation strategies implemented during development activities.

Following the Power Point presentation, the interview questions were projected on a screen and a round table discussion of the issues surrounding each question was conducted. Discussion was always lively and productive and two to four sets of notes were recorded. Following each workshop, the notes were compiled and emailed back to each regional office to ensure accuracy.

3.2 Interviews Conducted with Stakeholders

Telephone interviews were conducted with key representatives of the oil and gas sector including: Conoco Phillips, EnCana, Talisman Energy, Husky Energy, Shell Canada, Trident Exploration and Compton Petroleum; native seed supply companies including Brett Young Seeds, Pick Seeds, and Eastern Slope Rangeland Seeds, environmental consultants firms including: Tera Environmental Consulting, Rangeland Conservation Services, and Ghostpine Environmental Consulting and Cheryl Bradley; Base Environmental officers and rangeland agrologists from CFB Wainwright and CFB Suffield; the Alberta Research Council; and stewardship and conservation organizations including: Cows and Fish.

The letter of introduction, stakeholder interview questions, and a summary of the key recommendations by RCAG for enhancing the “Reclamation Criteria for Wellsites and Associated Facilities” (1995 Update) were sent via email prior to each interview. Interview dates were set and then conducted by phone. The issues and gaps identified were recorded in files for each interview. The interviews with the participants were very interesting and informative. All participants were very well informed and provided valuable practical information for the gap analysis.

3.3 Method Employed to Consolidate Key Findings and Gaps Identified from the Interviews Conducted

The method used to identify key findings and gaps from the interviews conducted was to consolidate common themes expressed during the interview process. This allows gaps to be identified in an iterative manner designed to promote further consultation and information exchange between all stakeholders.

3.3.1 Interviews Conducted with Sustainable Resource Development

The files created from each of the SRD workshops conducted were reviewed and compared to identify recurrent key findings and gaps that were brought forward in each of the workshops. These recurrent themes were consolidated and are presented in section 4.2 as “Key Findings and Gaps Specific to all Natural Regions and Natural Subregions”. These key findings and gaps are related to SRD’s commitment to environmental stewardship and identify key issues where policy changes are required.

The interview files were then further reviewed to identify key findings and gaps specific to each of the Natural Regions and Natural Subregions and are presented in section 4.3.

Recommendations for further improvement in the environmental stewardship of Alberta’s Public Lands were also consolidated from the SRD interview files and are presented in section 5.0 Draft Action Plan. SRD staff also contributed a list of topics and projects (sections 5.3 and 5.4) where policy change, research initiatives or further monitoring is required to improve the current knowledge base, and to allow science based decisions to influence future changes in revegetation policy for Public Lands.

3.3.2 Interviews Conducted with Stakeholders

The files created from each of the stakeholder interviews conducted were reviewed and the key findings and gaps identified during each interview were added to sections 4.2.and 4.3 The stakeholder interviews tended to reflect the specific area of interest and expertise of the individuals interviewed. Common gaps identified during stakeholder interviews often mirrored gaps identified by SRD, including the need to establish and consolidate terms of reference, enhance land use management, and to provide training and develop qualification standards.

Specific recommendations from the stakeholder interviews were added to each appropriate section in the gap analysis. Specific projects identified by industry that could be considered for further monitoring or research were added to the Draft Action Plan in section 5.4.

4 Gap Analysis

4.1 Key Findings and Gap Analysis from the Literature Review

4.1.1 SEEDING

Wild harvested seed presents particular difficulties, including uncertainty of the seed maturity dates, variable field conditions, the location of the seed source being not compatible with the reclamation site, the knowledge of the collector, hand-collection methods, storage methods and unreliable germination.

Native hay may be a viable technique for ensuring a reliable seed source, but its success depends on the variability of native seed production from year to year, e.g. some species do not seed every year; the timing, which will result in the dominance of whichever species have seeded at that time; and methods, such as tackifying, to keep the hay in place.

Cultivars for several native grasses are available in Canada and are widely used in the reclamation industry and in Alberta successful native plant cultivars that have been grown by the Alberta Research Council. While cultivation may improve the reliability of seed germination, it often results in a loss of genetic diversity as a result of genetic shift.

Gaps:

- Due to the difficulties of managing wild-harvested seeds, are native cultivars or ecovars™ a good alternative?
- What are the consequences of planting native cultivars from one natural subregion in a different subregion, or cultivating native cultivars from one natural region in a different natural region?
- Native seed collection could be incorporated into planning for development in an area, for example by harvesting native seed prior to development and storing it for reclamation use. Cutting and storing hay several times over a summer might be a useful technique.

4.1.2 SEED MIXES AND RATES

Recommendations for seed mixes include using less rhizomatous wheatgrasses, e.g. Western or Northern wheatgrass; using a more diverse seed mix and incorporate native species, and use broadcast seeding, which allows the incorporation of small native seeds. Seeding rate recommendations for native species have traditionally been around 10 kg/ha. However, the recommendations for seed mixes in the literature review are based on specific Natural Subregions (i.e. the Dry Mixedgrass, Northern Fescue and Central Parkland Natural Subregions) and are based on drill seeded rates. Drill seeding is not practical for all Natural Subregions and the recommended rates are specific to Natural Subregions where aridity is a key factor affecting reclamation success.

Gaps:

- Little research exists regarding optimal seed mixes or seeding rates for any of the subregions. What are the habitat requirements for specific native grassland species?
- Recommended seeding rates relate to specific Natural Subregions. What seeding rates are most effective and how do they differ by subregion?

4.1.3 SEASON OF SEEDING

The best season in which to seed native grasses depends on the species, e.g. cool-season grasses (C3), e.g. most wheatgrasses, rough fescue, June grass, benefit from spring or early spring seeding, while warm-season grasses (C4), e.g. blue grama benefit from warmer soils in late spring and early summer.

Gaps:

- While the biology of cool and warm season species is well known, the application of seasonality to seeding has been little studied. Include the preferred season for seeding based on the native species in the area.

4.1.4 TRANSPLANTS

Several research projects have shown that native grass species, especially perennial bunch grasses, can be successfully transplanted. These projects were all small scale, e.g. Montane transplant project with bluebunch wheatgrass and Richardson's needlegrass, rough fescue (Festuca hallii) and rough fescue (Festuca campestris) cuttings from mature plants in the Foothills Fescue subregion. Sod salvage has also had some success, again on a small scale.

Gaps:

- Is transplanting economically feasible on a large scale? Is sod salvage for small-scale projects really a viable technique?

4.1.5 PLANT COMPETITION

Attempts to reduce or eradicate non-native grasses in native grasslands have met with little success since some non-native species are too aggressive to be completely eliminated once established.

Gaps:

- The difficultly in eliminating several non-native species once they are established, e.g. smooth brome, Kentucky bluegrass, emphasizes the avoidance of those species in revegetation projects.
- Education and enforcement will be required to ensure only native species are seeded or transplanted where native grassland/riparian/forested areas are disturbed, or to rehabilitate sites in native grassland that had been improperly reclaimed with invasive species.

4.1.6 SOIL MANAGEMENT TECHNIQUES

Studies have shown the negative effects of topsoil storage on seedbank viability and recovery. Most successful recovery appears to be in minimal disturbance conditions, e.g. no-strip.

Gaps:

- While minimum disturbance is known to result in the best recovery, what other techniques are required and in what conditions? For example, erosion control or stream bank stabilization may require more intensive intervention.

4.1.7 NATURAL RECOVERY VERSUS SITE MANIPULATION

Natural recovery could result in an effective, though potentially slow native prairie recovery, with reduced revegetation costs and weed management. Conversely, the length of time may delay the issuance of a reclamation certificate and expose the site to erosion and weeds.

Natural recovery is not appropriate for all situations. Irrigation, fertilizer amendments or nutrient depletion may be required in certain situations when reclaiming native sites. The success of transplants may depend on irrigation soon after transplanting. Severally disturbed sites may require amendments such as fertilizer. Native species competition may be assisted by soil amendments, and weed reduction.

Gaps:

- Natural recovery may be considered the best solution for long-term recovery; however, it is not suitable in all situations. More analysis is required to determine the consequences of allowing a site to recover naturally rather than with assistance.

4.1.8 THE RUMSEY RID

The Rumsey RID provides a good template for defining best management practices for all Public lands in Alberta. However , demonstration of successful restoration is needed before oil and gas development can be considered compatible with the goal of ecosystem protection in areas of high environmental significance (e.g. protected areas) and with little known potential for restoration, such as the Rumsey Natural Area (Central Parkland Natural Subregion) and the southern foothills (Foothills Fescue, Foothills Parkland and Montane Natural Subregions).

Gaps:

- Which other provincial areas are sensitive and what management plans should be developed for those areas?
- The Rumsey RID, as accepted in 1993, provided a more progressive plan regarding reclamation practices than were routinely implemented on Public Lands at that point in time, However it does not include changes in technology that have occurred since 1993, or reflect current stakeholder concerns regarding restoration success. What science-based initiatives are required to improve the Rumsey RID model?
- How can the Rumsey model be revised, improved and incorporated into management plans for other sensitive areas such as the Foothills Fescue, Foothills Parkland and Montane Natural Subregions?

4.2 Key Findings and Gaps Specific to All Natural Regions and Natural Subregions

The Natural Regions and Subregions of Alberta (Natural Regions Committee, 2006) has been used to provide structure for the gap analysis. Implementing that structure, this report identifies gaps specific to the Foothills Natural Region, the Rocky Mountain Natural Region, the Parkland Natural Region and the Grassland Natural Region. A further delineation of gaps is provided within each Natural Region by identifying gaps specific to each Natural Subregion. Figure 1, the *2005 Natural Subregions of Alberta* map (Natural Regions Committee, 2006) illustrates the location of each Natural Subregion as currently defined in Alberta.

The goals defined in the *Prairie Conservation Action Plan 2006 to 2010* (PCAP) provided a framework for the organization of the gap analysis. The PCAP has set three clearly defined goals to be reached by 2010:

1. **Research** "*Enhance the information base for Alberta's native prairie and parkland landscapes*."
2. **Stewardship** "*Conserve Alberta's native prairie and parkland landscapes*."
3. **Education** "*Increase awareness of the value and importance of Alberta's native prairie and parkland ecosystems.*"

SRD is an active participant in the Prairie Conservation Forum and can provide valuable assistance in meeting the goals through the following gap analysis.

4.2.1 Establish and Consolidate Terms of Reference

4.2.1.1 Standardized Terminology to Assist Stakeholders in Goal-setting

When discussing revegetation strategies, goals are required that are clearly understood by all stakeholders. The terms used to describe the goals also require clear definition. For example, the term "minimal disturbance" currently has multiple definitions depending on the type of disturbance related activity (e.g. wellsite, pipeline or access road) and the location within the province the activity is planned to take place. Another example is "natural recovery". To some stakeholders it could mean applying standard practices with no seeding required or to other stakeholders it could mean a "cradle to the grave process" applied to a development activity that will provide a setting for the process of native plant succession to occur over time.

4.2.1.2 Documentation and Stakeholder Acceptance of Best Management Practices

The term "Best Management Practice" is commonly used to describe a practice that stakeholders have agreed is practical, innovative, and effective in achieving a desired result. Applied to natural landscapes, the term could apply to practices and procedures used to describe how industrial disturbance related activities will take place – while maintaining ecological health, function and operability.

The interview process indicated a lack of agreement by SRD and stakeholders regarding the success of currently implemented practices and procedures for revegetating industrial disturbances. Establishing Best Management Practices could provide a mechanism for agreement regarding revegetation strategies. No single strategy will be appropriate on a Natural Region basis given the diversity of soils, landforms, native plant communities and wildlife habitat requirements.

4.2.1.3 Organize and Consolidate Information Requirements

Consensus during the interviews indicated the Public Lands Operational Handbook requires modification to be more useful. Similarly, Energy Utility Board (EUB), Alberta Environment and SRD Information Letters, Directives, Codes of Practice and similar related materials are not readily available in a user friendly manner. They are located on numerous websites with no comprehensive, single location, via the internet. Also, there are an increasing number of new companies involved in industrial disturbances that are simply not aware of the Alberta regulatory processes. The following recommendations were compiled during the interview process:

1. A central information repository is required for all regulatory information that is easily accessible via the internet;

2. Modifying the Public Lands Handbook to address the specific issues of each Natural Region and Subregion would assist industry in identifying issues and assessment requirements. Currently the instructions for submissions for surface dispositions under the Public Lands Act are found in a separate document. Including the instructions in the revised Handbook would be more efficient. Continuing to improve and standardize the requirements of Environmental field Reports (EFR) or Area Operating Agreements (AOA) was also identified as a priority by interview participants;
3. Interview participants indicated that all existing publications regarding minimal disturbance and revegetation strategies should be reviewed and updated to reflect current conditions and levels of activity on the landscape. Key publications should be made available at the SRD district offices in hard copy;
4. The importance of active participation in the review of the Alberta's Wetland Policy was also identified by stakeholders as a priority, including a review of wetland setbacks; and
5. Creating and maintaining a central information repository for all reclamation and revegetation strategy information, including research and monitoring reports, was identified as a priority by SRD and stakeholder interview participants.

4.2.2 Enhance Land Use Management

4.2.2.1 Identification of Land Areas Highly Sensitive to Disturbance

There are sites within each of the Natural Subregions where the impact of industrial disturbance and the success of current revegetation strategies are unknown. Interview participants recommended that key indicators can be used to determine these sites based on the Natural Subregion, soils, landform, moisture and nutrient regimes, and the reference native plant communities adapted to the site. For example, topsoil depth, physical properties and nutrient regime can determine erosion risk or the potential for non-native species invasion following disturbance. To illustrate how these areas could be identified, these areas are listed by Natural Subregion in the form of Draft Prediction Confidence Tables, based on the Range Plant Community Guides developed by the SRD Rangeland Management Branch. Examples are provided in draft as Appendix B. It should be noted that further consultation with SRD and stakeholders is required to complete these tables.

Currently, there are areas where the mineral rights have been sold with no clear scientific evidence that the associated surface disturbance to the soils and native plant communities can be successfully restored. Stakeholder participants indicated the process by which mineral leases are sold for energy development requires re-examination within the SREM Land Use Framework.

4.2.2.2 Monitoring and Research Regarding Potential Revegetation Pathways

The literature review and the interview process indicated a lack of consensus and knowledge regarding potential revegetation successional pathways. The need for continued monitoring and research was identified as a priority.

4.2.2.3 Re-evaluation of Planning and Decision Documents

Consensus during the interview process indicated existing Integrated Resource Management Plans (IRP, Green Zone), Land Management Plans (LMP White Zone) and Regional Integrated Decisions (RID) require revision to accurately reflect current landscape conditions and the impact of man-made development activity on the landscape. Biophysical data needs to be updated to reflect current wildlife habitat use. The following recommendations were compiled from the interview process:

1. Protective Notations (PNT) require review and update. PNTs should embrace ecological integrity rather than simply support bio-diversity;

2. Regional cumulative effects assessments are required to monitor the impact of multiple use activities on the landscape over time. Thresholds need to be established to determine the acceptable level of multiple and sustainable use within each regional landscape; and

3. Representative areas are required within each Natural Subregion where development activity is not permitted. These areas could provide the baseline for scientific monitoring of man made disturbance related activity, within comparable ecosystems, on ecosystem function and change over time. These areas should have Protective Notations placed on them and the mineral rights withdrawn by the Department of Energy.

4.2.3 Provide Training and Develop Qualification Standards

4.2.3.1 Qualification Process for the Submission of EFRs , AOAs and EAs

At present there is no qualification requirement for consultants who submit Environmental Field Reports (EFR), Environmental Assessments (EA) and Area Operating Agreements (AOA). A combination of qualified individuals is often required to accurately assess the sensitivity to development activity. The following recommendations were compiled from the interviews:

1. Develop qualification requirements for consultants who submit EFRs and AOAs;

2. Include in the qualification requirements field based experience in construction related activities specific to the development;

3. Implement a mentoring program to ensure field based experience is passed on to new consultants; and

4. Develop specific methods for using Range Health Assessment and the Range Plant Community Guides when conducting assessments for proposed industrial activity in native rangeland. Establish qualification requirements, provide additional training and certification.

4.2.3.2 Raise Awareness of the Importance of Wetland and Riparian Function

Maintaining the ecological health and function of riparian zones adjacent to all classes of watercourses and wetlands is of major concern to SRD and stakeholders. Cows and Fish, a voluntary stewardship program funded by agricultural producer and community groups, conservation groups and government agencies, has worked extensively and successfully with the ranching and farming industries and community groups to raise awareness of the importance of riparian zones. The program has been successful in reducing the impact of agricultural activity on riparian zones. Cows and Fish has produced numerous excellent publications regarding the importance of maintaining riparian health and function. However, there appears to be a lack of awareness within industry as to what defines a riparian zone in the field, and a lack of understanding of the importance of riparian function within the landscape. The following recommendations were compiled from the interview process:

1. Establish education programs to increase industry awareness of the importance of riparian zones and their function within the landscape;

2. Establish qualifications and training requirements for the identification and assessment of riparian zones; and

3. Further research is required to determine the impact of industrial disturbance related activities within riparian zones. This includes impact to ground and surface water resources, the uncertainty of restoration success and the resulting impact to riparian habitat for all species.

4.2.3.3 Raise Awareness of the Importance of Rare Plants and Habitat Requirements for Species at Risk

The EFRs require industry to contact the Alberta Natural History Information Center regarding Species at Risk that might be encountered within the project footprint. This includes rare plants, rare plant communities and wildlife species identified under federal and/or provincial legislation. Guidelines have been established for sourcing available information and conducting the field surveys. However, where avoidance is not possible, there are no clear guidelines for acceptable mitigation options. Also there are no requirements for monitoring, and there is no standardized science-based method of evaluating the success of the mitigation implemented. Monitoring has been required and conducted for projects regulated by the National Energy Board, however the information is not readily available. The following recommendations were compiled during the interview process:

1. Available information on mitigation that has been implemented for Species at Risk (rare plants, rare plant communities or designated wildlife species) requires consolidation and review;
2. Acceptable mitigation options need to be clearly defined for Species at Risk;
3. Monitoring is required to further evaluate and determine suitable mitigation options for Species at Risk; and
4. Standardized, science-based methods of evaluating mitigation strategies are required.

4.2.3.4 Standardize Methods of Field-based Pre-disturbance Site Assessments

There currently is no standardized pre-disturbance assessment process. This makes it difficult to consistently assess proposed revegetation strategies, as information describing the pre-disturbance status of the landscape is either missing or inadequate. Generally, there is not enough information included in the reports to make adequate decisions. The following recommendations were compiled during the interview process:

1. The EFR template should be modified to reflect the biophysical issues associated with each Natural Subregion and the size and type of disturbance related activity;
2. A standardized method of field based assessment is required that is specific to each Natural Subregion. The Alberta Vegetation Inventory and the Grassland Vegetation Inventory with linkage to AGRASID, the Range Plant Community Guides, and the Range Health Assessment protocol could provide a standardized method of assessment; and
3. Standardized assessments could be attached to the disposition file through the Geographic Land Information Management & Planning System (GLIMPS), to improve the SRD audit process.

4.2.3.5 Risk Assessment as a Tool to Prioritize Erosion and Sediment Control Plans

Concerns regarding erosion and sediment control were expressed by stakeholders during the interview process. Sediment and erosion control are known to be important factors in achieving revegetation success. Technology has developed a number of erosion control fabrics, soil tackifiers, siltation control devices, and various types of matting that can be used to decrease the impact to the soils and native plant communities and enhance recovery. As well, other erosion control methods using site specific native plant material such as sod salvage, partial sod salvage, the use of “wild harvested hay” crimped into the disturbed soils are methods that have been implemented. However, there is limited documentation of success. The following recommendations were compiled during the interview process:

1. To determine the appropriate revegetation strategy, a risk assessment should be conducted to determine site specific erosion potential and the potential for sediment to enter water bodies;

2. Where erosion concerns exist, site specific erosion and sediment control plans should be developed and implemented; and
3. Monitoring should be conducted to evaluate the effectiveness of the method implemented and the information forwarded to a central information repository so that it is readily available for review by stakeholders.

4.2.4 To Seed or Not to Seed, That is the Great Debate

4.2.4.1 Define Where the Use of Natural Recovery is Appropriate

There was considerable discussion during the interview process regarding the use of native seed on reclaimed disturbances. Consensus indicated that natural recovery is the preferred revegetation strategy by both industry and SRD. However, consensus also indicated the use of natural recovery is not appropriate for all types of disturbances, nor is it appropriate in all Natural Regions and Subregions. To determine where natural recovery is appropriate, the following recommendations should be considered:

1. Clear guidelines are required indicating where natural recovery is appropriate. The guidelines must consider the size and type of disturbance, the surrounding plant community and the potential for natural encroachment to occur, topographic constraints and site erosion potential, site moisture regime, existing land use, and the presence of weeds and non-native invasive species in the surrounding landscape; and
2. Justification for the use of natural recovery must be clearly documented in the EFR.

Assisted natural recovery, through the use of non-persistent cover crops that provide initial soil stabilization while allowing natural encroachment to occur, was also a subject of considerable interest during the interview process. It was recommended that this is an area that requires further research and monitoring.

4.2.4.2 Define the Appropriate Use of Native Seed as a Revegetation Strategy

Concerns with the purity of native seed, source identification, lack of suitable species, germination potential, and the ability to spread off-site or affect the genetic integrity of native species in the surrounding landscape have been expressed by SRD, industry, and conservation groups such as the Alberta Wilderness Association and the Alberta Native Plant Council. The native seed industry is market driven and must rely on supply and demand in order to survive and continue to develop and produce suitable native species for revegetation of industrial disturbances. Interviews conducted with companies who sell native seed and companies producing native seed both indicate that markets have declined with the wide spread implementation of natural recovery. As markets decline, so do the opportunities to continue to develop and produce additional species not currently available for revegetation strategies.

The following gaps outlining some of the current problems associated with the use of native seed were identified during the interview process;

1. Three very useful guides have been published and are currently available for use when designing revegetation strategies: *The Native Plant Revegetation Guidelines for Alberta*, Native plant Working Group, Sinton-Gerling et al 2001; *A Guide to Using Native Plants on Disturbed Lands*, Sinton Gerling et al, 1996; and *Establishing Native Plant Communities*, Smreciu et al 2002. All three provide useful information for designing appropriate revegetation strategies. However, the interview process indicated that currently they are not widely used by industry;
2. Also, it appears that sourcing native seed and native plant material is often left to construction contractors, who do not have the knowledge to ensure quality standards are upheld. SRD has indicated that the native seed mixes that are documented in development applications are often very different that what is actually planted. Certificates of Seed Analysis are often not reviewed prior to purchase or provided to SRD for approval. Public Lands Update IND 2000-2, *Purity of Native Seed used for Natural Landscapes*, clearly outlines Public Lands concerns and the process for obtaining approval for the use of native seed;

3. SRD has indicated the preference for “source identified seed” to ensure that the seed is compatible with the surrounding off-site native plant communities. Although the oil and gas industry has been essentially responsible for and continues to support research and development of “source identified” native plant cultivars suited to specific Natural Regions and Subregions with the Alberta Research Council, the varieties produced are not widely used by industry;

4. Conservation groups are also concerned that the use of “source identified” native plant cultivars in sensitive plant communities may affect the genetic diversity of similar species in the surrounding native plant community, especially in protected areas such as the Rumsey Natural Area. While SRD recognizes the concern expressed, this issue requires further research, including DNA testing, to settle the debate;

5. Revegetation strategies that incorporate the use of wild harvest seed from an equivalent reference plant community within the same ecodistrict as the disturbance merits further trials and monitoring. Successful projects have been implemented in the Northern Fescue Natural Subregion, and there are projects in the Foothills Fescue Natural Subregion that may provide valuable information in the next few years; and

6. The use of wild hay harvested from adjacent native plant communities and spread on the reclaimed disturbance requires further trials and monitoring, and should be encouraged. Currently there is a trial site in the Central Parkland in the Rumsey Block and another in the Dry Mixedgrass on the Hargraves Ranch, north and east of Medicine Hat. This method has also been used for reclaiming wellsite and pipeline tie-in locations at CFB Suffield in the Dry Mixedgrass.

4.2.5 Improve and Clarify Stewardship Concerns

The interview process indicated that clarification of stewardship responsibilities is an issue that requires review within the SREM Land Use Framework. Currently industry is expected to assume the responsibility of their activities on the landscape. However, there is often a lack of demonstrated awareness of landscape values or stewardship concern during the implementation of development activities. This is a serious gap that needs to be resolved. For example, failure of existing revegetation strategies can sometimes be linked to contractor purchased seed. Currently the revegetation strategy proposed by the developer is submitted for review by SRD during the approval process. What happens after approval is often left to contractors who do not have the experience to adequately source and secure the seed. Another example is the operator who is directed to go into a wellsite located on native prairie. The access trail is wet, so the operator decides to drive on the undisturbed prairie instead, resulting in serious rutting and additional disturbance, clearly illustrating a lack of environmental awareness and responsibility. The following recommendations were derived from the interview process:

1. Empower the role of SRD Land Management Specialists. Define the role of the EUB regarding environmental compliance;

2. Provide additional training for industry and EUB regarding environmental stewardship;

3. Clarify the responsibility for adequate supervision to foster stewardship within industry;

4. Clarify responsibilities during the referral process with Fish and Wildlife, Rangeland Management Branch and the Forest Health Section of the Forestry Branch;

5. Assess SRD staffing requirements and increase staff where required;

6. Empower SRD with the right to make recommendations based on “landscape resource values”;

7. More frequent and more in-depth audits are required. More time and manpower is required for field inspections by SRD Land Management Specialists to ensure industry compliance with SRD conditions of approval;

8. Currently there is no clear mechanism for resolving non-compliance issues regarding revegetation strategies; and
9. Audit contracts are currently contracted out of Edmonton. The interview participants recommend more manpower and regional coverage to increase both frequency and depth of analysis in the audits.

4.2.6 Revegetation Strategies for Large Disturbances

The interviews conducted also indicated a need to improve revegetation strategies currently implemented for other large scale disturbance related activities such as timber harvest, mines, quarries, gravel pits and road construction.

1. Alberta Transportation and municipalities should be required to implement re-vegetation strategies that would promote healthy and sustainable native plant communities along roads and other disturbances that are adjacent to Public Lands;
2. The current reclamation criteria for quarries and burrow pits located on Public Land are inadequate and should be revised. Revegetation strategies that are compatible with the surrounding native plant communities and land use are required. A standardized pre-disturbance assessment protocol is required to enhance the Conservation and Reclamation application. Reclamation at abandonment should reflect the restoration of ecological health, function and operability;
3. The current reclamation criteria for mines should be reviewed and revised to reflect the restoration of ecological health, function, and operability at abandonment; and
4. Current revegetation strategies within the forest industry should be re-evaluated to reflect the restoration of ecological health, function, and operability within a multiple use landscape.

4.3 Key Findings and Gaps Specific to Each Natural Region and Subregion

4.3.1 Gaps Relevant to the Foothills Natural Region

The Foothills Natural Region is influenced by a moist, cool climate. Gently undulating to rolling till-covered hills and plateaus with deciduous and mixedwood forests are typical of lower elevations, and strongly rolling to steeply sloping hills with coniferous forests are prevalent at higher elevations. The Region extends along the eastern flank of the Rocky Mountains north from the Bow River valley to just south of Grande Prairie. It also includes the Swan Hills and Pelican Mountain outliers to the east and the Saddle Hills Outlier north of Grande Prairie (Natural Regions Committee 2006).

The interviews conducted with SRD staff indicated that the use of currently available native plant cultivars is limited due to the lack of species that are suitable to and adapted to the Foothills Natural Region. Sediment and erosion control are key issues associated with industrial development within the Natural Region. Where native plant cultivars have been used, initial observations by industry and SRD suggest that the currently available species do not provide adequate cover to control erosion in the first two growing seasons. Therefore, agronomic mixes, such as the recommended forestry mix, are being used for sediment and erosion control. However, the agronomic mixes inhibit forest cover re-establishment.

Gaps identified include:

- Further research is required to assess the performance of suitable short lived cover crops to provide initial erosion and sediment control while allowing natural succession to occur;
- Monitoring trials are recommended to test the performance of erosion control fabrics for erosion control on steep slopes and for sediment control devices within the riparian zone;

- Monitoring trials are recommended to evaluate the success of surface roughness manipulation methods such as spread back, roll back, furrowing and terracing combined with natural recovery, assisted natural recovery with the use of cover crops, and with native seed mixes;
- Further research is required, through the ARC native plant cultivar program, for the development of suitable native species for revegetation strategies;
- Varietal plots need to be established and monitored within the region to test the performance of currently available native plant cultivars that are suited to the natural region;
- Guidelines for seeding rates for native plant cultivars need to be established specific to the application method used within the Natural Region. Heavy seeding rates can inhibit natural successional pathways;
- Research is required to study the optimum depth of mulch that can be applied to the surface of the soil as a means of disposing woody plant material, and the impact of the mulch on revegetation success;
- Research is required to study the amount of wood chip mulch that can be incorporated in stripped and conserved topsoil, and the effect of such on revegetation success;
- The Forest and Prairie Protection Act needs to be examined regarding the accumulation of woody debris on Public Land and the amount of roll back and spread back that can be used for erosion and recreational access control;
- Research is required to determine the effects of pump-off fluids from oil and gas activities on treed ecotypes;
- Recreational activities are impacting revegetation success despite on-going efforts by industry to control access; and
- Review and revise the guidelines for the use of natural recovery. Update the 'Forested Area Natural Recovery Guide'. Currently it is the only reference material used.

4.3.1.1 Upper Foothills Natural Subregion

The Subregion includes large areas of productive timber, but is somewhat less productive than the Lower Foothills Natural Subregion due to a shorter growing season. Grazing occurs on native rangelands, on disturbed areas that have been reclaimed, and on recently harvested forest stands. Open pit coal mines have been developed and there has been intensive oil and gas exploration and development that have opened access for recreation activity (Natural Regions Committee 2006).

Northwestern portions of the subregion are occupied by the Narraway, Redrock/Prairie Creek and Little Smoky caribou herds. Recent oil and gas exploration and development activity in the Kakwa River area has resulted in the formation of the Kakwa Copton Industrial Access Planning Committee to reduce the footprint of industrial activity.

Gap identified include:

- Identification of the preferred revegetation strategy within the framework of the terms of reference of the West Central Woodland Caribou Range Team; and
- The mapping and avoidance of wetlands is an issue that requires more attention.

4.3.1.2 Lower Foothills Natural Subregion

The subregion includes some of the most productive timber production areas in Alberta. The footprint of logging operations combined with intensive oil and gas exploration and development, open –pit coal mining, livestock grazing and impact of recreational activity has resulted in a highly fragmented landscape.

Wetlands can cover 15 to 40% of the area in the valley bottoms, particularly on the benchlands and plains. Wetlands are characterized by peat accumulations up to 3 m. thick.

Gaps identified include:

- Guidelines for disturbance related activities within or near peat lands are required;
- Weed and non-native invasive species control are issues that need to be considered when designing revegetation strategies due to intense multiple use activities, including increased recreational activity; and
- Additional mapping and avoidance of wetlands and peat lands is required.

4.3.2 Gaps Relevant to the Rocky Mountain Natural Region

The Rocky Mountain Natural Region has, on average, the coolest summers, the shortest growing season, highest mean annual precipitation, and snowiest winters of any Natural Region. Unique geologic and botanical features and wildlife species of special concern such as the Grizzly bear and the Woodland caribou are found within this natural region. More than 300 rare plant species are found within the natural region, the highest concentration of rare plants in the province, occurring in the Waterton-Crowsnest area (Natural Regions Committee 2006).

4.3.2.1 Alpine Natural Subregion

The Alpine Natural Subregion is characterized by the shortest growing season of all the Natural Subregions. The growing season is too short to support tree growth, and plant communities are found on microsites protected from wind and temperature extremes. Steeply inclined to vertical bedrock exposures are typical of the subregion. There is very little soil development, reflecting both the frequent naturally occurring disturbances that rework soil profiles and low biologic activity because of acidic litter and low temperatures (Natural Regions Committee 2006). Forage productivity is very low compared to the valley bottoms and recovery from over grazing by domestic livestock will be very slow. As a result, grazing by domestic livestock should be discouraged (Willoughby and Alexander 2003).

To date there is very little industrial activity within the Alpine Subregion. Most of the subregion has been zoned prime protection within existing integrated resource plans, or is protected from resource development by designation as National Parks, Provincial Parks, ecological reserves, wilderness areas or natural areas. An example of industrial activity that pre-dates the implementation of the IRPs is the access road and well pads located within the Plateau Mountain Ecological Reserve. The process of recovery of native plant communities within the Alpine is very slow due to the short growing season, severe climatic limitations and nutrient deficient soils. ARC native plant cultivars have been developed for revegetating disturbances within the Alpine Natural Subregion, primarily for use within the mountain National Parks. Species currently available include: ARC Sentinel Spike trisetum, ARC Plateau and ARC Butte Rocky Mountain fescue and ARC Glacier Alpine bluegrass.

Gaps identified include:

- Clarification within the SREM Land Use Framework to determine whether industrial disturbance related activities should be permitted in the Alpine Natural Subregion;
- The use of natural recovery as a revegetation strategy for industrial disturbances has not been well documented to date;

- The use of locally harvested seed and cuttings to restore alpine shrubland plant communities requires further research and monitoring;
- The effect of industrial disturbance on surface and groundwater resources within the Alpine Natural Subregion requires further research;
- The effect of industrial disturbance on identified rare plants and rare plant community types is not well documented and requires further research;
- The effect of industrial disturbance on focal wildlife species and Species at Risk and their habitat requirements requires further research and monitoring; and
- The use of ARC developed alpine native plant cultivars for the revegetation of industrial disturbances requires further research.

4.3.2.2 Subalpine Natural Subregion

Short, cool, wet summers and long cold winters with heavy snows are typical of the Subalpine Natural Subregion. Vegetation patterns are influenced by elevation, topography and latitude. The Lower Subalpine zone is characterized by closed fire-origin lodgepole pine forests, with Engelmann spruce and subalpine fir with Engelmann spruce hybridizing with white spruce at lower elevations. The Upper Subalpine zone is forested by closed Engelmann spruce-subalpine fir forests that become more open near the forest line and include subalpine larch and whitebark pine (Natural Regions Committee 2006).

There appears to be a distinct difference in native plant communities within the natural region from north to south, with strong ecotonal effects from the surrounding subregions. The Central and Northern Rocky Mountains are influenced by the Upper and Lower Natural Subregions, resulting in grassland plant communities that are dominated by hairy wildrye grass, junegrass and shrubby cinquefoil. In southern Alberta the subalpine grasslands and shrublands are strongly influenced by the Montane subregion with rough fescue, Pary oatgrass and Idaho fescue dominating on south facing slopes (Willoughby and Alexander 2003).

Topography is highly variable, from moderately to steeply inclined slopes with generally narrow valley bottoms. Surficial deposits are mainly a mixture of coarse morainal deposits, with colluvial materials on the steeper slopes. Seepage is common along lower valley slopes. Unstable slopes occur throughout the region and are a concern for industrial disturbances. Wind and water erosion are also concerns for development activities once the protective vegetation is removed.

The Subalpine provides valuable wildlife habitat for focal species, such as elk, and wildlife species of concern such as Grizzly bears and Mountain caribou in the northern portions of the subregion. The subregion provides diverse recreational opportunities. Industrial activities include timber harvesting, extensive oil and gas exploration and development, and coal mining. Livestock grazing occurs on native rangelands and on disturbed areas (Natural Regions Committee 2006). Weeds and invasive non-native species are prolific in the subregion due to intense multiple use in many areas and pose a major concern for native revegetation strategies.

No single revegetation strategy was identified during the interview process. Strategies are approved on a site specific basis and depend on the type and size of disturbance. Many industrial disturbances prior to 1995 were seeded to agronomic mixes. Native seed (primarily non-source identified cultivars) has been used on pipeline RoWs, wellsites, and access roads since 1995. Natural recovery has been used in the forestry industry. However, natural recovery has not been used extensively for oil and gas related disturbances due to erosion and sediment control concerns along with concerns regarding weed and non-native species control.

Gaps identified include:

- The effect of logging operations on the spread of weeds and non-native invasive species, and the cumulative effect within multiple land use zones is not known;
- Guidelines specific to the location of log decks is required to protect sensitive native grassland plant communities;
- Best Management Practices and minimal disturbance construction techniques need to be developed for oil and gas exploration and developments, including production phase facilities such as pipelines, access roads and product processing facilities;
- Access management plans that include all land uses need to be developed to reduce disturbance and habitat fragmentation for focal wildlife species and Species at Risk;
- At present there is considerable negative impact to the recovery of existing disturbances such as seismic lines, reclaimed RoWs and access trails by recreational all terrain vehicles. Continued support for Forest Land Use Zones is required;
- Further research is required to determine suitable revegetation species that will stabilize erosion prone soils, while allowing the process of natural succession to occur through encroachment;
- Further research is required to determine suitable revegetation strategies that will reduce non-native species invasion within the disturbance and reduce the edge effect in adjacent non-disturbed native plant communities;
- The effectiveness of erosion control methods such as contour furrowing, roll back and spreadback and the use of erosion and sediment control devices should be monitored and the results reported to SRD; and
- The use of tree and shrub transplants propagated from locally available seed sources or cuttings to restore wildlife habitat requires monitoring and documentation to determine the most effective procedures.

4.3.2.3 Montane Natural Subregion

The Montane Natural Subregion occurs on lower slopes and valley bottoms of the Front Ranges south of the Bow Valley, the Porcupine Hills, and within the lower valleys of major river valleys north of the Bow Valley. The uppermost elevations of the Cypress Hills are also classified as Montane. Chinooks are frequent along the Front Ranges, and winters are warm with much less snow than in the Subalpine Natural Region. Highly variable microclimates produced by differing aspects, slope positions and wind exposures produce abrupt changes in vegetation over very short distances. Lodgepole pine, Douglas fir and aspen stands occur on easterly and northerly aspects, with grasslands on southerly and westerly aspects at lower elevations. Closed mixedwood and coniferous forests dominated by Lodgepole pine occur at higher elevations. The Montane provides important wildlife habitat, and is highly valued for recreational activity and domestic grazing. Land use includes timber harvesting, mining, oil and gas exploration and development, ranching, and major transportation corridors located in the valley bottoms. (Natural Regions Committee 2006).

Steep south facing slopes, erosion potential from both wind and water and non-native species invasion offer significant challenges for reclamation projects.

EUB Information letter IL-93-9 Oil and Gas Developments Eastern Slopes (Southern Portion) applies to the region and is currently under review.

Most of the oil and gas development in the sub-region is deep sour gas and most of the producing fields predate 1995, when the use of native seed became a condition of approval on Public Lands. However, on more recent deep sour development north of Burmis, native seed mixes have been used for production phase reclamation of wellsites, access roads and pipelines. These projects could provide insight into restoration potential.

Interviews conducted with SRD indicate the current revegetation strategy is: avoidance of native grassland where possible, minimizing the footprint of development, and the use of native seed mixes.

Gaps identified include:

- Re-generation following timber removal can be challenging in the southern part of the Montane Subregion, particularly in the Porcupine Hills, due to the potentially droughty conditions and calcareous soils;
- There is no supporting data that the rough fescue grasslands found in the Blairmore and Morley Foothills eco-districts can be successfully restored;
- Weeds and non-native species invasion is of particular concern following industrial disturbance in this subregion;
- Clearly defined access management plans are required due to increased recreational activity;
- Completion of GVI mapping is required;
- Protective Notations should be considered for old growth Douglas fir, Limber pine, rough fescue plant communities and the wildlife habitat they provide;
- Trials are required to access the success of locally harvested tree and shrub transplants in revegetation strategies to reduce the visual impact of industrial disturbances;
- The development of minimal disturbance wellsite, access road, and pipeline construction procedures are required for this region;
- Guidelines for the timing of construction activities are required and need to be clearly defined; and
- A draft prediction confidence table for the Montane Subregion is included in Appendix B.

4.3.3 Gaps Relevant to the Parkland Natural Region

4.3.3.1 Central Parkland Natural Subregion

The Central Parkland Natural Subregion occupies a broad intensively cultivated and heavily populated fertile crescent in Central Alberta. In the northern and eastern parts of the Subregion almost all of the area is cultivated, but a mosaic of aspen and prairie vegetation occupies remnant native parkland areas (Natural Regions Committee 2006). The largest remnant native parkland located in this area is found within CFB Wainwright and the Wainwright Dunes Ecological Reserve, where significant eolian deposits and active sand dunes provide habitat for unique parkland native vegetation, specific wildlife habitat features, and numerous rare plants (Wainwright Dunes Ecological Reserve Management Plan AEP, 1998).

In the southern and eastern portion of the subregion plains rough fescue is the dominant vegetation with clumps of aspen present but restricted to moister sites (Natural Regions Committee 2006). The Rumsey Block, which includes the Rumsey Ecological Reserve and the Rumsey Parkland South, is the largest remaining representative site of aspen parkland left in the world (Rumsey Parkland South RID, 1993).

Interviews conducted with SRD indicated that the current revegetation strategy includes adherence to the terms and conditions of the Rumsey RID, which specifies minimal disturbance development procedures and guidelines for revegetation strategies. SRD staff encourages continued research and the use of the best available new technology when approached with development proposals. SRD staff have worked closely with industry and the Alberta Research Council to develop “source identified” native plant cultivars for the Central Parkland Subregion; for use in the revegetation of industrial disturbances on Public lands.

Gaps identified:

- There is a need for avoidance of native rough fescue grassland;
- There is a need for further research and monitoring regarding the restoration of plains rough fescue grasslands that have been disturbed;
- There needs to be an increased awareness of the importance of ephemeral wetlands and riparian areas within the subregion. There are serious issues regarding ephemeral wetlands and high density drilling developments. Research into the cumulative effects of development on wetlands of all classes and riparian zones is required to make informed decisions on further development activity;
- Regional cumulative effects assessments are required to assist land management decisions. Thresholds for development activity are required;
- Revegetation strategies for the interim production phase development require more detailed planning;
- SRD efforts to minimize the footprint of CBM on the landscape are compromised through EUB Directive 027. This Directive deals with Shallow Fracturing Operations in gas reservoirs less than 200 meters deep. In this directive the EUB requires “verification of the cement integrity through available public data of all oilfield wells within a 200 metre radius of the well to be fractured’ as well as a minimum offset of 200 meters from water wells. As a result of this directive, industry is reluctant to use existing well sites, as they would assume liability for damage to the existing well. This increases the amount of new disturbance and associated fragmentation native prairie;
- Weeds and non-native species invasion are a major issue that affects revegetation strategies in the subregion;
- Municipal road ditches seeded to agronomic seed mixes containing Smooth brome adjacent to native parkland are of particular concern. There is an “edge affect” associated with disturbances that are seeded to agronomic species adjacent to native plant communities (Bradley et al 2002), as the seeded agronomic species spread into and modify the adjacent native plant communities;
- The spread of Leafy Spurge, a weed listed as noxious under the Alberta Weed Control Act, is a concern following disturbance related activity at CFB Wainwright. Effective control measures for this species in native grassland plant communities are unknown at present. Biological control methods such as the use of beetles that feed on the Leafy Spurge plants have not been effective, possibly due to the northern climate. Further research is required;
- IL 2002-1 requires revision to reflect current industrial activity. It should be revised to reflect the issues specific to each of the Natural Subregions; and
- Completion of the Central Parkland Range Plant Community Guide, combined with GVI mapping and the use of the Range Health Assessment protocol for pre-disturbance assessment could assist SRD during the approval process. SRD indicated completion of the Prediction Confidence Table based on the Central Parkland Natural Subregion could provide valuable assistance during the referral process.

4.3.3.2 Foothills Parkland Natural Subregion

The Foothills Parkland occurs as a narrow band along the eastern edge of the Rocky Mountain Foothills, between the Montane and the Foothills Fescue Natural sub-regions. It extends as a band northwest from the Montana border at Carway to Lundbreck, then north through the Highway 22 corridor to the Cochrane-Cremona area northwest of Calgary. The Subregion is dominated by Thick Black Chernozemic soils. Parent materials are dominantly glacial till veneer to blanket over bedrock. Climate is characterized by relatively short summers with warm days and cool nights, and long cold winters that are frequently modified by Chinook winds (McNeil 2003).

Industrial disturbance within the Subregion is concentrated primarily on private lands north of Longview in the Black Diamond-Turner Valley area. This northern portion of the Subregion has also been highly fragmented by rural residential sub-division and cultivation.

South of Longview, recent industrial activity has been limited to the construction of Highway 22 during the 1990s, looping of the TransCanada mainline pipeline in 2002, the Alta Link 600 KVA transmission line and recent exploration wells constructed near Highway 22.

Livestock grazing is the predominant land use south of Longview, combined with the production of forage crops, which supports the local ranching operations.

The Thick Black Chernozemic soils underlying the native grassland and shrubland plant communities are very fertile, and once disturbed, are prone to invasion by weeds and non-native invasive species such as timothy, Kentucky bluegrass and smooth brome. These invasive non-native species alter the ecological health, function and operability of native grassland and shrubland plant communities.

Consensus from the interview process with SRD indicated that the current revegetation strategy is avoidance of native grassland plant communities, minimal disturbance, and the use of native seed mixes.

Gaps identified include:

- Completion of Foothills Parkland Range Plant Community Guide is a priority for this subregion;
- Support for the Grassland Vegetation Inventory is required for adequate mapping of the native grassland and shrubland native plant communities;
- Clearly communicate to industry the character and location of the grasslands most at risk through tools like Protective Notations (PNTs), Information Letters and dialogue;
- Successful control of the spread of non-native invasive species in native rangeland plant communities following industrial disturbance is an area where further research is required, and should be considered a priority. Both the application of herbicides and cultural processes should be explored;
- Successful control of invasive non-native species such as timothy, Kentucky bluegrass and smooth brome on reclaimed disturbances has not been documented and is of particular concern in this subregion;
- Continued monitoring of existing and newly reclaimed disturbances over time is required to document the response of native plant community successional trends;
- The effect of herbicide application on the germination and growth of newly seeded native plant species such as rough fescue is not documented, nor is the effect of repeated herbicide applications on native plant community successional pathways; and
- Native seed mixes have been used on the Trans Canada pipeline and other disturbances in the subregion. However, there is no documentation available to indicate how the seed mixes are performing over time, whether natural encroachment is occurring, or how they are affecting native plant successional trends.

4.3.3.3 Peace River Parkland Natural Subregion

The Peace River Parkland is the smallest Natural Subregion in Alberta. It is defined in three areas by the gently rolling plains and steep south facing grassy and forested slopes along the Peace River Valley, a small level to gently undulating glaciolacustrine plain centered on Spirit River and a smaller disjunctive area of undulating to rolling glaciolacustrine plain adjacent to Grande Prairie. Although historically described as an extensive tract of "native prairie,' almost all the upland plains have been cultivated. Most of the remaining upland native grasslands occur on Solonetzic soils. Native grassland vegetation more closely resembles the Grassland Natural Region and suggests an ecosystem distinct from the surrounding Boreal landscape (Natural Regions Committee 2006).

The majority of Public Land located in the Peace River Parkland is adjacent to, or located within, the Peace River Valley. Industrial disturbance within the Peace River Valley is relatively minor compared to the uplands. Pipelines and power lines are the primary disturbances. As technology has advanced watercourse crossings are now bored or directionally drilled.

Very little Public Land is located in the uplands of the Peace River Parkland. In the white area, under grazing disposition, the leasee is consulted and the disturbance is usually revegetated to a certified tame pasture seed mix to provide forage for livestock. On vacant public land, where livestock grazing is not a priority, native seed is used to revegetate industrial disturbance.

Gaps identified include:

- Mapping of remnant native prairie plant communities on Public Lands and inclusion in GVI to ensure adequate protection from industrial disturbance;
- Completion of the Range Plant Community Guide for the Peace River Parkland Natural Subregion;
- Evaluation of the Trans Canada crossing of the Peace River at Bear Canyon where bio-stabilization methods using locally harvested native shrub cuttings and transplants were used in site specific locations to stabilize erosion prone soils; and
- Further monitoring of the sod transplant trial with *Festuca altica*, conducted by Alberta Transportation and Western Rangeland Consultants Inc.

4.3.4 Gaps Relevant to the Grassland Natural Region

The Grassland Natural Region includes the level to rolling part of Alberta, often referred to as prairie. The Region is located in the southern portion of the province and extends from the Alberta/Montana border north to the Central Parkland Natural Subregion, and west to its boundary with the Foothills Parkland Natural Subregion and the Montane Natural Subregion. Chernozemic soils and a warm, dry climate are characteristics of the Region (Natural Regions Committee 2006).

The following gaps identified are relevant to each of the four Natural Subregions within the Grassland Natural Region: the Dry Mixedgrass, the Mixedgrass, the Foothills Fescue and the Northern Fescue Natural Subregions.

- The continued development of the Grassland Vegetation Inventory (GVI) combined with the Agricultural Regions of Alberta Soil Information Database (AGRASID), the Range Plant Community Guides, and Range Health Assessment could assist SRD and industry in minimizing the impact on native prairie;
- Establish a protocol for industry collected vegetation data to be provided to SRD to facilitate further growth and refinement of the Range Plant Community Guides, thus contributing to evolving and robust ecological tools;
- IL 2002-1 requires revision to reflect current industrial activity. It should be revised to reflect the issues specific to each of the Natural Subregions;

- Guidelines that clearly define the timeframe when disturbance related activities are acceptable from an ecological perspective;
- Clear definitions are required for industrial disturbance related activity. Criteria should be established for field based assessment of "suitably dry or frozen ground conditions"; and
- Minimal disturbance should be defined more precisely and related to specific disturbance related activities, i.e. shallow gas, oil wells, production facilities, small diameter pipeline gathering systems, mid-sized production sales lines or large diameter pipelines.

4.3.4.1 Dry Mixed Grass Natural Subregion

The Dry Mixed Grass Natural Subregion occupies the south and eastern portion of Alberta. Brown Chernozems are the dominant soils, but Brown Solonetzic soils have developed where saline and sodic conditions prevail. Native grassland vegetation is characterized by low-growing, drought tolerant mixed grass communities (Natural Regions Committee 2006). This Subregion has been subjected to intense shallow gas development on Public Lands. The ranching community also relies on Public Lands for seasonal grazing, essential to sustain their operations.

The preferred revegetation strategy for the Dry Mixed Grass Natural Subregion is avoidance, minimal disturbance and natural recovery. Minimal disturbance drilling, pipeline construction methods, and natural recovery (no seed) have been used extensively for shallow gas development projects since the mid-1990s. Assisted natural recovery (seeding the disturbance with a specified short-lived agronomic cover crop, such as fall rye and flax at ½ bushel to the acre) is implemented in site specific locations to stabilize sandy erosion prone sites during periods of drought. Assisted natural recovery is generally avoided, and was used primarily during the drought of 2001-2002, and even then only for approximately 5% of disturbed sites.

There is no specific strategy for larger disturbances, so reclamation is planned on a site specific basis with natural recovery being first choice whenever possible. Field observations by SRD staff and industry indicate that minimal disturbance development combined with natural recovery is suited to the arid climate and native plant communities of the subregion.

Gaps identified:

- The cumulative effects of increased development activity on the landscape is an issue that must be addressed in land use planning. The decreased well spacing for shallow gas development allowed by the EUB is of particular concern, and should be addressed by SREM;
- The impact of the intensive level of activity for shallow gas development on other traditional land uses, such as livestock grazing, is not known. The extent to which the native plant communities can recover from impact of industrial disturbance and fragmentation, combined with current stocking rates and grazing practices is unknown. The recent in-fill drilling program in the Koomati and Casa Barardi areas of CFB Suffield, or the present well, road and pipeline density in the Manyberries Badlands may be examples where the threshold of sustainable development has been exceeded. Thresholds need to be established for wildlife Species at Risk such as the Sage Grouse and the Burrowing Owl, as they may be the key indicators of ecological function;
- Access management plans on a sub-regional basis should be established to reduce the fragmentation of native prairie. Co-operation between companies in the oil and gas sector is required with shared responsibility for the maintenance of designated access requirements;
- There is a lack of field supervision of contractors by industry, resulting in unnecessary impact and disturbance. Currently there is no requirement for on-site environmental field monitors to deal with environmental issues and ensure compliance. Sub-regional planning units could help identify areas where environmental monitors are required;

- Research and monitoring is required to accurately evaluate current minimal disturbance procedures and natural recovery revegetation strategies. Science based initiatives are required;
- Field observations from SRD staff indicate that steep slopes, choppy sandhills and solonetzic or saline soils can be difficult to reclaim and revegetate in the Dry Mixedgrass;
- Minimal disturbance construction procedures, that reduce or eliminate soil handling, are required for oil wellsites;
- Guidelines for the type of equipment used to install pipelines are required to reduce disturbance. The type (i.e. spider plough vs. plough) should be defined by season of activity and by soil type, then the information should be made available to contractors;
- Re-evaluation after ten years would provide very useful information on the progress of revegetation and site restoration on large diameter pipelines where soil stripping was required. Express Pipeline & TCPL are recommended as possible research projects within the area. Express pipeline has permanently marked monitoring sites that were established 10 years ago;
- There is insufficient research and information on reclamation and revegetation strategies, and how they affect Species at Risk. It is recommended that comparative studies be implemented to evaluate the effects of different revegetation strategies on Species at Risk;
- Weeds and invasive non-native species invasion could present additional challenges on large disturbances. It is not known if natural recovery is suited to large industrial disturbances, particularly if stripped replaced soils have been stored for more than a growing season; and
- There is a need for a proactive, scientific based assessment and planning approach to proposed highway through Lodge Valley before it is approved for construction.

4.3.4.2 Mixedgrass Natural Subregion

The Mixedgrass Subregion occurs in a broad fertile band of intensely cultivated prairie in south central Alberta. Dark Brown Chernozemic soils define the subregion. The climate is slightly moister than the Dry Mixedgrass, with somewhat cooler summers and milder winters. Native vegetation communities are similar to the communities found in the Dry Mixedgrass, however the higher productivity and occurrence of species associated with the cooler and moister conditions differentiate this Subregion from the Dry Mixedgrass. Two transitional areas occur: Cypress Hills Upland between the Cypress Hills Montane and the Dry Mixedgrass; and the Milk River Upland is a zone of transition between the Dry Mixedgrass and the Foothills Fescue Natural Subregions (Adams et al 2005). This subregion has also been subjected to intense shallow gas development. Parcels of Public Lands are smaller and more isolated than in the Dry Mixedgrass Natural Subregion. The ranching community also relies on seasonal grazing on Public Lands to sustain their operations.

The preferred revegetation strategy for the Mixedgrass Natural Subregion consists of minimal disturbance followed by natural recovery. The strategy works for 75% of smaller disturbances, like small diameter pipelines, and is fairly adequate. There are no specific strategies in place for larger disturbances.

The following gaps have been identified during the interview process:

- There is insufficient data on the cumulative effects of development activity in the highly fragmented Mixedgrass Natural Subregion. Given the intensity of activity, the long term outcome of the current revegetation strategies with multiple use is unknown. Thresholds for development activities need to be established;
- The decreased well spacing for shallow gas development allowed by the EUB is of particular concern, and should be addressed by SREM. The Mixedgrass is already a highly fragmented landscape. The remaining native prairie tends to occur on relatively isolated areas of Public Lands. The impact on the native plant communities and range health, livestock carrying capacity, wildlife habitat for focal species, and species at risk is unknown. There is currently insufficient base data to formulate conclusions;

- Minimal disturbance lease construction strategies for oil production sites are required to reduce disturbance while ensuring that issues of possible contamination are addressed;
- There is no current revegetation strategy for large disturbances such as gas plants or oil batteries;
- Ammonite mines are large scale disturbances that will need to be reclaimed, and will require specific revegetation strategies appropriate to the site;
- Best Management Practices for minimal disturbance drilling and pipeline construction have been established, but they should be reviewed and revised to capture past experience of field based personnel. The BMPs should reflect new advances in technology and should be updated on a regular basis;
- Access management plans on a sub-regional basis should be established to reduce the fragmentation of native prairie. Co-operation between companies in the oil and gas sector is required with shared responsibility for the maintenance of designated access requirements;
- There are no monitoring requirements currently in place for gathering systems and small diameter pipelines. These programs add significantly to the fragmentation of the native prairie landscape;
- Pre-disturbance assessments for sand or gravel dispositions are inadequate;
- The impact of chemical contaminate spills on native prairie vegetation requires further research;
- Disturbances in the Mixedgrass are more prone to invasion by non-native species, such as Crested wheatgrass and Smooth brome, due to higher moisture regimes and more fertile soils than the Dry Mixedgrass. Natural recovery may not be suited to all native plant communities in the Mixedgrass, particularly in highly fragmented areas;
- Subsoil handling and minimal disturbance practices should be researched more for problem soils;
- More information on native plant sucessional pathways is required to improve revegetation strategies. What is the order of plant succession and therefore the trajectory? ;
- More research is required regarding the specific triggers required to stimulate native grass seed production; and
- A draft prediction confidence table for the Mixedgrass Natural Subregion is included as Appendix B.

4.3.4.3 Foothills Fescue Natural Subregion

The Foothills Fescue Natural Subregion occupies an irregular south-north belt between 15 to 100km wide, extending north from the Alberta-Montana border to northwest of Drumheller. The Subregion has the highest precipitation, warmest winters and shortest growing season of any of the Grassland Natural Subregions. Proximity to the mountains and a greater incidence of Chinooks are both responsible for these characteristics. The Subregion has many native plant species in common with the adjacent Mixedgrass, Foothills Parkland and Montane Natural Subregions. Black Chernozemic soils distinguish this Natural Subregion from the Mixedgrass and the Northern Fescue Natural Subregions (Natural Regions Committee 2006). The Foothills Fescue Natural Subregion includes four Ecodistricts. From south to north are: a highland area on the Milk River Ridge named the Del Bonita Plateau, the Cardston Plain, the Willow Creek Upland which occurs at lower to mid elevations on the flanks of the Porcupine hills and the Delacour Plain, which is entirely on the plains, densely populated and, mainly under cultivation. There are two isolated occurrences of Foothills Fescue also within the Mixedgrass Natural Subregion, between Mossleigh and Milo called the Buffalo Hill Upland where elevations are higher than the surrounding plains (Adams et al 2005). Foothills rough fescue plant communities are dominant with reference plant communities responding to moisture regime, aspect, and soils. The Subregion provides diverse wildlife habitat including critical winter range for elk and mule deer.

On Public Lands, domestic grazing is the primary land use and the grasslands provide valuable grazing for the ranching industry. Other land use includes Oil and Gas exploration and development as well as recreation. The private lands are becoming increasingly fragmented by rural residential development and gravel extraction.

Interviews conducted with SRD indicate the current revegetation strategy for industrial disturbance on Public Lands is avoidance, minimal disturbance and the use of native seed mixes.

The issue regarding the success of revegetation strategies that have been implemented on past industrial disturbances in the Foothills Fescue Natural Subregion has long been disputed by the ranching community and conservation groups.

Gaps identified include:

- To date, there is no evidence to support that rough fescue plant communities can be restored to the pre-disturbance plant communities;
- Completion of GVI mapping is required;
- Clearly communicate to industry from the time of mineral sales forward, the character and location of the grasslands most at risk through tools like Protective Notations (PNTs), Information letters and dialogue;
- Minimal disturbance drilling and construction techniques are not well developed in this subregion. Pad drilling is used in some areas to reduce the footprint of disturbance on the landscape. However, Best Management Practices, incorporating innovative techniques and the best available technology, are required to reduce the impact of lease, access road and pipeline construction;
- The highly variable climate offers significant challenges for developments including extremely high winds in the form of Chinooks, periods of drought, and sudden high precipitation events in the form of either snow or rain. The impact of climate on industrial development in the Foothills Fescue is not well understood by industry;
- Foothills rough fescue, the dominant native grass, is very difficult to grow from seed. It is only available through wild harvest and is an erratic producer of seed. To date, propagation methods are not well understood;
- On a recently reclaimed natural recovery site, competition from invasive non-native species such as Kentucky bluegrass appears to present the greatest difficulty for restoration success. Natural recovery may only be appropriate where there is minimal soil disturbance on well drained range sites with high rangeland health scores. Clear guidelines for the use of natural recovery are required;
- There is a need for continued monitoring of existing, recently constructed wellsites, access roads and pipeline projects in this subregion. Further research is required for older wellsites to determine if native plant successional trends are occurring;
- Further research in the development of suitable native plant cultivars is required. The Alberta Research Council is in the process of developing a proposal;
- Due to the relatively short growing season and the ability of rough fescue to store energy and remain dormant during periods of drought, the timing of construction and reclamation activities is of considerable importance in this subregion. Clear guidelines are required;
- EUB Information letter IL 93-9 applies to Oil and Gas Developments in the western portions of this Subregion. It is currently under review and the issue of the uncertainty of restoration success should be considered by reviewing agencies;

- Research is required to assess the revegetation success of the reclaimed gravel pit on Public Lands in the Ross Lake Community Pasture, north and west of Del Bonita in the Del Bonita Plateau ecodistict. The reclaimed site was seeded with Foothills rough fescue, wild harvested in close proximity to the site. The Public Lands Agrologist has kept very good records. The site is ideally suited for a detailed monitoring project;

- Continued support, guidance and information sharing is required for several monitoring projects and research trials presently being conducted by Compton Petroleum in the Foothill Fescue Natural Subregion; and

- A draft prediction confidence table for the Foothills Fescue Natural Subregion is included in Appendix B.

4.3.4.4 Northern Fescue Natural Subregion

The Northern Fescue Natural Subregion occupies a 50 to 80 km crescent, bordered on the north by the Central parkland natural Subregion and on the south and west by the Dry Mixedgrass, Mixedgrass and Foothills Fescue Natural Subregions. Hummocky to rolling hill systems with medium textured glacial till deposits occur to the east, south and west; the central portion is a gently undulating fine textured till and lacustrine plain. Plains rough fescue dominated communities are found on mesic sites in remnant native prairie. Drier than average sites support grasses typical of mesic sites in the Mixedgrass and Dry Mixedgrass Natural Subregions. Moister than average sites support native shrubland plant communities. Dark Brown Chernozems are the dominant soils. Agriculture is the primary land use with about 55% under annual cultivation. Domestic grazing occurs on the remainder of the area. There is significant oil and gas development and surface coal mining occurs as well (Natural Regions Committee 2006).

Interviews with SRD indicated the current revegetation strategies follow Regionally Integrated Decisions (RID) with outcome based focus towards the end land use, which is retention of native grassland and domestic grazing. The Rumsey RID model applies on Public Lands providing direction for industrial disturbance activities.

Gaps identified include:

- GVI mapping of native grassland plant communities;

- Completion of Rangeland Plant Community guide for the Northern Fescue Natural Subregion;

- Completion of a Prediction Confidence Table for the Northern Fescue Natural Subregion;

- Continued research is required to establish the preferred revegetation strategy for the Northern Fescue Natural Subregion. Monitoring trials conducted on abandoned cultivation in the Special Areas could provide valuable insight into the use of natural recovery;

- Research regarding native species encroachment and establishment in old crested wheat pastures may also be useful. The competitive ability of crested wheat grass, over time, in the Northern Fescue Natural Subregion is not well understood; and

- Research is required regarding the success of locally harvested plains rough fescue on abandoned cultivation in the Special Areas. Projects have been completed that are now over ten years old.

5 Draft Action Plan

Gramineae and associates were asked to provide SRD with a framework for a Draft Action Plan. It is recommended that the goals of the action plan include:

Goal 1. Enhance the information base for the Grassland Natural Subregions, the Parkland Natural Subregions, the Foothills Natural Subregions and the Rocky Mountain Natural Subregions.

Goal 2. Improved environmental stewardship of Alberta Public Lands.

Goal 3. Improved communication and information between all stakeholders.

Goal 4. Define and establish research initiatives based on the gap analysis.

The framework provided in the draft action plan is designed to address the gaps identified and recommendations included in sections: 4.1 Key Findings and Gap Analysis from the Literature Review; and 4.2 Gaps Specific to Natural Regions or Natural Subregions. Where appropriate, recommendations are further expanded to assist SRD when preparing the plan in consultations with stakeholders.

Objectives of the draft action plan include:

1. To provide a framework for review and discussion within SRD, SREM and with stakeholders that can be revised and adopted through an iterative and consultative process. The action plan should establish priorities and set a timeline for implementation; and
2. To provide a list of the research or monitoring projects provided by SRD and industry that will assist SRD and stakeholders.

Priorities for the development of the action plan include:

- Posting this report on the Integrated Land Management (ILM), web page to facilitate a wide review of the document by all stakeholders;
- Finalizing the Boreal Gap Analysis and posting the report for review on the ILM web page;
- Presenting this report to SREM to respond to requests for clarification;
- Presenting this report at workshops held with SRD staff and industry representatives at key locations where there is uncertainty regarding the outcome of current revegetation strategies. It is recommended that these workshops be arranged and conducted early in the 3rd quarter of 2007;
- Similar workshops are recommended following the completion of the Boreal Gap Analysis;
- Establishing priorities and funding for research initiatives with the research institutions and proceeding with the chosen priorities in 2007; and
- Establishing a central repository for information sharing.

5.1 Establish and Consolidate Terms of Reference

5.1.1 Standardize Terminology

Create a glossary of standardized terms for review, revision and adoption by stakeholders.

5.1.2 Documentation and Stakeholder Acceptance of Best Management Practices

Explore this gap with stakeholders who are currently working on establishing BMPs. It is recommended that a process be defined to regularly review and update BMPs as new information and technology become available.

5.1.3 Organize and Consolidate Information Requirements

Review the gaps identified and implement the recommendations.

5.2 Enhance Land Use Management

The opportunity exists within the SREM Land Use Framework to evaluate existing and future land use initiatives on Public Lands. The opportunity is timely, given the increased pressure of industrial activity on Public Lands and the uncertainty that ecosystem health, function, and operability can be maintained with the existing levels of multiple uses. An example of the public's concern regarding conflicting land use is validated in the co-ordination and implementation of the Southern Foothills Regional Cumulative Effects Study.

The Alberta Prairie Conservation Action Plan provides practical direction, in the form of a strategic plan, for conserving native prairie and parkland landscapes throughout Alberta. Now is the time to focus and apply the vision, guiding principles, and goals on a regional basis.

Regional Land Use Strategies should be evaluated for Public Lands within each Natural Subregion. A suitable model exists in the Great Sand Hills Land Use Strategy initiated in June 2004 by the Great Sand Hills (GSH) Land Use Strategy Review Committee. The GSH Land Use Strategy 2004 was tabled and reviewed by the Government of Saskatchewan. The government's response (GSH Land Use Strategy Review, 2004) to the report indicated that the overall future approach would be one of integrating environmental and economic interests while maintaining a high degree of environmental protection. To achieve this:

- Existing protected areas were substantially consolidated and increased;
- A Regional Environmental Study (by impartial, internationally recognized ecological experts) was engaged to consider the cumulative human impacts in the area to date and make scientific recommendations regarding future land use in the area; and
- While existing mineral rights are honored, a moratorium on further mineral sales is in place.

There are a number of ongoing initiatives that can provide the framework for decision making. The Grassland Vegetation Inventory, combined with the Range Plant Community Guides developed for each Natural Subregions, and AGRASID provide useful tools for identifying areas that require focus for integrated land use initiatives. This information, linked with current knowledge or lack of knowledge of restoration success following industrial disturbance, could assist in identifying areas that require Regional Integrated Decisions or further protective status.

While all Natural Regions and Subregions have unique areas of high conservation value, it is hoped that the following summary is of assistance during decision making:

1. **Central Parkland Natural Subregion**: The subregion is highly fragmented, with isolated Public Lands representing the largest remaining Parkland Ecosystem in the world. Restoration of ecosystem health function and operability following disturbance is undocumented to date. Includes extensive wetlands, aspen parkland, plains rough fescue grassland and diverse wildlife habitat. Invasive non-native species such as Smooth brome a serious issue for revegetation strategies. Rumsey RID applies, but requires review and update.
2. **Foothills Fescue, Foothills Parkland and Montane Natural Subregions**: Successful restoration of Foothills rough fescue grasslands has not been documented. These highly valued grasslands are the “backbone” of long term, sustainable ranching operations in the southwestern part of the province. The climate presents numerous challenges for industrial development. Revegetation success is hampered by invasive non-native species such as Kentucky bluegrass, Timothy and Smooth Brome; and limited seed availability. The key that unlocks the mystery of rough fescue restoration has not been found. Often considered as Alberta’s “signature landscape”, development activity is always a subject of public controversy.
3. **The Dry Mixedgrass Natural Subregion**: These native grasslands have born the brunt of the shallow gas activity that has substantially contributed to the wealth of this province. Industry has been innovative in reducing disturbance and natural recovery, which does work well in this arid landscape. However, the impact of decreased well spacing allowed by the EUB and the resulting fragmentation of the native plant communities that are relied upon for recovery remains unknown. This combined with the impact of grazing, which is vital to the sustainable ranching economy, is also unknown. There are signs that wildlife and the loss of wildlife habitat may provide key indicators that the threshold of multiple use development may already have been exceeded.
4. **Northern Fescue Natural Subregion**: These grasslands are highly fragmented with the remaining undisturbed native grassland in isolated areas such as the Hand Hills and the Neutral Hills. There is significant oil and gas activity and coal mining as well. Again successful restoration of plains rough fescue grassland following disturbance is not well understood or documented to date.
5. **The Mixedgrass Natural Subregion**: These native grasslands are more fragmented than the Dry Mixedgrass. Cooler climate, higher moisture regimes, and deeper more fertile soils can hamper natural recovery in some areas. This is due to increased fragmentation by adjacent agricultural activity and the ability of the native plant communities to compete with invasive non-native species, such as smooth brome and crested wheat grass. The issues of development are similar to the Dry Mixedgrass; intense shallow gas development, oil development and decreased well spacing allowed by the EUB. These grasslands are also very productive for livestock grazing when well maintained. Again, it is not known if the threshold of multiple development activity may have already been exceeded.
6. **Rocky Mountain and Foothills Natural Regions:** Watershed issues and the reassessment of Prime Protection Zones are major conservation and stewardship issues that need to be addressed by the SREM Land Use Framework. Timber harvest, oil and gas development and recreational activity have increased substantially in the last ten years, resulting in increased fragmentation. The ability of the native plant communities and associated wildlife habitat to sustain ecological health and function is unknown.

5.3 Provide Training, Develop Capacity and Develop Qualification Standards

1. Continued workshops within SRD regarding regional revegetation strategies are recommended to promote information sharing between agencies. The Reclamation 100 Course held at Hinton, Alberta annually could provide a valuable vehicle for information sharing within SRD.

2. SRD needs to immediately persue capacity building in the application of cumulative effects monitoring tools and indicators as well as the establishment of land use footprint thresholds for native landscapes. This capacity building needs to preceed priorities, strategies and recommendations that may emerge in the next 12 to 18 months from the SREM land Use Framework. Local projects could be established to evaluate current footprints using accepted and emerging indicators, so that staff will begin to factor the use of such tools into their everyday decision making processes.

3. It is recommended that Cows and Fish be contacted to discuss the organization of field based stewardship workshops with industry to raise awareness of the importance of the riparian zones and the important functions that all classes of wetlands perform within the landscape. The workshops should include identification of all classes of wetlands and riparian zones. It is recommended that surface land agents, surveyors, seismic companies, construction consultants, environmental consultants, drilling contractors, and pipeline contractors be involved in the workshops. Funding for these workshops could come from CAPP or other industry related organizations.

4. Information workshops and presentations are required to inform surface land agents, petroleum engineers, and petroleum geologists of the challenges faced regarding development in each of the Natural Regions and Subregions. These industry professionals can influence the purchase of mineral leases and surface lease site selection, so they need to be well informed.

5. The Alberta Chapter of the Canada Land Reclamation Association is a well established organization committed to information sharing.

6. GVI training and workshops related to the use of GVI are required to increase the Grassland and Parkland knowledge base as well as improve the accuracy of pre-development planning and site assessments.

7. Range Health Assessment Workshops designed for environmental consultants and tailored to assessments for industrial development are recommended. Focus on information sharing with Public Lands Agrologists. A mentoring program should be established to ensure accurate data collection, as experience is needed to accurately complete the assessment. A list of qualified consultants is required to ensure accuracy of data collection. This program combined with GVI training could prove to be the most valuable asset in determining revegetation strategies for Public Lands.

8. Annual workshops and field tours are recommended in each SRD regional area to facilitate identification of regional issues, and to facilitate information sharing with industry. Invitations should be sent out to industry representatives with interests in the area, as well as their field based personnel, and all consultants and construction companies working in the area. This process has worked well in the Central Parkland Natural Subregion and the Northern Fescue Natural Subregion. The Southern Alberta Sustainable Community Initiative Oil and Gas Sub-Committee meet on a regular basis, and could be approached to discuss regional issues and BMPs.

9. Conducting information workshops, field tours and mentoring programs with post secondary education institutions such as: the regional community colleges (Lethbridge, Olds, Lakeland, Grande Prairie); and the Universities of Alberta, Calgary and Lethbridge; will enhance the development of the next generation of professionals in the environmental sciences.

5.4 Identified Research Initiatives

Priorities need to be set when considering research initiatives. An advisory committee is recommended to avoid duplication of effort, and to provide funding for the projects.

5.4.1 Funding Options

1. The Reclamation Research Technical Advisory Committee (RRTAC) performed this function in the 1980s to the mid 1990s with funding through the Heritage Trust Fund. During the interview process, representatives of Shell Canada, Talisman and Husky recommended that the RRTAC process should be re-evaluated, revised where required for improvement, and re-instated within the SREM model.
2. The "New Energy Innovation Fund" announced by the Department of Energy, August 30, 2006, which has dedicated $200 million dollars over the next three year period to support energy development and environmental protection, could be a source of funding for reclamation and revegetation research.
3. The oil and gas industry has contributed significantly to revegetation research over the last twenty years through the Canadian Association of Petroleum Producers and through individual projects initiated by petroleum production companies and pipeline transmission companies. These industry initiated projects have contributed significantly in the production of the native plant cultivars that are available today for revegetation strategies. These companies have also contributed funding to many of the currently ongoing research and monitoring projects.
4. Regional oil and gas producer groups have also been established with the goal of working together to co-ordinate monitoring programs and share information to achieve improved environmental stewardship. An example is the Southern Alberta Sustainable Community Initiative (SASCI), a community based initiative headquartered in Pincher Creek. An oil and gas sub-committee has formed that is working toward improved reclamation through information sharing and joint funding of regional environmental initiatives.

5.4.2 Projects Identified

The following research initiatives and monitoring projects were brought forward for discussion during the interview process:

1. Research initiatives to study the cumulative impact of decreased well spacing and infill drilling on range health and stocking rates. Recommended areas are Majorville in the Mixedgrass and the Koomati area of CFB Suffield in the Dry Mixedgrass Natural Subregion.
2. Research initiatives are required to fully understand the impact of industrial activity on the riparian zone and all classes of wetlands. Mapping of all classes of wetlands in all Natural Regions would provide valuable information and should be considered a priority. Wellsites and access trails located less than 100 meters from permanent and ephemeral wetlands are of particular concern. A research initiative that would evaluate the impact of development activity on ecosystem health and function would provide valuable input to Alberta's Wetland Policy.
3. Continued support for the research initiatives currently underway regarding development activity in the Rumsey Block in the Central Parkland Natural Subregion. Contact Dr. Anne Naeth, University of Alberta.

4. Continued monitoring of the recent use of wild harvested hay on a pipeline in the Rumsey Block. Contact Kirsty Venner, Trident Exploration
5. Continued research at the ARC on the development of additional native plant cultivars suitable for revegetation strategies for the Upper and Lower Foothills Natural Subregions. Contact Jay Woosaree, Alberta Research Council. Establish native plant cultivar varietal plots within each subregion.
6. Research initiatives are required to assess the impact on the ecological health and function of peatlands in the lower Foothills Natural Subregion.
7. Research into revegetation strategies currently used in Caribou Protection Areas in the Foothills Natural Region. Also, research into the reclamation practices and revegetation strategies required to restore the moss and lichen components of caribou habitat on reclaimed wellsites, access road, and pipeline RoWs.
8. Research into the optimum depth of mulch that can be applied to the surface of the soil as a means of disposing woody plant material, and the impact of the mulch on revegetation success in the Foothills and Rocky Mountain Natural Regions and specific to each of the Natural Subregions.
9. Research is required to study the amount of wood chip mulch that can be incorporated in stripped and conserved topsoil, and the effect of such on revegetation success in the Foothills and Rocky Mountain Natural Regions and specific to the Natural Subregions.
10. Continued support for Stephen Tannas in his research at the University of Alberta into rough fescue restoration using nursery raised plugs and divided transplants in the Foothills Fescue. Contact: Kurtis Averill, Compton Petroleum.
11. A research initiative to assess the potential success of a gravel pit reclamation project in the Foothills Fescue Natural Subregion. Locally collected, wild harvested, rough fescue seed was used. Very good records have been kept. Site is located on the Del Bonita Plateau in the Ross lake Community Pasture. Contact: Jake Willms, SRD, Lethbridge.
12. Continued monitoring of the recent use of wild harvested hay mulch in pipeline revegetation on the Hargrave Ranch in the Dry Mixedgrass. Contact Tracey Kupchenko, SRD Medicine Hat. Also, a similar project at the Park Lake Recreation Area in the Mixedgrass may provide valuable insight. Contact: Ken Pitcher, SRD Lethbridge.
13. Re-evaluate reclamation trial sites on Express Pipeline 10 years after construction and reclamation. This could provide valuable insight into the progress of the revegetation strategies implemented over time on a large diameter pipeline. The TransCanada Eastern mainline and Alliance Pipeline may also provide very valuable information.
14. Research initiative to evaluate success of Crested wheat grass control on a pipeline in the Dry Mixedgrass. Contact Bill D'Andrea, Conoco Phillips.
15. Continued evaluation of trial sites on wellsites in the Foothills Fescue and Foothills Parkland, with Compton Petroleum. Sites located on the a7 ranch, seeded to wild harvested rough fescue to monitor germination and competitive ability of seeded rough fescue; and a controlled burn to control Kentucky bluegrass on a natural recovery wellsite, Bill Cross Ranch. On the Cross Ranch, seeding trials will be established to evaluate the use of annuals to reduce soil fertility of decomposing sod and control Kentucky bluegrass. Contact Kurtis Averill, Compton Petroleum, Marilyn Neville or Varge Craig.
16. Additional seeding trial sites may be available on the Waldron Ranch (Foothills Fescue) with involvement of ARC. Contact Varge Craig.

17. Continued monitoring of seeding trial with Foothills rough fescue, on Public Lands: access trail to CPR train wreck site, Lundbreck, Alberta, also trial sites in Pole Haven. Contact Jody Best, SRD Pincher Creek.

18. An assessment of native vegetation species recovery of Shell Waterton Corner Mountain wellsite and access road development in the Sub-alpine to Alpine Natural Sub-regions with the AWA. Contact Roger Creasey, Shell Canada.

19. Continued monitoring of native seed mix trials on recent Shell Waterton Pipeline in the Carbondale area, Contact Rod Sinclair, Shell Waterton.

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Appendix A Range Site Definitions

Table 3. Ecological Range Site Definitions

Ecological Range sites with revised definitions and abbreviated AGRASID correlations.

From Adams et al (2004).

[Z]Ecological/ Range Site	Revised Definition	AGRASID 3.0 (ASIC 2001) Correlation
Water (Wa)	Any permanent open body of water, including lakes, reservoirs and rivers.	Undifferentiated water bodies (ZWA) and W1, W2 or W3 landscape model.
Subirrigated (Sb)	Water table is close to surface during growing season, but rarely above.	Gleyed non-saline medium- to coarse-textured soils.
Riparian (Ri)	Zone most closely adjacent to stream and river channels. Also known as the lotic zone.	Any SLM with floodplain or stream channel landscape model (FP1,FP2, FP3, SC1-l, SC1-h, SC2, SC3or SC4)
Overflow (Ov)	Areas subject to water spreading and sheetflow. Typically on gentle inclines or terraces prone to stream overflow.	Inclined, low relief landscapes including fans and aprons; or soils developed on fans, aprons or terraces.
Wetland (WL)	Typically low-lying or depressional positions subject to occupation by water ranging from temporary to semi-permanent in duration. Also known as the lentic zone.	Non or weakly saline Gleysols or Organic soils. OR undifferentiated water bodies (ZWA) with any landscape model **except** W1, W2 or W3.
Clayey (Cy)	Clayey textured soils including silty clay, sandy clay, clay, and heavy clay. Generally >40% clay.	Fine- and very-fine-textured soil groups.
Loamy (Lo)	Includes loam, silt loam, silt, clay loam, sandy clay loam, and silty clay loam.	Medium- and moderately-fine textured soil groups.
Sandy (Sy)	Sandy-loam-textured soils.	Moderately coarse soil group.
Limy (Li)	Eroded or immature soils with free lime ($CaCO_3$) at the soil surface. Soil pH generally >7.5.	Eroded, Rego and Calcareous soils or subgroups.
Sand (Sa)	Loamy sand and sand soils, and not with a duned surface.	Very-coarse-textured soil group and not on duned landscape models.
Blowouts (BlO)	Areas with eroded surface pits reflecting the presence of abundant Solonetzic (hardpan) soils.	Dominant or Co-dominant Solonetzic Order Soils.

[z]Ecological/ Range Site	Revised Definition	AGRASID 3.0 (ASIC 2001) Correlation
Choppy Sandhills (CS)	Loamy sand and sand soils with a duned land surface.	Very-coarse-textured soil groups with duned landscape models.
Thin Breaks (TB)	Areas with bedrock at or near the soil surface; largely vegetated. May include thin, eroded or immature soils on gentle to steep landscapes.	Landscape models I3m and I3h; OR layered, medium, or fine materials with mas pm of L6, L7, L8, L16, M5, or F5.
Shallow to Gravel (SwG)	Soil with 20 to 50 cm of a sandy or loamy surface overlying a gravel or cobble- rich substrate.	Layered materials denoted by mas pm (parent material) codes L4 or L5.
Saline Lowland (SL)	Areas with negligible vegetation due to electrical conductivity (salts) and/or sodium adsorption ratio limitations.	Saline Regosolic or Saline Gleysolic series OR sodic Regosolic series.
Gravel (Gr)	Dominated by gravels or cobbles (>50% coarse fragments). May be covered by a mantle with few gravels, up to 20 cm thick.	Layered or coarse materials with mas pm codes L1, L17, L19, L21 or C1.
Badlands/ Bedrock (BdL)	Nearly barren lands with exposures of softrock or hardrock. Includes steep valley walls.	Specific Landscape Models I4h, I5.
Urban (Urb)	Cities, towns, or disturbed lands.	Any SLM with DL landscape model.

For more information on AGRASID Correlation Symbols/Abbreviations visit the database website at: http://www1.agric.gov.ab.ca

Appendix B Prediction Confidence Tables

Table 4. Mixed Grass Natural Subregion Prediction Confidence Table

Ecodistrict	Ecological Range Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction confidence
Milk River Upland	Overflow 1	MGB2 Snowberry/Kentucky Bluegrass-Tufted Hair Grass	Minimal	Natural recovery	Moderate, disturbance may increase Kentucky Bluegrass
			Significant	Assisted natural recovery or native seed required	Moderate, disturbance may increase Kentucky Bluegrass
	Overflow 2	MGC2 Snowberry/Green Needle Grass-Kentucky Bluegrass	Minimal	Natural recovery	Moderate, disturbance may increase Kentucky Bluegrass
			Significant	Assisted natural recovery or native seed required	Moderate, disturbance may increase Kentucky Bluegrass
	Loamy 2	MGA10 Idaho Fescue-Northern Wheatgrass-Needle and Thread	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Moderate, Idaho fescue may not recover
	Loamy 6	MGA14 Needle and Thread-Northern Wheatgrass-June grass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Moderate, depending on range health scores
	Sandy 1	MGA 16 Needle and Thread-Northern Wheatgrass-Sand Grass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Moderate
	Blowout 2	MGA9 Silver Sagebrush/Northern Wheatgrass-June Grass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Moderate
	Thin Breaks 2	MGA20 Northern Wheatgrass-Needle and Thread-June grass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Low, site not suited to major disturbance
	Saline Lowlands 2	MGA19 Salt Grass-Western Wheatgrass-Sedge	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Low, site not suited to major disturbance
Cypress Upland	Loamy 1	MGA1 Plains Rough fescue-Western Porcupine grass-Sedge	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low

Ecodistrict	Ecological Range Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction confidence
Cypress Upland (Cont. from previous page)	Loamy 4	MGA30 Western PorcupineGrass-Northern Wheatgrass-June grass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Moderate
	Loamy 5 low elevations	MGA4 Needle and Thread-Northern Wheatgrass-June grass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Moderate
	Blowout 1	MGA5 Needle and Thread-Plains Rough Fescue-Western Wheat Grass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Low
	Shallow to Gravel	MGA31 Plains Rough Fescue-Northern Wheatgrass-Western Wheatgrass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Low
	Gravel	MGA7 Plains Rough Fescue-June Grass-Northern Wheatgrass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Low
	Thin Breaks 1	MGA8 Plains Rough Fescue-Plains Muhly	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Low, site not suited to major disturbance
	Saline Lowlands 1	MGA6 Salt Grass-Sedge-Western Wheatgrass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Low, site not suited to major soil disturbance
Lethbridge-Vulcan-Majorville Plain	Loamy 3	MGA21 Wheatgrass-Needle and Thread	Minimal	Natural recovery	High
			Significant	Assisted natural recovery or native seed required	High
	Loamy 7	MGC Snowberry/Needle and Thread-Low Sedge-Northern Wheatgrass	Minimal	Natural recovery	High
			Significant	Assisted natural recovery or native seed required	High
	Sandy 2	MGA 25 Snowberry/Northern Wheatgrass-Needle and Thread	Minimal	Natural recovery	High
			Significant	Assisted natural recovery or native seed required	High
	Sands 1 Little Bow	MGA28 Snowberry/Needle and Thread-Sand Grass-Low Sedge	Minimal	Natural recovery	High
			Significant	Assisted natural recovery or native seed required	High

Ecodistrict	Ecological Range Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction confidence
Lethbridge-Vulcan-Majorville Plain (Cont. from previous page)	Saline Lowlands	MGA29 Sand Grass-Foxtail Barley-Western Wheatgrass	Minimal	Natural recovery	High
			Significant	Assisted natural recovery or native seed required	Low, site not suited to major soil disturbance
Blackfoot Plain	Limy (Li)	Unconfirmed Plant Community	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low
	Sandy (Sy)	MGA24 Needle and Thread-Low Sedge-Pature Sagewort	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Moderate
	Loamy (Lo)	MGA22 Needle and Thread grass-June Grass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Moderate
Standard Plain	Clayey (Cy)	Unconfirmed plant community,	Minimal	Natural recovery	Moderate,highly fragmented landscape
			Significant	Assisted natural recovery or native seed required	Moderate, highly fragmented landscape
	Loamy (Lo)	MGA22 Needle and Thread grass-June Grass	Minimal	Natural recovery	Moderate, highly fragmented landscape
			Significant	Assisted natural recovery or native seed required	Moderate, highly fragmented landscape
Sweetgrass Upland	Loamy (Lo)	MGA34 Foothills Rough fescue	Minimal	Natural recovery	Low, avoidance recommended
			Significant	Assisted natural recovery or native seed required	Low, avoidance recommended
	Limey (Li)	Unconfirmed plant community	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low
	Blowouts (BlO)	Unconformed plant community	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low
	Thin Breaks (TB)	MGA8 Plains Rough Fescue-Plains Muhly	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low, site not suited to major disturbance

Ecodistrict	Ecological Range Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction confidence
Sweetgrass Upland (Cont. from previous page)	Shallow to gravel	MGA31 Plains Rough Fescue-Northern Wheatgrass-Western Porcupine Grass	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low
	Gravel	MGA7 Plains Rough Fescue-June grass-Northern Wheatgrass	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low

Table 5. Foothills Fescue Natural Subregion Prediction Confidence Table

Ecodistrict	Ecological Range Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction Confidence
Del Bonita Plateau					Rated as High, Moderate or Low
	Loamy (Lo)	FFA1 Rough fescue-idaho fescue-western wheatgrass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Moderate to Low
	Shallow to gravel (SwG)	FFA2 Rough Fescue-Idaho Fescue-Sedge	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Low, site not suited to major disturbance
	Thin Breaks (TB)	FFC6 Creeping juniper/Northern and Western Wheatgrass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Low, site not suited to major disturbance
	Limy (Li)	FFA29 Northern and Western Wheatgrass-Rough Fescue	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Moderate
	Gravel	FFA2 Rough Fescue-Idaho Fescue-Sedge	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Moderate
	Overflow (Ov)	FFA9 Rough Fescue -Parry Oatgrass-Kentucky Bluegrass	Minimal	Natural recovery	Low, may increase Kentucky Bluegrass
			Significant	Assisted natural recovery or native seed required	Low, competition needed to prevent increase in Kentucky Bluegrass
	Clayey (Cy)	FF24 Foothills Rough fescue-Northern and Western Wheatgrass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Low
	Sub-irrigated	FFA15 Undifferentiated Sedge-Kentucky Bluegrass-Tufted hir Grass	Minimal	Natural recovery	Low, may increase Kentucky Bluegrass
			Significant	Assisted natural recovery or native seed required	Low, site not suited for major soil disturbance
Cardston Plain	Clayey (Cy)	FFA5 Foothills Rough Fescue-Parry Oat Grass	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low

Ecodistrict	Ecological Range Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction Confidence
Cardston Plain (Cont. from previous page)	Limy (Li)	FFA29 Northern and Western Wheatgrass-Rough Fescue	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low
	Loamy (Lo)	FF6 Parry Oatgrass-Rough Fescue-Kentucky Bluegrass	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low
	Loamy (Lo2)	FFA2 Rough Fescue-Idaho Fescue-Sedge	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low
	Blowouts (BlO)	FFA24 Foothills Rough fescue-Northern and Western Wheatgrass	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low
	Thin Breaks (TB)	FFA17 Foothills Rough fescue-Parry Oat Grass-June Grass	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low, site not suited to major disturbance
	Overflow (Ov)	FFA27 Northern and Western Wheatgrass-Green Needle Grass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Low site not suited to major soil disturbance
	Sub-irrigated	FFA15 Undiffertiated Sedge-Kentucky Bluegrass-Tufted hair grass	Minimal	Natural recovery	Low, may increase Kentucky Bluegrass
			Significant	Assisted natural recovery or native seed required	Low,site not suited to major soil disturbance
Willow Creek Upland	Loamy (Lo1)	FFA5 Rough Fescue-Parry Oatgrass	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low
	Loamy (Lo2)	FF2 Rough Fescue-Idaho Fescue-Sedge	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low
	Thin Breaks (TB)	FFA17Foothills Rough Fescue-Parry Oat Grass-June Grass	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low, site not suited to major disturbance
	Limy (Li)	FFA29 Northern and Western Wheatgrass-Rough Fescue	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low

Ecodistrict	Ecological Range Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction Confidence
Willow Creek Upland (Cont. from previous page)	Shallow to gravel (SwG)	FFA9 Rough Fescue-Parry's Oatgrass	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low
	Gravel	FFA9 Rough Fescue-Parry Oat Grass	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed required	Low
	Overflow (Ov)	FFA27 Northern and Western Wheatgrass-Green Needle Grass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Low, site not suited to major soil disturbance
Buffalo Hill Upland	Loamy (Lo)	FFA1 Foothills Rough Fescue-Idaho Fescue-Western Wheat Grass	Minimal	Natural recovery	Low, highly fragmented landscape
			Significant	Assisted natural recovery or native seed required	Low, highly fragmented landscape
Delacour Plain	Loamy (Lo1)	FFA5 Rough Fescue-Parry Oatgrass	Minimal	Natural recovery	Low, highly fragmented landscape
			Significant	Assisted natural recovery or native seed required	Low, highly fragmented landscape
	Sandy (Sy)				
	Sand and Choppy Sandhills				
	Saline Lowland (SL)				
	Blowouts (BlO)				
	Shallow to gravel (SwG)				
	Gravel				
Milk River Ridge	Loamy (Lo3)	FFA1 Rough fescue-Idaho Fescue-Western Wheatgrass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Moderate

Ecodistrict	Ecological Range Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction Confidence
Transitional to Mixed grass	Loamy (Lo4)	FFA24 Foothills Rough Fescue-Northern and Western Wheat Grass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Moderate
Landscape	Overflow	FFA27 Northern and Western Wheatgrass-Green Needle Grass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Low, site not suited to major soil disturbance
	Subirrigated site	FFC2 Beaked Willow/Sedge-Tufted hair grass	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed required	Low, site not suited to major soil disturbance
	Wetlands			Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances
				Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances
	Riparian Lotic			Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances
				Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances

Table 6. Montane Natural Subregion Prediction Confidence Table

Moisture/Nutrient Regime	Ecological Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction Confidence
Subxeric/poor	**a limber pine/juniper**	E2 Pf-Fd/Juniper/Bearberry	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Avoidance, site not suited to major disturbance	
Subxeric/medium	**aa Bluebunch wheatgrass grassland**	B3 Bluebunch wheatgrass-Sedge	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		A1 Fringed sage/Junegrass	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Avoidance, site not suited to major disturbance	
		A2 Northern wheatgrass-Sheep fescue	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Avoidance, site not suited to major disturbance, steep slopes	
		A3 Small leaved everlasting/Junegrass	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		A4 Creeping juniper/N. wheatgrass-C. needlegrass	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Avoidance, site not suited to major disturbance, steep slopes	
		A5 Little clubmoss/Richardson needlegrass	Minimal Soil Disturbance	Avoidance,possibly a unique plant community	
			Significant Soil Disturbance	Aviodance, possibly a unique plant community	
		B5. Big sagebrush/B. wheatgrass-Sedge	Minimal Soil Disturbance	Avoidance, unique plant community	
			Significant Soil Disturbance	Avoidance, unique plant community	
		B6 Saskatoon-Rose-Snowberry/Bearberry	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low

Moisture/Nutrient Regime	Ecological Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction Confidence
Submesic/poor	**b bearberry**	E3 P1 Bearberry - Juniper	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Avoidance, site not suited to major disturbance, steep slopes	
		F1 Aw-Fd/Bearberry	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		G1Aw/Bearberry/Rough fescue	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		E4 Sw-Pl/Alder/Bearberry	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low, site may be limited by nutrient regime
		D1 Yellow mtn. avens - River alder/low forb	Minimal Soil Disturbance	Avoidance, site indicates a groundwater seep	
			Significant Soil Disturbance	Avoidance, site indicates a groundwater seep	
		D2 Yellow mtn avens/Junegrass	Minimal Soil Disturbance	Avoidance, site indicates riparian zone	
			Significant Soil Disturbance	Avoidance, site indicate riparian zone	
		F2 Sw-Pl-Pb/Yellow Mtn. avens	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Avoidance, site not suited to major disturbance, riparian zone	
		A7 bearberry - juniper	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
Submesic/medium	**c Canada buffalo-berry/hairy wild rye**	E6a Fd/needle litter	Minimal Soil Disturbance	Assisted natural recovery or native seed mix required	Low, disturbance could increase Kentucky bluegrass
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low, disturbance could increase Kentucky bluegrass

Moisture/Nutrient Regime	Ecological Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction Confidence
Submesic/medium	**c Canada buffalo-berry/hairy wild rye** (continued from previous page)	E6 Fd/Hairy wildrye	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Avoidance, site not suited to major disturbance, steep slopes	
		E5 Pl/Buffaloberry/Pinegrass	Minimal Soil Disturbance	Natural recovery	Low, if invasive species are present
			Significant Soil Disturbance	Avoidance, site not suited to major disturbance, steep slopes	
		E7 Pl/Dwarf bilberry/Hairy wildrye	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		F3 Aw-Pl/Buffaloberry/Hairy wildrye	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		G2 Aw/Rose/Hairy wildrye	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		G3 Aw/Hairy wildrye	Minimal Soil Disturbance	Assisted natural recovery or native seed mix required	Low, disturbance could increase invasive species
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low, disturbance could increase invasive species
		F5 Aw-Sw/Blueberry	Minimal Soil Disturbance	Assisted natural recovery or native seed mix required	Low, disturbance could increase invasive species
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low, disturbance could increase invasive species
		B2 Idaho fescue-Parry oatgrass-rough fesce	Minimal Soil Disturbance	Assisted natural recovery or native seed mix required	Low
			Significant Soil Disturbance	Native seed mix required	Low
		B4 Rough fescue-sedge/Bearberry	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		E1 Pf/Rough fescue	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Avoidance, site not suited to major disturbance, steep slopes	

Moisture/Nutrient Regime	Ecological Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction Confidence
Submesic/medium	**c Canada buffalo-berry/hairy wild rye** (continued from previous page)	I1 Foothills rough fescue - Western porcupine grass	Minimal Soil Disturbance	Natural recovery	Moderate,site located in Cypress hills
			Significant Soil Disturbance	Assisted natural recovery	Moderate,site located in Cypress hills
submesic/rich	**cc Rough fescue grassland**	A11. Rough fescue-Fringed brome-Sedge	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		A12. Rough fescue-Sedge-Junegrass	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Avoidance, site not suited to major disturbance, steep slopes	
		B1 Rough fescue-Idaho fescue-Parry oatgrass	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		B15 Rough fescue-Hairy wildrye	Minimal Soil Disturbance	Natural recovery	Low, due to climatic conditions
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low, due to climatic conditions
		I2 Shrubby cinquefoil/Foothills rough fescue-Intermediate oatgrass	Minimal Soil Disturbance	Natural recovery	Moderate,site located in Cypress hills
			Significant Soil Disturbance	Assisted natural recovery	Moderate,site located in Cypress hills
		I4 Shrubby cinquefoil/Foothills rough fescue-Idaho fescue	Minimal Soil Disturbance	Natural recovery	Moderate,site located in Cypress hills
			Significant Soil Disturbance	Assisted natural recovery	
		Forest succession			
		B8 Fd/I.fescue-R.fescue	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		B9 Fd/I.fescue-S.bluegrass	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Avoidance, site not suited to major disturbance, steep slopes	

Moisture/Nutrient Regime	Ecological Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction Confidence
submesic/rich	**cc Rough fescue grassland** (continued from previous page)	B9 Fd/I.fescue-S.bluegrass	Minimal Soil Disturbance		
			Significant Soil Disturbance		
		B9 Fd/I.fescue-S.bluegrass	Minimal Soil Disturbance		
			Significant Soil Disturbance		
mesic/medium	**d creeping mahonia-white meadowsweet**	E10 Sw-Fd/White meadowsweet	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		E10a Fd/Snowberry	Minimal Soil Disturbance		
			Significant Soil Disturbance		
		F4a Fd-Aw/Pinegrass	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		F6 Aw-Fd/White meadowsweet	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		E8 Pl/White meadowsweet	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		E9 Pl/Pinegrass	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		E11 Pl/Moss	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		I7 Pl-Aw/Bunchberry/Moss	Minimal Soil Disturbance	Natural recovery	Moderate, site located in Cypress Hills
			Significant Soil Disturbance	Assisted natural recovery	Moderate, site located in the Cypress Hills
		E12 Sw/Moss	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		G4 Aw/White	Minimal Soil Disturbance	Natural recovery	Low

Moisture/Nutrient Regime	Ecological Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction Confidence
mesic/medium	**d creeping mahonia-white meadowsweet** (Cont. from previous page)	meadowsweet/Pinegrass	Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		G5 Aw/Rose/Pinegrass	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		A10 Bog birch-Sedge-Rough fescue	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		B6a Snowberry-Rose-Saskatoon	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low, may increase aspen and decrease Rough fescue
		B7 Pinegrass-Hairy wildrye/strawberry	Minimal Soil Disturbance		
			Significant Soil Disturbance		
mesic/rich	**e thimbleberry/pinegrass**	E13 Pl/Thimble berry	Minimal Soil Disturbance		
			Significant Soil Disturbance		
		E14 Pl/Thimbleberry/Beargrass	Minimal Soil Disturbance	Natural recovery	Low, little is known of Beargrass re-establishment
			Significant Soil Disturbance	Natural recovery	Low, little is known of Beargrass re-establishment
		E15 Pl/River alder/Thimbleberry	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Natural recovery	Low
		G10 Aw/Thimbleberry	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		G11 Aw/Cow parsnip	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Low
		F7 Aw-Pb-Sw/Pinegrass	Minimal Soil Disturbance	Natural recovery	Moderate
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Moderate

Moisture/Nutrient Regime	Ecological Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction Confidence
mesic/rich	**e thimbleberry/pinegrass** (continued from previous page)	F8 Aw-Fa/Snowberry/Pinegrass	Minimal Soil Disturbance	Natural recovery	Moderate
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Moderate
		G8 Aw/Snowberry-Saskatoon	Minimal Soil Disturbance	Natural recovery	Moderate
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Moderate
		E16 Sw/Thimbleberry	Minimal Soil Disturbance	Natural recovery	Moderate, low if invasive species are present
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Moderate,low if invasive species are present
		B11 Thimbleberry brush	Minimal Soil Disturbance	Natural recovery	
			Significant Soil Disturbance	Avoidance recommended site not suited to major disturbance, steep slopes	
		B14 Forb meadows	Minimal Soil Disturbance	Natural recovery	Low, rough fescue component could be lost
			Significant Soil Disturbance	Avoidance recommended site not suited to major disturbance, small isolated sites with Rough fescue component	
subhygric/rich	**f balsam poplar**	F11 Spruce-Pb/Snowberry	Minimal Soil Disturbance	Natural recovery	Moderate
			Significant Soil Disturbance	Assisted natural recovery or native seed mix required	Moderate
		G12 Pb/Thimbleberry	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Avoidance due to presence of rare plant	Low
		G15 Aw/Birch-Willow	Minimal Soil Disturbance		
			Significant Soil Disturbance		
subhygric/very rich	**g meadow**	D3 Bebb willow/Hairy wildrye	Minimal Soil Disturbance	Natural recovery	Low
			Significant Soil Disturbance	Avoidance recommended	
		D5 G.alder-S.willow-Raspberry	Minimal	Natural recovery	Low
			Significant		

Moisture/Nutrient Regime	Ecological Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction Confidence
subhygric/very rich	**g meadow** (Continued from previous page)	D10 Dwarf birch-S.cinquefoil/Valerian/Sedge	Minimal	Natural recovery	Moderate
			Significant		
		D13 Water birch-Smooth willow/Pinegrass	Minimal	Natural recovery	Moderate
			Significant		
		B13 Tufted hairgrass-Baltic rush	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed mix required	Low
		A9 Tufted hairgrass-Sedge	Minimal	Natural recovery	Moderate
			Significant	Assisted natural recovery or native seed mix required	Moderate
hygric/rich	**h horsetail**	F12 Sw-Aw/Scouring rush	Minimal	Natural recovery	Low may increase Kentucky bluegrass
			Significant	Assisted natural recovery or native seed mix required	Low, may increase Kentucky bluegrass
		E12a Sw/Horsetail	Minimal		
			Significant		
		E12b Sw/Silverberry/Horsetail	Minimal		
			Significant		
		D7 Flat lv'd willow/Horsetail/Sedge	Minimal	Natural recovery	Low
			Significant		
subhydric/rich	**ij fen**	E17 Sb-Lt/Labrador tea	Minimal		
			Significant		
		D12 Sb/Willow/Wire rush-Sedge/Moss	Minimal		
			Significant		
		D2a Drummond's willow	Minimal		
			Significant		
		D3a Bebb willow/Beaked sedge	Minimal	Natural recovery	Low
			Significant	Assisted natural recovery or native seed mix required	Low, may encourage invasive species invasion
		D8 Mrytle lv'd willow/Sedge	Minimal		
			Significant		

Moisture/Nutrient Regime	Ecological Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction Confidence
subhydric/rich	**ij fen** (Continued from previous page)	D9 Basket willow/Sedge	Minimal	Natural recovery	Low, may encourage invasive species invasion
			Significant	Assisted natural recovery or native seed mix required	Low, may encourage invasive species invasion
		D11 Sw/Willow/Water sedge/Golden moss	Minimal	Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances.
			Significant	Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances.
		B12 Beaked-Water Sedge	Minimal	Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances.
			Significant	Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances.
		B12a Awned sedge	Minimal	Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances.
			Significant	Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances.

Moisture/Nutrient Regime	Ecological Site	Reference Plant Community	Degree of Soil Disturbance	Revegetation Strategy	Prediction Confidence
subhydric/rich	**ij fen** (Continued from previous page)	B17 Creeping spike rush	Minimal	Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances.
			Significant	Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances.
		B18 Small fruited bulrush	Minimal	Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances.
			Significant	Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances.
		B19 Great bulrush	Minimal	Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances.
			Significant	Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances.
		B20 Cattail	Minimal	Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances.
			Significant	Avoidance only	Preserve ecological integrity by avoiding disturbance and provide acceptable setback distances.