DEVELOPMENT OF RECLAMATION BENCHMARKS AND TARGETS IN THE
ATHABASCA OIL SANDS REGION OF ALBERTA, CANADA

By

EVELYNE MORAA NYAIRO

B.Sc., The King’s University College, 2003

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the requirements for the degree of

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We accept this thesis as conforming
to the required standard

..........................................................
Dr. Vivienne Wilson, Thesis Supervisor

..........................................................
Dr. Lenore Newman, MEM Program Head
School of Environment and Sustainability

..........................................................
Dr. Tony Boydell, Director
School of Environment and Sustainability

ROYAL ROADS UNIVERSITY
Victoria BC Canada
June 2009

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ABSTRACT

Alberta’s Athabasca Oil Sands Region (AOSR) is located in the boreal forest region of northeastern Alberta. The oil sands in this region are ranked as one of the world’s largest oil bearing formations. All oil sands operators are required by legislation to return disturbed land to capabilities similar to those that existed prior to the mining activities taking place, and as development continues, sustainable reclamation targets and benchmarks are necessary to ensure sustainable growth. This research reviews case studies in related extraction industries that have developed and successfully implemented reclamation benchmarks and targets. To demonstrate how lessons learned from these case studies could be implemented in the AOSR, a management plan has been developed that is focused on the reclamation of tailings ponds.

Key words: reclamation, benchmarks and targets, oil sands, sustainability, governance, resilience, revegetation, landform.
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“Education is the ability to perceive the hidden connections between phenomena”. To my loving daughter Eliana Bianca this is for you. Education is the only gift that cannot be taken away from you. I pass the gift of education to you just like it was passed to me. May you live to achieve more. Thank you for being so supportive and reminding me what I needed to do to complete this program. To my family members: thank you for being there all the time. My mother Elizabeth, it is my sincere hope that completing this program, fulfills one of your wishes for me. Mom, I hold dearly the three things that you asked me to accomplish. My father Johnson Nyairo, thank you for setting the foundation, the words you instilled in me at a young age motivated me through this research. My girl friends that took care of Eliana so I could take the program: Stephanie Robinson, Rim Tanta, Dana Strasser, Alice Omayo, Jenifer Portas and Anita Pohl your support is greatly appreciated. My Canadian Mom Jane White, your words of wisdom are appreciated. My cousin Joyce I hope you do know how much I appreciate all the good work you have done with Eliana and the support that you have given me. My friend and mentor Patricia Brost, you have inspired in different ways, Pam Poon, thank you for your support starting from the proposal phase, my former colleagues at MWH Canada Inc., Margot Ferguson, and Jenica von Kuster you have supported me in different ways for which I am very thankful. Gillian Donald, you were the foundation of this research, thank you for being there for me.

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1 CHAPTER ONE

1.1 INTRODUCTION

1.1.1 Background

Alberta’s crude bitumen resources are contained in three oil sands regions - the Athabasca, Cold Lake, and Peace River regions, which together occupy an area of about 140,000 km$^2$ (Figure 1). Development is occurring in all three regions, with the most extensive occurring in the Athabasca Oil Sands Region (AOSR) in northeast Alberta.

Oil sands development in Alberta has intensified over the past few years. Several aspects have driven the pace and magnitude of the development in the AOSR. In particular geopolitical pressures and economics are among the top drivers, as sources of energy and new strategic supplies of fuel are being developed. The availability of economical and secure supplies of crude oil are especially important to nations like the United States of America (USA), which consumes approximately 25% of the world’s energy supply (Utilis Energy [UTILIS], 2006). Uncertainty, created as a result of instability in the Middle East, has driven the USA to seek crude oil supplies that are closer to its demand base, making Canada’s close proximity and political stability more favourable. In recent years, reserves of conventional crude oil have decreased while the worldwide demand for oil has increased. As conventional crude oil production has matured and declined, the significance of oil sands development has increased at an international level to offset the decline (UTILIS, 2006). The current regulatory environment has also driven development. Increasing development in the region has resulted in higher oil sands-derived revenues gained by the Province of Alberta in the form of royalty payments from oil sands operators.

There is a critical need to develop achievable and appropriate benchmarks and targets for the reclamation of developed land in the oil sands regions. Alberta’s environmental and natural resource management systems are designed to ensure that disturbed areas are reclaimed to reach a capability equivalent to pre-disturbance conditions (Alberta Environment [AENV], 1999a, 2001). Since a large part of the oil sands development involves the AOSR, a Regional Sustainable Development Strategy (RSDS) focused on this region has been developed by the Alberta government to ensure a
balance between development and environmental protection (AENV, 1999a, 2001). Maintaining sustainable ecosystems, end land uses, and reclamation performance are among 72 issues of concern that require sustainable development strategies at a project and regional level (AENV, 1999b). The province of Alberta recently released a province-wide Land Use Framework that recognizes the challenges and pressures that economic growth is placing on Alberta’s landscape (AENV, 2008a). The Framework lays out an approach of managing public and private lands and natural resources to ensure that Alberta’s long-term environmental, social and economic objectives are achieved (AENV, 2008a). A “cradle to grave” approach to resource development that encompasses progressive reclamation is required in order to achieve these regional and provincial objectives. Progressive reclamation is continuous reclamation and rehabilitation of mined land as mining operations continue (Indian and Northern Affairs Canada [INAC], 2002).

The objective of this research is to explore how sustainable reclamation benchmarks and targets can be developed for mineable oil sands found in the AOSR. To achieve the research objective the following activities were carried out:

- A review of how related extraction industries like coal, gold and uranium mining have developed reclamation benchmarks and targets;

- An examination of the lessons that can be learned from these industries and the degree to which these targets and benchmarks are applicable to the AOSR; and

- An assessment of how previously developed reclamation benchmarks relate to the regional sustainability strategies that have been developed for AOSR by the Alberta Government.
Figure 1: Alberta Oil Sands Deposits

1.1.2 Issue Description

Oil sands were first identified by the First Nations people of northern Alberta who used bitumen found in outcroppings along the Athabasca River to waterproof their canoes (Syncrude, 2003). Early European explorers also noted the bitumen outcroppings. It was not until the mid-1930s that oil was first extracted from the oil sands by Absands Oil Limited (Syncrude, 2003). Today the oil sands have been well mapped and are estimated to contain 1.71 trillion barrels of bitumen (Alberta Department of Energy [DOE], 2006). Only 20% of the total area is recoverable using surface mining (DOE, 2006), as this process is suitable for the small portion of the oil sands that lie within 75 m of the surface. Surface mining is also not feasible for areas where bitumen is interspersed with large volumes of sedimentary material and water. The remaining 80% of the bitumen is planned to be extracted from the oil sands using in situ processes such as Cyclic Steam Stimulation (CSS) and Steam Assisted Gravity Drainage (SAGD).

The surface mining approach has been employed in the AOSR deposits to the north of Fort McMurray. Oil sand deposits are exposed by stripping the overburden, followed by removal of the oil sand by truck and shovel. The extraction process involves the separation of bitumen from the sand by adding warm water and agitating the resulting slurry (Alberta Employment, Immigration, and Industry [AEII], 2007).

The in-situ approach involves the removal of the bitumen from the sand while oil sands deposits remain in place underground. Many in-situ projects require the addition of heat to make the bitumen less viscous to allow it to be pumped up to the surface. In the CSS method, steam is injected into the oil sands using vertical wells and the liquidized bitumen is subsequently pumped to the surface using the same well. The SAGD process involves the addition of steam to the oil sands using a horizontal well and simultaneously lifting the liquidized bitumen using another horizontal well located just below the steam injection well.

There are other methods that have recently emerged in the in-situ extraction process including the vapour recovery extraction method (VAPEX), which involves the use of solvents as a supplement to steam and Toe to Heel Air Injection (THAI) which combines a vertical air injection well with horizontal production. Both methods are still in the pilot stages (AEII, 2007).
Mineable oil sands deposits occupy approximately 3,500 km\(^2\) of boreal forest in northeast Alberta (Pembina Institute [Pembina], 2008). The latest statistical information indicates that the mineable portion of the AOSR currently produces approximately 856,000 bbl/d of bitumen (Pembina, 2008). Bitumen is a mixture of organic liquids that are highly viscous, black, sticky, and composed primarily of highly condensed polycyclic aromatic hydrocarbons (AENV, 2008b). Bitumen found in the oil sands region is naturally occurring. It is a tar-like form of petroleum that is extremely thick and heavy and requires heat or dilution before it can flow freely.

According to the latest statistical information available, crude oil derived from oil sands accounts for approximately 50\% of Canada’s crude oil output (UTILIS, 2006). This figure is expected to increase to 77\% of Canadian crude production by the year 2012 (UTILIS, 2006). It is forecasted that over the next decade, the volume of synthetic crude produced from the AOSR will reach 1.5 to 1.7 million barrels per day (bbl/d) (UTILIS, 2006).

Since oil sands mining started in the AOSR in 1967, the cumulative area disturbed from 1967 to 2006 was 47,832 hectares (Pembina, 2008). Recent publically available data from 2006 indicates that 6,498 hectares have been reclaimed (Pembina, 2008). Currently, approved projects in the AOSR occupy total area of 61,762 hectares (Pembina, 2008), with another 72,762 hectares of approved projects that have not become fully operational. One reclamation certificate was issued by the Alberta government in March, 2008 (AENV, 2008c). The reclaimed and certified land of 104 hectares represents 0.2 \% of the total disturbed land base (Pembina, 2008). Planned projects that are currently undergoing the regulatory application process will result in a cumulative disturbance of approximately 191,000 hectares (Pembina, 2008).

All oil sands operators are required by the Alberta Environmental Protection and Enhancement Act (AEPEA) to return disturbed land to capabilities similar to those that existed prior to development activities (AENV, 1998a). Most development operators in the AOSR have publically demonstrated their commitment to environmental responsibility by developing policies that include a pledge of returning disturbed land to a stable and biologically self-sustaining state and payment of a security bond each year, calculated to be the dollar amount required to remediate and reclaim the current
cumulative disturbance. To achieve this commitment, good social and environmental responsibility will require development of best practices and a clear strategy for implementation and monitoring.

It is estimated that 35 billion barrels of oil are recoverable from the AOSR using current technology (DOE, 2007). With an energy crisis developing around the world due to increased global demand for oil, Canada’s oil sands deposits already provide a valuable alternative to other oil deposit reserves. Oil sands extraction in Alberta has fragmented the boreal forest and wetlands overlying the Athabasca deposit, leaving a stark environment unrecognizable as a natural landscape, prior to reclamation activities. While this state of disturbance is temporary, closure, conservation and reclamation (CC&R) plans developed by oil sands operators indicate that the land will eventually be reclaimed back to either boreal forest, wetlands, lakes or grassland. There is uncertainty associated with the achievement of planned end land uses, as the technologies required to remediate and reclaim the land to the desired end land uses are in the most part in the early stages of development.

Reclamation statistics indicate that the current rate of development does not match the rate of reclamation. Reported statistics of areas that have been reclaimed and certified could be alarming and misleading; however, the following explains the primary underlying issues:

- **Certification Process**: Operators are required by legislation to demonstrate that disturbed land has been reclaimed to equivalent land capability prior to returning the land and associated liabilities to the Crown. Operators working in the AOSR are endeavoring to ensure that disturbed land is fully reclaimed prior to applying for a reclamation certificate.

- **Oil sand mining in the region is a young industry**: Natural and fully functioning ecosystems develop over time. Industrial activities in this region are approximately 40 years old; this duration is not enough to demonstrate that an equivalent land capability similar to the one that existed prior to development has been achieved.
Liability: Returning land to the Crown would pose public liability issues, as this means that the public will have access to reclaimed land.

Existing Infrastructure: Existing infrastructure like roads and pipelines are still being used for current development activities, returning the land to the crown will make the use of this infrastructure difficult to access.

Monitoring activities: Operators in the AOSR that are undertaking reclamation activities still need access to the sites to monitor the progress of the reclamation activities.

Aggravating each of the above mentioned areas is the significance in variation in the definition of reclamation best practices between the operators and the various regulatory bodies. This leads to reluctance on the part of the operators to request certification of the reclaimed land, leaving industry and Canadians in a potential stalemate.

Oil sands mines are early in development, and none has ever been closed before; therefore, there is a lack of information available on difficulties associated with the reclamation process of landforms found in this region. These uncertainties pose a question of whether the boreal forest and its abundant biodiversity of flora and fauna can be restored in a way that reflects the pre-disturbance state as well as support the traditional land use practices of First Nations of Alberta.

The government of Alberta is in the process of developing comprehensive guidelines for reclamation of lands disturbed by oil sands development. Currently, the following are the main reclamation guidance documents:

- Guidelines for Reclamation to Forest Vegetation in the AOSR (AENV, 1998a);
- AEPEA approval conditions and requirements;
- Land Capability Classification System for Forest Ecosystems in the Oil Sands (AENV, 2006); and
• Soil Quality Criteria Relative to Disturbance and Reclamation (Alberta Agriculture, 1987).

Different forums including universities and multi-stakeholder groups like the Cumulative Environmental Management Association (CEMA) and Canadian Oil Sands Network for Research and Development (CONRAD) are venues through which oil sands operators have invested in reclamation research. Research has encompassed a number of issues including: modeling forest success, reconstruction of peatlands, wetland re-establishment, establishment of saline-tolerant plants and contaminant transport in the food chain.

**CEMA**: The mandate of the organization is to study the cumulative environmental effects of industrial development in the region and produce guidelines and management frameworks. Since the group was formed, many reports have been produced including eight Management Frameworks documents. This multi-stakeholder organization is governed by forty four members that represent all levels of government, industry, regulatory bodies, environmental groups, aboriginal groups, and the local health authority, that have an interest in protecting the environment in the Wood Buffalo Region. There are several working groups under CEMA that are tasked with finding solutions to different issues, among them is the Reclamation Working Group (RWG).

**CONRAD**: The mandate of CONRAD is to initiate research into new ideas that will permit new grass-root development while improving the performance of existing operations. CONRAD has produced many reports including a Framework for Oil Sands Reclamation Performance Assessment, Oil Sands Mining End Land Use Committee Report and Recommendation (Oil Sands Mines End Land Use Committee [OSMELUC], AENV,1998b), and analysis of vegetation and soils associated with reclamation programs.

CONRAD is comprised of several research groups including the Environmental Reclamation Research Group (ERRG). The ERRG carries out reclamation research priorities in collaboration with CEMA’s RWG. Many of the CONRAD ERRG research activities include field trials and monitoring plots. Results from these research programs have been reported in symposiums and workshops that are sponsored by CONRAD.
1.1.2.1 Research Scope and Objective

The objective of this research will be to review current reclamation practices in the mining industry and identify indicators that could contribute to the development of sustainable reclamation targets and benchmarks in the AOSR. The scope of the research will be to answer the main research question using a series of sub-questions as illustrated in Figure 2.

Due to the complexity of environmental, social and economic issues that prevail in the AOSR, the scope of this research will focus on reviewing the potential of creating reclamation targets and benchmarks that will be applicable in the AOSR. The most applicable benchmarks and targets have been demonstrated in the management plan in Section 5.2. The model used to develop the management plan could potentially be applied in addressing other sustainability issues in the oil sands region. Further, this research recognizes that there are a number of key factors not addressed by this study that will contribute to the successful development of reclamation benchmarks and targets in the AOSR, including the following:

- Reclamation design of variable closure drainage with watershed management plans;
- Soil management;
- Stakeholder collaboration;
- Regulatory climate; and
- Inclusion of First Nations in the reclamation process.

While the above components are critical in the success of reclaiming the AOSR, this research focuses on the ecological benchmarking process and targets for the reclamation of oil sands landforms in the AOSR.
Main Question: What potential sustainable reclamation targets and benchmarks can be developed and applied in the Athabasca Oil Sands Region of Alberta, Canada?

Sub-question 1: How do related extraction industries develop reclamation benchmarks and targets?

Sub-question 2: What are the lessons learned regarding reclamation benchmarks and how applicable are they to the Athabasca Oil Sands Region?

Sub-question 3: How do these reclamation benchmarks relate to sustainability strategies in the Athabasca Oil Sands Region?

Sub-question 4: How effective will these reclamation targets and benchmarks be if applied to a reclamation landform (e.g. tailings ponds)?
1.2 THE BENCHMARKING AND TARGET SETTING PROCESS

1.2.1 What are Benchmarks?

Benchmarking is a strategic process used to evaluate and measure performance in relation to best practices of a given sector (Australian Government, 2006). The term benchmark has various definitions; however, for this research, benchmark will mean points of reference or comparison that may include standards, critical success factors and indicators in relation to reclamation.

1.2.2 What are Targets?

Targets are defined as specified objectives that indicate the number, timing and location of that which is to be realized (Kusek and Rist, 2004). For this research the term target will mean quantifiable levels of the indicator that AOSR stakeholders want to achieve within a given timeframe in relation to reclamation. Performance indicators will take into consideration baseline information, resource constraints, and determined reclamation timeframes. Flexibility is important when setting targets, as changes might be required to be made within the program lifecycle.

1.2.3 Best Management Practices

Best Management Practices (BMP) are measures that help achieve goals and objectives (Ministry of Environment British Columbia [MOE B.C.], 2005). For this research BMP will mean measures and practices that will be employed to facilitate the achievement of reclamation benchmarks and targets for the AOSR.
1.2.4 Why Should Reclamation Targets and Benchmarks Be Developed?

Development of reclamation benchmarks and targets for the AOSR will be a proactive way of promoting sustainability by indicating functional ecosystems and returning end land use values to stakeholders of the region. Specifically, the benchmarking and target setting process will aid in the following areas:

- Create a mechanism for continuous improvement of reclamation performance;
- Create a learning opportunity from the accomplishments of other industries;
- Be a management tool for environmental issues related to oil sands development; and
- Promote achievement and maintenance of self-sustaining ecosystems.

Benchmarks and targets will act as indicators to understand the following:

- Effective current approaches to reclamation planning; and
- Present gaps that require stakeholder attention.

The benchmarking and target-setting process should be applied at a regional level as the impact of past mining activities may affect adjacent properties and larger landscape units such as watershed boundaries.

1.3 THESIS RESEARCH

1.3.1 Significance

In both the developing and the developed world there is a need to ensure that human activities do not permanently disable ecosystem processes at the landscape level, or leave a legacy of abandoned contaminated land for government to clean up at public expense. There is a need for involved oil sand region stakeholders (i.e., industry, government, non-government organizations [NGOs], First Nations, municipalities and
researchers) to have guidelines for developing sustainable reclamation benchmarks and targets in these regions.

This research will be of direct significance at three levels:

- **Governmental level** – The government of Alberta has already expressed its commitment to sustainable resource use and planning by developing various guidelines. Development of reclamation targets and benchmarks for the AOSR will contribute towards one of the key objectives of the government of Alberta by providing guidance for progressive and timely reclamation. This will in turn contribute towards the creation of a resilient reclaimed boreal ecosystem.

- **Oil sands project development level** – Developing reclamation targets and benchmarks will promote the performance of reclamation timelines and support research activities that are currently being proposed by the industries working in this region.

- **Environmental sustainability level** – Developing reclamation targets and benchmarks will promote the continuity of landform, watershed and vegetation systems across oil sands mine closure landscapes.

Additionally, there is potential for indirect benefits at the following levels which are closely tied to the direct benefits mentioned above:

- **Economic sustainability level** – Developing reclamation targets and benchmarks will provide one mechanism of balance between the economic prosperity that oil sands development has brought to Alberta, and the well being of the environment and the human communities that occupy this region.

- **Social sustainability level** – Inclusion of First Nations in the reclamation process will aid in traditional land use (TLU) knowledge being protected and passed on to future generations. This will also support a sense of belonging for communities whose lives have been transformed as a result of oil sands
development, and promote a model where natural systems and human systems are constantly interacting with each other in balance.

Given that this industry is in its early development stages, this research is critical and timely in providing potential options for the planning process for closure and reclamation of oil sands mines in the AOSR.

1.3.2 Context

1.3.2.1 Economic and Social Implications

Oil sands development has produced unprecedented economic growth in the Fort McMurray region of Alberta. Hunting, fishing, trapping and logging have been traditional economic activities in the AOSR. Although oil sands extraction occurred as early as the 1930s, it did not begin to dominate the socio-economic character of the region until approximately 35 years ago (AEII, 2007). Today the oil sands and oil and gas industry directly employ 51.5% of the Fort McMurray labour force (AEII, 2007).

Oil sands development has had a dual effect on the First Nations of this region. The positive impacts include creation of employment and business opportunities that did not exist before. However, economic benefits have not been evenly distributed. Opponents argue that oil sand activities have jeopardized the traditional ways of the region’s First Nations people and possibly their health (AEII, 2007). Oil sands leases occupy a large portion of First Nation traditional territories and have disrupted the landscape and ecosystems from which First Nations have traditionally drawn sustenance (AEII, 2007).

Current and future economic growth in Alberta and Canada is closely tied to the development of the oil sands. The oil sands sector in Canada has experienced record levels of both international and domestic investments. Projects under construction and planning are forecasted to generate billions of dollars for the Canadian economy over the next decades (Canadian Association of Petroleum Producers [CAPP], 2005a). The United State’s Energy Administration and the Oil and Gas Journal formally recognize Canada’s oil sands as an economically viable resource (CAPP, 2005b). In 2003, Canada’s oil reserves were moved from the 21st position in the world to 2nd position, moving closer
to Saudi Arabia (Pembina, 2008). Developing reclamation benchmarks and targets will provide a framework and a set of trajectories to measure a return of set land uses and ecological viability that are important in ensuring that ecological sustainability in the AOSR is maintained for future generations.

1.3.2.2 Oil Sands Industry Activities in the Athabasca Oil Sands Region

Currently, there are four large oil sands mining operations in the AOSR. These are activities operated by Canadian Natural Resources Limited (Canadian Natural), Syncrude Canada Limited (Syncrude), Suncor Energy Inc., (Suncor), and Shell Albian Sands (owned by Shell Canada, Chevron, and Marathon Oil Sands Ltd). Major producing or planned development in the AOSR includes the following (DOE, 2006):

- Canadian Natural’s Horizon Project currently produces 120,00 bbl/d;
- Suncor Energy’s Steepbank and Millennium mines currently produce 304,028 bbl/d;
- Syncrude’s Mildred Lake and Aurora mines currently produce 360,000 bbl/d; and
- Shell Albian Sands’ Muskeg River Mine currently produces 169,000 bbl/d.

1.3.3 Research Question and Related Sub-questions

The research question and related sub-questions are provided in Figure 2.

1.3.4 Hypothesis

The study hypothesis considered is as follows:

H = Sustainable reclamation targets and benchmarks exist in other extraction industries that can be applied in the AOSR of Alberta.

H0 = There are no sustainable reclamation targets and benchmarks in other extraction industries that can be applied in the AOSR of Alberta.
1.3.5 Report Layout

This thesis report is composed of six Chapters as follows:

- **Chapter 1** introduces the research subject, including background information, issues description, significance and research context;

- **Chapter 2** provides a summary of literature reviewed;

- **Chapter 3** describes the research methodology;

- **Chapter 4** provides case studies of benchmarks and targets from other related extraction industries;

- **Chapter 5** is the proposed management plan for application of selected reclamation benchmarks and targets, and a discussion that includes areas of future research; and

- **Chapter 6** contains the research references.
CHAPTER TWO

2.1 LITERATURE REVIEW

2.1.1 The Alberta Environmental Impact Assessment Process

As part of the effort to protect the environment, applicants for major projects are required to include an Environmental Impact Assessment (EIA) in their Energy Resources Conservation Board (ERCB) and AENV applications. The EIA must be conducted and ‘deemed complete’ by the various government departments involved in the approval process.

The EIA must include an outline of the environmental impacts that a project is expected to have, as well as a detailed reclamation plan outlining how the company intends to reclaim the land once operations have ceased. As part of the application process, the opponent is required to submit a Closure, Conservation and Reclamation (CC&R) plan. CC&R plans that have been developed for projects around the AOSR outline how the project area will be reclaimed to an equivalent land capability upon completion of project operations (Suncor, 2007, Syncrude, 2007, Shell, 2007 and Canadian Natural, 2007), and are required to demonstrate how end land use objectives will be achieved. Closure reclamation landforms are required to be geotechnically stable, to support a variety of habitats with a range of biodiversity potential, and to integrate surface drainage structures with adjacent undisturbed areas (AENV, 1998a). Companies are required to report annually on their reclamation progress. The update reports must have a status and record of surface disturbance and reclamation, demonstrate AEPEA approval compliance, and identify problem areas and resolutions (Pembina, 2008).

General reclamation requirements include replacing soil and repopulating the surface with trees, shrubs, and other vegetation indigenous to the area or non-native species that are approved by a government agronomist. Under provincial legislation, companies must remediate and reclaim land that has been disturbed by industry activity so that it is productive again (AENV, 1998a).
2.1.2 Government Departments and the Environmental Impact Assessment Process

There are several provincial and federal departments that are involved in the development application process for mining of bitumen in the AOSR. These departments are in most cases involved all the way to the final decommissioning and reclamation phase of the process. The following is a list of the main federal and provincial agencies involved in the project lifecycle:

Federal Departments:

- Department of Fisheries and Oceans Canada (DFO) – impacts to fish and fish habitat;

- Canadian Wildlife Service (CWS) – issues related to migratory birds and their habitat;

- Committee on the Status of Endangered Wildlife in Canada (COSEWIC) – issues related to endangered wildlife; and

- Canadian Environmental Assessment Agency (CEAA) – issues related to cumulative environmental effects.

Provincial Departments:

- Alberta Environment - assesses and reviews land, air, and water aspects of the project;

- Alberta Sustainable Resource Development (ASRD) – focuses on forest resources, and fish and wildlife;

- Public Lands Division of ASRD – evaluates projects that are planned on public lands;

- Energy Resources Conservation Board (ERCB) – evaluates the economic feasibility of the development to ensure the project is of benefit to Albertans; and
- Alberta Health and Wellness – evaluates human health issues of the development.

2.1.3 Adaptive Management

During the development of new industries, it is difficult to forecast all potential impacts of industrial activities on the environment. Many factors can influence the direction of the regulatory process, such as the geographic uniqueness of each project, limited availability of scientific research and development, and challenges associated with long-term planning. To mitigate this uncertainty, industry and government working in the AOSR have embraced the philosophy of adaptive management.

Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs (Taylor, Kremsater and Ellis, 1997). Adaptive management identifies uncertainties, and then establishes methodologies for addressing them. It uses management as a tool not only to change the system, but as a tool to learn about the system (Walters, 1986). Increased collaboration between industry and government has been the direct result of the application of this model of resource management.

Development approval conditions in the AOSR provide some details of reclamation, and to support these conditions a series of guidelines were developed specifically for the AOSR. The developed guidelines are generally not legally binding, unless they have been incorporated into the regulations or added to the AEPEA approval conditions. Nevertheless, it is expected from the governments and public’s perspectives that industry will follow them. An example of a jointly-developed series of guidelines are the “Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region” (AENV, 1998a), as a means of ensuring oil sand mine sites are adequately reclaimed to boreal mixedwood forest. The scope and goals of these guidelines are to ensure that commercial forests are established, a system of biophysical monitoring mechanisms are established, and research and development of advanced reclamation practices continue to be conducted in order to facilitate the most effective means of land reclamation in the Alberta oil sands context (AENV, 1998a).
2.1.3.1 Reclamation Security

The Alberta government requires that oil sands industry operators post security equivalent to the cost of reclamation before commencing oil sands development. The collected funds are kept in the Environmental Protection Security Fund (Alberta Regulation 111/93, 2008). Following successful completion of all reclamation activities, and once a reclamation certificate has been issued, the Alberta government will return the held funds to the oil sands operator. The reclamation process is lengthy and can take upwards of 50 years; however, reclamation best practices promote progressive reclamation to return the disturbed land to a natural state after development. Progressive reclamation is beneficial as it sets the stage for a self-sustaining ecosystem early in the process, allows for acquisition of long-term performance record, and identified problems can be fixed while the mines are still in operation.

To date, 7.5 million tree seedlings have been planted by major oil sands operators towards reclamation efforts (AENV, 2008b). The government of Alberta is using payment of securities as a tool for ensuring that reclamation is conducted by the oil sands operators. Currently, there is approximately $645 million in the securities fund (AENV, 2008c). While this economic tool might be adequate in ensuring that reclamation occurs, there is uncertainty associated with reclamation and the economics associated with providing securities funding. It is unclear whether adequate resources are being collected by the securities program should mine sites be abandoned without full reclamation.

2.1.4 Alberta’s Reclamation Certification Process

The AEPEA requires an operator to conserve and reclaim land disturbed or affected by an industrial activity such as an oil sands mine, and to obtain a reclamation certificate. Land capability is the ability of land to support a given land use (e.g., agriculture, forestry, wildlife habitat, recreation, etc.) based on an evaluation of the physical, chemical and biological characteristics of the land, including landscape (i.e., topography, hydrology, hydrogeology), soils and vegetation (AENV, 1998a). The objective of equivalent land capability is to provide for sustained levels of use at least equivalent to those that existed prior to development. The concept is flexible in that
individual land capabilities and land uses may change, but overall land capability and land use will be equivalent to pre-disturbance conditions (AENV, 1998a).

Oil sands operators are required to be granted a reclamation certificate to demonstrate that reclamation has been successful. If specific criteria or land capability evaluation procedures are available, they are used to assess reclamation. Currently, there are a lack of consistent reclamation criteria and guidelines for all oil sands operators; however, AEPEA and its regulations offer a regulatory framework for reclamation. Should a site be considered contaminated following AEPEA certification, the proponent retains responsibility for site remediation.

On submission of the application for a reclamation certificate, a detailed review is conducted by regulatory staff, followed by a site inspection, and recommendations are provided to the ASRD for decision making.

The general information requirements for a reclamation certificate application are outlined in Section 14 of the *Conservation and Reclamation Regulation* and include the following (Alberta Regulation 115/1993):

1. a map, with references to legal boundaries, showing the land for which the certificate is being requested and the adjacent land use;
2. particulars of the characteristics and properties of the conserved and reclaimed land including topography, drainage, soils, vegetation, and land capability;
3. documentation of conservation and reclamation procedures;
4. documentation of the history of surface disturbance;
5. documentation of and justification for any surface improvements to be left on the conserved and reclaimed land and written acceptance of the improvements by the owner of the land;
6. a declaration that the operator has complied with:
   (i) all terms and conditions of any applicable approval, Environmental Protection Order, or Enforcement Order;
   (ii) the directions of an inspector or the Director, and
   (iii) any applicable standards or criteria established under Section 3(1);
7. the name, address and telephone number of all of the owners of the land;
8. particulars of any surface lease or right of entry order for the land;

9. a description of any substances present as a result of the operator's activity on the land and a description of the nature and extent of the adverse effect caused by the presence of the substance;

10. particulars of any remedial measures taken with respect to a substance referred to in 9; and

11. any additional information required by an information document or requested by the Director.

In March 2008, the Alberta government issued a reclamation certificate to Syncrude for a 104 hectare parcel of land known as Gateway Hill, approximately 35 km north of Fort McMurray. The site was used for replacement of overburden material during the mining phase of the project. In early 1980, Syncrude began the replacement of topsoil and planting of trees and shrubs, and applied for certification in 1998. Critics of the current regulatory process argue that the certification process was very slow (10 years) and there was a lack of transparency about reclamation certification targets.

2.1.5 Conservation and Reclamation Policy

The development of reclamation and conservation policy in Alberta can be broken down into three stages (Macyk, 2000) as follows:

**Remedial stage** – Prior to 1963, the only requirement under the early *Coal Mine Regulation Act* was that the operator leave the site in a safe condition;

**The cosmetics stage** – Between 1963 and 1968, companies were required to level the disturbed site to facilitate easy working. Provisions of the 1963 *Surface Reclamation Act* stated that the mined areas had to be levelled and contoured to provide water drainage for all normal practices to be carried out at the site. This requirement established a field enforcement staff in the form of the Reclamation Council, and also provided reclamation certificates.

**Modern era** – This era began in 1973 when the *Land Surface Conservation and Reclamation Act* began to require CC&R planning (Macyk, 2000). This act applied to all lands within Alberta except those used for residential purposes or agricultural operations. The Act makes it mandatory that referral and coordination of government departments
occurs. Under this Act, the following three committees were established: the Crown Mineral Disposition Review Committee, the Exploration Review Committee, and the Development and Reclamation Review Committee. The reclamation standards associated with this Act required that the land be returned to a level of capability that is equivalent to that prior to development.

Other legislation that applies to oil sands mining includes: the *Oil Sands Conservation Act*, *Water Act*, *Public Lands Act*, *Fish and Wildlife Act*, *Federal Fisheries Act*, *Federal Migratory Birds Act*, and the *Federal Navigable Waters Act*. All Acts are legally binding, and are administered and enforced by government departments represented by each Act. Should any aspect of these Acts be broken during operation of oil sands mining and reclamation phases of operation, the proponent is considered liable and could be fined or put onto an enforcement ladder.

The terms and conditions of operating in the region have evolved over the years from very general requirements to specific measurable requirements. The AEPEA approval conditions for the four main operators in the AOSR identified in Section 1.2.6.2 are very similar. They clearly state requirements for materials placement, backfilling and contouring, soil placement and revegetation. A general clause requires the operators to reclaim the land to a point that the soil and landforms are capable of supporting a self-sustaining, locally common boreal forest, regardless of the end land use. Further, the approval holder is required to revegetate the disturbed land to target the establishment of a self-sustaining, locally common boreal forest integrated with the surrounding area. Specific revegetation terms require the approval holders to develop a plan, regardless of end land use, for establishing of forest ecosystems. General reclamation requirements for the four larger operators are as follows; (Canadian Natural AEPEA Approval No.149968-00-00, Suncor AEPEA Approval No. 94-01-25, Syncrude AEPEA Approval No. 18942-00-00 and Shell Canada Albian Sands AEPEA Approval No. 20809-00-01):

- Incorporation of vegetation and vegetation communities of traditional value that characterize the locally common boreal forest;

- Re-establishment of the capability for long term biodiversity consistent with the provincial biodiversity program;
• Re-establishment of the continuity of vegetation patterns, where practicable, between the reclaimed lands and the land adjacent; and

• Establishment of commercially viable forest ecosystems on areas equivalent to the pre-disturbance areas of commercially viable white spruce mixedwood, deciduous and total coniferous ecosite phases.

The latest requirements recognize interrelation of ecosystems while prior reclamation requirements were company-specific.

The government of Alberta recognizes the pressure that is imposed by oil sands development. To mitigate impacts that this growth imposes on the land, the government recently released a Land Use Framework (AENV, 2008a). The purpose of the Land Use Framework is to sustain the rapid growth of the development by balancing Alberta’s economic, social and environmental goals (AENV, 2008a). The Land Use Framework consists of six strategies aimed at improving land-use decision making in Alberta. The following is a summary of the six strategies (AENV, 2008a):

• Develop six regional land-use plans based on six new land-use regions;

• Create a Cabinet Committee supported by a Land-Use Secretariat and establish a Regional Advisory Council for each region;

• Use cumulative effects management at the regional level to manage the impacts of development on land, water and air;

• Develop a strategy for conservation and stewardship on private and public land;

• Establish an information monitoring and knowledge system to contribute to the continuous improvement of land use planning and decision making; and

• Include aboriginal people in land-use planning.

Further, the government of Alberta recognizes that oil sands extraction and related activities are economic drivers for the province’s economy; however, the pace of the
growth has created pressure on the essential services, infrastructure and the natural ecosystem (AENV, 2008a).

2.1.6 Oil Sands Land Forms

Oil sands mining activities have disrupted natural land forms and created several post-mining landforms. The following are the commonly created closure landforms from oil sands mining activities (AENV, 1998a):

- **Overburden dumps**: created to store overburden materials comprised of recent fluvial deposits, glacial deposits, and bedrock formations. The created topography can be level to steeply sloping;

- **Dyke walls**: dyke structures are designed to provide secure impoundment of tailings and water;

- **External tailings facilities**: temporary above ground engineered facilities where tailings are stored;

- **In-pit tailings areas**: created as a result of backfilling open mine pits with tailings;

- **Pit Lakes**: man-made lakes, used to partially fill a mine pit area with remaining fine tailings at the end of mine life that are stored under a water cap; and

- **Ancillary areas**: such as the plant site, camp area, crusher slot, ore preparation areas, roads and settling ponds.

Structural stability is the primary objective when contouring landforms. Further modifications to slopes, grades, and micro-terrain are designed to provide a range of ecosite diversities and areas suitable for meeting equivalent land capability requirements as stipulated by the legislation.
2.1.7 Reclamation Efforts in the Region

Reclamation practices in the mineable oil sands have evolved as a result of a number of factors including (Macyk and Drozdowski, 2008):

- Lack of precedent – initially there was a need to research methods for reclamation;

- The nature of predominant material including tailings sand and overburden; and

- Lack of reclamation material (e.g., native seed sources).

Due to the above challenges, initial reclamation efforts focused on site stabilization and erosion control (Macyk and Drozdowski, 2008). Initial practices in the AOSR were selection of a wide range of grass and legume species to assess which ones would establish and provide cover and erosion control. In 1971, Suncor initiated research with Alberta Agriculture focused in determining seeding techniques for reclaiming tailings sands (Macyk and Drozdowski, 2008).

In 1996, the Oil Sands Reclamation Committee was formed and tasked with preparing guidelines on the establishment of forest vegetation (AENV, 1998a). The committee’s focus was on providing appropriate starter vegetation to be used in reclaiming oil sand leases in the AOSR. An integrated approach that involves the following three stages was adopted (AENV, 1998a):

- Facility design and layout;

- Land use planning; and

- Development of reclamation strategies and techniques.
2.1.8 Initial Revegetation Efforts in the AOSR

Initial revegetation practices in the AOSR were adopted from agricultural practices. These practices involved selection of mixtures of agronomic grasses and legumes, seeded at relatively high rates to establish cover that would stabilize soil, limit erosion and re-establish soil function (Macyk and Drozdowski, 2008). The decision to use agronomic seeds was due to a lack of native materials available commercially in significant quantities. In the AOSR, different combinations of species were used for tailings, dykes slopes and overburden dumps (Macyk and Drozdowski, 2008). Invariably fertilizers were applied to ensure vegetation establishment and to amend nutrient-poor tailings, overburden and soil capping materials that were being revegetated (Macyk and Drozdowski, 2008). The agronomic species used included alfalfa, timothy, smooth brome, sweet clover, creeping red fescue and crested wheatgrass. Creeping red fescue was an excellent species for erosion control; however, it was highly persistent, limiting native species invasion and establishment of shrubs and trees (Macyk and Drozdowski, 2008).

The season for seeding has also been evaluated over the years to determine optimum seeding times. Spring and fall have been noted as the most effective seasons (Macyk and Drozdowski, 2008). Early spring seeding allowed for a lengthy growing season to ensure establishment and to take advantage of precipitation which is relatively high in June. Fall seeding mimics the phenomenon of natural seed drop at the end of the year. Salvage and replacement of surface organic horizon (LFH) material in the AOSR has resulted in a substantial increase of native species and associated community diversity and species richness compared to peat mineral mixes (Macyk and Drozdowski, 2008).

Early experimental tree planting in the AOSR was to determine which species, both native and non-native, would grow best (Macyk and Drozdowski, 2008). This experimental program revealed that agronomic grass and legumes planted to establish initial covers were impacting the establishment of trees and shrubs. In the 1980s it was observed that a barley cover crop promoted increased tree survival by providing shade and trapping moisture in the summer and snow in the winter to provide an insulating effect from harsh winter conditions (Suncor, 2006). The use of barley or similar covers
has now become standard practice, with initial cover crop planting in year one followed by tree and shrub planting in years two to three.

The current goal in the AOSR is to provide a sustainable forested ecosystem with the number of stems/ha of species defined for the different ecosites and capability classes (Macyk and Drozdowski, 2008). Ecosites are site types that are defined by abiotic factors (soil depth and texture, nutrient regime, moisture regime, and hydrology) as well as biotic factors (plant community structure and composition) (Beckingham and Archibald, 1996).

The Land Capability Classification is an integrated soil and landscape rating calculated from key parameters including soil moisture regime properties, soil nutrient regime properties, and potentially limiting soil physical and chemical properties, in the three principal soil horizons, which include; the topsoil (0 to 20cm depth), upper subsoil (20 to 50 cm depth), and the lower subsoil (50 to 100cm depth) (AENV, 2006).

2.1.9 Reclamation Challenges

Restoring the biophysical aspects and biodiversity in the AOSR to the state that is equivalent to the pre-disturbance state presents several challenges. The key stakeholders are endeavouring to ensure that oil sands operators do not leave costly reclamation burdens as a legacy. The following sections provide an overview of reclamation challenges being faced in the AOSR.

2.1.9.1 Geology

The geological formations in the AOSR are composed of Clearwater and McMurray formations, glacial sediments and recent sediments. During the mining phase of the oil extraction process, overburden is stockpiled in holding areas and later used during the reclamation phase when the mine site is being backfilled and capped.

Geological layers cannot be reconstructed since the transfer of overburden mixes the various geological layers. The challenges associated with this practice include changes in ground water flow, direction, and quality. The process of backfilling the mine can potentially lead to an overall increase in volume of material. This will potentially pose challenges when re-contouring the landscape.
2.1.9.2 Groundwater

Reclamation of oil sands mines presents two primary groundwater issues. Groundwater flow is closely associated with geological formations (Intercontinental Engineering of Alberta Ltd. [ICEA], 1972). Thus, the movements of groundwater will likely change considerably once the mine site has been backfilled. It is difficult to quantify groundwater impacts associated with oil sands mining given the age of reclaimed areas in the AOSR. Groundwater in these areas has not been fully recharged. It is possible that the water table may either rise or fall compared to pre-disturbance levels which will influence flow patterns, such as rate, volume and direction. Of primary concern is the 100-fold increase in permeability of sand once bitumen has been extracted (ICEA, 1972). Lowered water tables have a direct impact on vegetation productivity following site reclamation. The groundwater system has the potential of becoming contaminated if leachates from tailing ponds enter the system. Manipulating groundwater quality and flow has trans-boundary implications on surrounding watersheds. These alterations of groundwater flow rate and direction will in turn impact wetland recharging.

2.1.9.3 Tailings Ponds

Tailings are produced at oil sands mines through the oil sands extraction process. They are a mixture of water, clay, sand and residual bitumen. Tailings ponds are dumping sites for waste created during several stages of oil recovery from bitumen deposits. Residual water and particulates separated from the bitumen are stored in large tailings ponds and are sometimes combined with a coagulant to allow consolidation of material (Syncrude, 2003). These ponds have high pH levels, and potential pollutant concentrations (ICEA, 1972). Prior to reclamation, surface water contained in these ponds is typically removed.

Currently, the plan is to cover these tailings ponds with overburden and revegetate the areas. The primary challenges with reclaiming these areas are associated with leachate transfer into groundwater and adjacent waterbodies. Recent plans are proposing to cap tailings with overburden as a measure to prevent leaching from occurring. Reclamation of liquid waste and migration of tailings toxins are uncertain. To address
this growing problem, the ERCB released Directive 074 entitled “Tailings Performance Criteria and Requirements for Oil Sands Mining Schemes” (ERCB, 2009) which applies to all oil sands operations.

2.1.9.4 Rivers, Lakes and Wetlands

The reclamation process will require the development of a watershed plan that will include the creation of new wetlands, re-establish diverted rivers and streams, and establish new flowing water corridors. The planning phase of the watershed recovery will likely be relatively complex, and the contouring will be costly. Reclamation of peatlands (fens and bogs) in the AOSR has not yet been demonstrated. Watershed systems are integral in the boreal forest ecosystem, but there is no demonstrated success in reclaiming peatlands (fens and bogs), and uncertainty exists as to whether natural wetlands ecosystems can be reconstructed.

2.1.9.5 Soils

Overburden soil layers are separated and stored for eventual reclamation. There are potential impacts to soil chemistry and homogenization of soils. Subsequently, this will affect the productivity of the landscape following site reclamation. Depending on soil capability, revegetation of the disturbed landscape may be difficult.

2.1.9.6 Forest Lands

The primary challenge for reclamation will be to revegetate disturbed lands to a level of diversity and productivity that was present prior to disturbance. Establishment of upland boreal forest communities will likely be attainable. However, establishment of muskeg communities will be difficult due to the challenges associated with emulating complex hydrological regimes associated with this community type. Muskeg is a soil type comprised primarily of organic matter, also known as peat (Shell, 2007). As with any human-induced forest disturbance and subsequent re-vegetation attempts, the tendency is for homogenization of forest stand characteristics (e.g. stand age, species
diversity, and stand structure) and potential introduction of exotic plant species (Hanus, Crites and Wasel, 2001).

2.1.9.7 Fish and Wildlife

Although the boreal forest natural region is composed of assemblages of nine tree species, this region is home to the largest diversity of birds in North America. Surveys prior to site disturbance indicated that fish and wildlife diversity is highly related to habitat heterogeneity. Given the complexities of undisturbed habitat, the challenges of providing suitable habitat following mine site decommissioning is formidable. The direct result is a loss of habitat diversity and subsequent species richness and abundance. Generally, time will need to be invested for ecosystem community reestablishment.

2.1.9.8 Human Use

Prior to oil sands development, relatively few people inhabited and used the area. Activities were largely limited to hunting, trapping, fishing, camping, and forestry (AEII, 2007). It is expected that people will be able to use the reclaimed landscapes as they once did. The types of activities humans enjoy on reclaimed lands are often different following reclamation than prior to development, but the intention of re-establishing some degree of aesthetic and recreation appeal for people is a key challenge. There is uncertainty as to what can truly be reclaimed and habitat types that will be formed.

2.2 CURRENT RECLAMATION TARGETS

As discussed in previous sections of this report, equivalent land capability is the primary target of development and reclamation approvals in the AOSR. Several aspects including the ones discussed in following subsections are being developed to measure the achievement of this target.
2.2.1 Land Capability for Forest Ecosystems

In 1996 the *Land Capability Classification System for Forest Ecosystems* (LCCS) was developed and later updated in 2006, to act as a working document to facilitate evaluation of land capabilities for forest ecosystems on natural and reclaimed lands in the AOSR (AENV, 2006). With a focus on commercial forestry, the LCCS targets soil and soil erosion and aspects related to tree growth. The LCCS for forest ecosystems in relation to reclamation is composed of soils and landscape components and is based on an integration of numeric values assigned to soil and landscape characteristics that are known to be fundamental to ecosystem productivity (AENV, 2006). Parameters that are considered include soil moisture and soil nutrient regimes, and soil physical and chemical properties that are limiting to plant growth (AENV, 2006). It is recommended that forest productivity be determined on the principal soils assessed during pre-disturbance assessment and after reclamation (AENV, 2006). The site index of tree species in suitable stands in a given location will play a role in determining if equivalent land capability has been reached. Because forest productivity cannot be demonstrated yet, LCCS should be considered as a tool for evaluating the site and reclamation planning and by itself will not ensure replacement of equivalent land capability (AENV, 2006).

2.2.2 Forest Productivity

Current forest establishment programs are based on target ecosites and require regular surveys for up to 14 years on every established stand (AENV, 1998a). Long-term measurements of productivity are measured by assessing forest growth and soil capability (AENV, 1998a, 2006). There are challenges associated with measurement of forest productivity on reconstructed soils using natural ecosystems as criteria. The updated LCCS manual recognizes this limitation and suggests further monitoring and research (AENV, 2006). The Northern Interior Vegetation Management (NIVMA) Sampling Protocol was modified to be used to provide measurement of forest productivity in the AOSR (AENV, 1998a). The protocol calls for permanent plot measurement every 5 years for the first 15 years after reclamation and every 10 years thereafter (Szauer, 1995).

Ecosite revegetation requires development of appropriate landscapes, soils, seed selection, and application of reclamation techniques that will promote the achievement of
the desired ecosite. The relative value for a reclaimed commercial forestry is determined by the following factors (Beckingham and Archibald, 1996):

- Landscape design;
- Soil productivity;
- Size, shape and species of a given vegetation community polygon; and
- Placement of polygons in the landscape.

### 2.2.3 End Land Uses

The Oil Sands Mining End Land Use Committee (OSMELUC) was established in 1996 to make recommendations relating to end land use of reclaimed lands resulting from surface mining of oil sands (AENV, 1998b).

Reclaimed oil sands leases can be integrated to various end land uses. Current guidelines focus on commercial forest and wildlife habitat for nine wildlife species within commercial forest (AENV, 1998b). Wildlife habitat, recreation, and traditional uses are also being incorporated as there is flexibility in the guidelines with regards to end land use. The recommendations from the OSMELUC along with the newly developed Land Use Framework will aid the planning process for end land use in the AOSR.

### 2.2.4 Target Ecosite

Target ecosites depend on possible end land uses, which include; TLU, wildlife habitat, future development, recreation and forestry. Identification of ecosites that naturally occur in the AOSR and that can be fully supported in the reclaimed landscape was conducted using the “Field Guide to Ecosites of Northern Alberta” by Beckingham and Archibald (1996), which provides ecological classification system for the Boreal Mixedwood. There are 12 ecosites that occur naturally based on moisture and nutrient regime, 25 ecosite phases that are based on similar dominant plant species and 73 plant community types based on similar understorey species composition and abundance (Beckingham and Archibald, 1996).
2.2.5 Vegetation Establishment

The revegetation of landform surfaces is determined by the nature and type of landform structures, slope, land capability, and soil moisture regime (AENV, 1998a). Research has been conducted in the AOSR to determine vegetation communities that re-establish under the above conditions.

The following revegetation objectives in the AOSR have been established:

- Provision of erosion-resistant plant cover;
- Utilization of native woody-stemmed reclamation species common to the region;
- Establishment of a diverse range of plant species; and
- Establishment of a viable plant community that is self-sustaining.

One of the reclamation focus points in the AOSR is to encourage the establishment of native woody plants along with planted seedlings (AENV, 1998a). Industry working in this region recognizes that selection of appropriate seed mixture, application methods, and application rates can influence and impact species diversity and seedling survival. Use of plant varieties with local seed provenance will reduce risk of maladaptation and will maintain the genetic integrity of local forest tree populations.

The seed source or tree seed variety used in seeding or planting programs must be registered with Alberta Tree Improvement and Seed Centre and follow seed provenance rules, which require the seed source or variety to be on the Silviculture Records Management System or equivalent system for long-term documentation (AENV, 1998a).

2.2.5.1 Seeding and Seed Source

To achieve reclamation objectives, selection of appropriate seed mixtures, application methods and seeding rates can influence plant species diversity and seedling survival on reclaimed areas (Limstrom, 1964), as discussed in earlier sections.
2.2.5.2 Weed Management

Weed management is essential in implementing a successful reclamation program. In the AOSR, concerns over spread of noxious weeds from areas undergoing reclamation to adjacent natural areas has led operators to establish weed management programs. Operators have implemented permanent monitoring programs to determine the presence of noxious weeds on their leases (Suncor 2007, Syncrude 2007, Shell 2007 and Canadian Natural 2007).

2.3 CURRENT BENCHMARKS

2.3.1 Reforestation Regulations

The Green Zone is the forested portion of the province that comprises most of northern Alberta as well as the mountain and foothills areas along the province's western boundary (ASRD, 2009 online access). Forest within the Green Zone is administered by the Province of Alberta and is regulated by the *Forests Act*. Under this act, equivalent amounts of coniferous, mixedwood and deciduous commercial forest is required in the reclaimed landscape as in pre-disturbance conditions (AENV, 1998a). The productive capability should meet or exceed pre-disturbance conditions as outlined in the yield curve table for commercial forest ecosites (AENV, 1998a).

The Alberta Regeneration Survey Manual outlines the benchmark standards applicable (ASRD, 2008) and is periodically updated. Currently three standards are acceptable, which include conifer, mixedwood and deciduous all of which require 80% of the plots in a standard survey to be stocked with an acceptable tree species to a minimum height standard (AENV, 1998a):

- The conifer standard prescribes a minimum 70% stocking with conifer (white spruce, jack pine or black spruce) and 10% of aspen, balsam poplar, birch or fir;

- The mixedwood standard requirement is reduced from 80% to 50% conifer; and
• The deciduous standard does not require a conifer component.

2.3.2 Measurement of Soil Capability

Measurement of suitability for various uses will be accomplished by integrating forest productivity and soil monitoring. Land capability determination provides classes and subclasses and soil moisture and nutrient regime indices for an assessed soil polygon (AENV, 2006). Soil capability is integrated with forest capability calculated from key parameters including soil moisture regime properties, soil nutrient regime and possible limiting soil physical and chemical factors (AENV, 2006). Potential limiting factors include soil structure and consistence, pH, electrical conductivity, and sodium adsorption ratio (AENV, 2006). A soil horizon is defined as a layer of mineral or organic soil material approximately parallel to the land surface that has characteristics altered by processes of soil formation (AENV, 2006). For reclaimed soils the LCCS principal horizons include reconstructed soil strata salvaged from natural landscapes and may also include waste materials (AENV, 2006).

2.3.3 Mean Annual Increment and Site Indices

The forest productivity benchmark is associated with yield curves that have been established by Alberta-Pacific Forest Industries (AENV, 2006). A review of these curves is conducted periodically and adjusted. The yield curves provide available Mean Annual Increment and volumes per hectare based on the age of the stand (AENV, 1998a). These quantities provide the baseline for stand productivity measurements.
CHAPTER THREE

3.1 RESEARCH METHODOLOGY

This research will follow a framework as illustrated in Figure 2. To achieve the overall objective of the research, two activities will be carried out.

Activity 1: Critical review of existing reclamation targets and benchmarks and acceptable best practices in the mining industry, selecting the most applicable to the AOSR. A list of best practices has been generated. This required the following activities:

- Review of relevant case studies and peer reviewed papers; and
- Review and selection of the most applicable targets and benchmarks.

Activity 2: Incorporation of all the findings to assess the applicability of the selected reclamation targets and benchmarks for selected landforms planned for closure in the AOSR. Using the selected best practices a potential revegetation management plan has been developed for tailings pond landforms that exist in the AOSR.
CHAPTER FOUR

CASE STUDY OVERVIEW FROM RELATED EXTRACTIONS INDUSTRIES

Three case studies from extraction industries (uranium, gold and coal mining) were reviewed to assess how reclamation benchmarks have been applied. The review and assessment were conducted with consideration of differences in geographical and biophysical settings of the regions in relation to the AOSR.

4.1.1 Case Study One - Panna Maria Mill and Tailings Impoundment (Strachan and Raabe, 2008)

The Panna Maria uranium facility was operated by Panna Maria Uranium Operations (PMUO) as an open pit mine and conventional milling operation for the recovery of uranium. Five open-pit mine sites covering approximately 485 hectares were developed by PMUO starting in 1977 and operated until 1985. The site is approximately 97 km southwest of San Antonio in Karnes County, Texas. The site is located within the South Texas uranium belt, a region of uranium mining. The south Texas Plains vegetation region has general characteristics of gently rolling hills covered with grasses and brushwood.

A stockpile of overburden material was used as the primary borrow material for reclamation. The uranium ore produced from the Panna Maria mines came from mineralized areas comprised of primarily fine-grained sands.

Overburden removal and mining were conducted by both truck-and-shovel and scraper operations. Mine sites were reclaimed concurrently with mining by backfilling the open pit with overburden, and revegetating the surface. Final reclamation at the site occurred in 1994.

The Panna Maria tailings pond site was selected based on proximity to the mill and underlying geology. The impoundment was designed as a ring-dyke structure, with tailings contained with a zoned earth embankment and above natural silts and clays. The tailings impoundment within the embankment centerline covered approximately 61 hectares and was designed for an ultimate capacity for 10 million tons of tailings. The
zoned earth embankment was constructed in one phase to a crest elevation of 114 m. The embankment contained a central core that was keyed into underlying silts and clays.

4.1.1.1 Closure Criteria

Closure criteria for the tailings impoundment outlined in Texas regulations are based on U.S. Environmental Protection Agency (EPA) reclamation standards (40 CFR 192), and were used as technical criteria for reclamation. In order to meet these criteria, the closure plan for the tailings impoundment included the following components:

- Consolidating and covering the tailings with random fill;
- Constructing a multi-layered cover system over the tailings, which is designed to reduce the rate of radon emanation and the rate of precipitation infiltration;
- Regrading the original tailings embankment slopes to a maximum slope of 5:1;
- Managing surface runoff from the reclaimed tailings impoundment with designed slopes, channels, and selected vegetation and rock protection for non-erosive conveyance of storm runoff; and
- Regrading and excavating soils as necessary.

Tailings re-grading and covering was a key component of tailings pond closure; the goal for initial covering was to provide a surface for earthmoving equipment and a foundation for subsequent cover system construction. As the first stage, causeways were constructed across the tailings impoundment with random fill. In limited areas, tailings were re-graded to be consistent with the planned sub-grade surface. Re-grading was accomplished with low ground-pressure equipment in tailings areas that had experienced sufficient consolidation and drying to allow equipment travel. From the causeways, a random fill or interim cover zone was constructed over the tailings using random fill soils from adjacent area cleanup and stockpiled soils not suitable for cover material. The random fill zone was constructed with low ground-pressure or conventional earthmoving
equipment, depending on the consolidation and moisture conditions of the tailings. The random fill zone was an important component of tailings covering, providing a firm base for cover system construction, a zone of separation between tailings and uncontaminated cover materials, and a fill zone with capacity for materials from soil cleanup.

The portion of the cover system above the random fill zone consisted of the components summarized below. The source of cover materials was primarily the stockpiled mine overburden. These materials were evaluated for compaction, hydraulic conductivity, radon attenuation, and dispersivity prior to use in construction. Topsoil was obtained from existing stockpiles on site and had previously been evaluated (along with establishment of vegetation species) as part of the mine site reclamation work completed by PMUO. The total cover system thickness is a minimum of 1.2 m, meeting design criteria for tailings isolation, radon attenuation, and reduction of infiltration. The area outside of the tailings impoundment was reclaimed in a manner that removed contaminated soils and established drainage for runoff away from and around the reclaimed tailings impoundment.

4.1.1.2 Establishment of Vegetation

The reclaimed impoundment cover surface, reclaimed embankment slopes, and surrounding areas were covered with topsoil for establishment of vegetation. For all of the vegetated areas on site, species were selected for eventual establishment of a full, self-sustaining vegetative cover. These species consisted of King Ranch bluestem (*Bothriochloa ischaemum* Var. *songarica*), buffalograss (*Buchloe dactyloides*), sideoats grama (*Bouteloua curtipendula*), and kleingrass (*Panicum coloratum*) on gently sloping areas; and kleingrass and medio bluestem (*Dichanthium aristatum*) on embankment slopes and channel surfaces. Future maintenance plans of these species will be conducted by fertilizing and mowing.

The reclaimed tailings impoundment described above is in the final stages of performance monitoring prior to property transfer to the U.S. Department of Energy. Tailings impoundment closure has been designed to meet the design criteria for tailings isolation, radon emanation, infiltration, and erosional stability. The closure plan was
developed around existing site conditions, and closure costs have been reduced as much as possible by:

(a) Designing the closure surface to match the tailings surface at mill shutdown;
(b) Using on-site materials as much as possible; and
(c) Carefully selecting off-site materials (when necessary).

Post-closure performance monitoring of the reclaimed tailings impoundment and surrounding areas has been conducted for nearly 10 years.

The monitoring results have shown good vegetation success with minimal erosion in all of the reclaimed site areas. Reclaimed areas of the site have been successfully used for grazing and wildlife habitat, with environmental monitoring showing key air quality and water quality constituents within accepted values. Cover settlement over the tailings has been relatively low, with values within predicted ranges. Monitoring data from the reclaimed tailings pond exhibits positive drainage with no standing water and no areas of settlement that could impact the integrity and performance of the vegetation cover (MWHGlobal [MWH], 2008). The pond structural integrity has been monitored and monitoring results indicates that there is no tailings material that is exposed or released. No vertical/horizontal displacement or slumping was been observed and the vegetation cover established is sufficient to control erosion (MWH, 2008).

Summary of reclamation best practices:

• Use of established regulatory reclamation guidelines as reclamation criteria;

• Conducting reclamation activities concurrently with mining by backfilling the open pit with overburden and revegetating the surface;

• Strategic species selection; and

• Fertilization and mowing.
4.1.2 Case Study Two - Direct Re-vegetation of Acidic Mine Tailings at the Idarado Mine Site in Southwest Colorado (Redente, 2009)

Mining in the Red Mountain and Telluride mining districts in southwest Colorado began in the mid-1800s and left behind facilities and structures including old town sites, railroads, bridges, power plants, mining and milling structures, and mine rock and tailing piles. There was a legacy of mine and mill features scattered along the Telluride and Red Mountain landscapes requiring reclamation, remediation or source-control measures as a result of over 100 years of mining.

Idarado produced gold, silver, copper, lead and zinc. In 1983, the State of Colorado filed a natural resource damage claim against Idarado to address the historic environmental impacts in the two mining districts. The reclamation efforts were successful in part due to collaboration between a number of stakeholders, including the local communities of Telluride and Ouray, local town and county governments, the State of Colorado and Idarado. The objective was successful in achieving a balance between historic preservation and environmental protection.

Idarado sought a better solution-based approach involving reclamation technology; converting the tailing materials into viable soil substrate that would support a self-sustaining plant community and be wind and water erosion resistant.

The selected approach departed from traditional techniques in consultation with subject experts, the local community and government agencies. A field scale test of direct, in-situ revegetation in the mid 1980s was established as a precursor to final reclamation. Based on the results of field-scale testing, a plan was designed and implemented for full-scale reclamation beginning in the mid-1990s. The reclamation plan that was developed between Idarado and the State of Colorado established revegetation success standards for live plant cover, total cover (i.e. live vegetation and litter), and species diversity).

Revegetation success will be determined after 15 years of annual monitoring and reporting. The following presents a summary of plant cover and metal uptake data collected over a 12-year period to measure success of the direct revegetation program initiated by Idarado on tailing piles in the Telluride and Red Mountain mining districts.
The reclamation of the tailings piles included soil amendment, re-vegetation, and monitoring. Limestone, manure, hay or straw and fertilizer were used in the soil amendment process. Soil chemical analysis was conducted prior to amendment and re-vegetation.

4.1.2.1 Revegetation Methods

Telluride tailing piles were revegetated in 1993 and 1996. The revegetation process included the incorporation of limestone, manure, hay or straw and fertilizer. Limestone, manure and hay were mixed to a depth of 45 cm in summer and fertilization was completed at the end of September. The tailing piles were then seeded with the following seed mixture: slender wheatgrass (*Elymus trachycaulus*), Smooth brome (*Bromus inermis*), Mountain brome (*Bromus marginatus*), Orchardgrass (*Dactylis glomerata*), Common Timothy (*Phleum pretense*), Canada bluegrass (*Poa compressa*), Kentucky bluegrass (*Poa pratensis*), Creeping wildrye (*Elymus triticoides*), Hard fescue (*Festuca ovina duriuscula*), Cicer milkvetch (*Astragalus cicer*), Sainfoin (*Onobrychis viciaefolia*), Rocky Mountain penstemon (*Penstemon strictus*), Red clover (*Trifolium pretense*), Lewis flax (*Linum lewisii*), and Alfalfa (*Medicago sativa*). The site was mulched with straw immediately after seeding.

4.1.2.2 Sampling Methods

In August of each year, plant cover was measured on the tailings piles. Cover was measured by the point method, using a vegetation sighting scope mounted on an adjustable tripod with a level. Cover was measured for each species encountered, as well as litter, rock, and bare ground. Cover measurements were made along permanent and randomly placed transects on both top and slope segments of the tailing piles. Bonham (1989)’s sample adequacy calculations were used to estimate the mean population.
4.1.2.3 Revegetation Success Standards

Revegetation success on tailing piles will be determined by applying certain criteria, agreed on by all stakeholders and documented in the reclamation plan. The criteria include total cover, live cover, and species diversity. Final determinations of success will be based on vegetation data collected during the last two years of the evaluation period. The top surface of each pile will be judged successful if the following criteria are met:

- Total cover (i.e. live vegetation and litter) is equal to or greater than 80%;
- Live cover is equal to or greater than 60%;
- No single species contributes more than 50% of the live cover; and
- At least four perennial species each contribute a minimum of 3% of the live cover.

The revegetation of the side slopes will be deemed successful if the following criteria are met:

- Total cover is equal to or greater than 70%;
- Live cover is equal to or greater than 60%;
- No single species contributes more than 50% of the live cover; and
- At least four perennial species each contributes a minimum of 3% of the live cover.

Summary of reclamation best practices:

- Consultation with all stakeholders on proposed reclamation plan prior to implementation;
- Site specific assessment prior to implementation of the reclamation plan;
• Field scale testing on reclamation plan prior to undertaking full reclamation;

• Annual monitoring and reporting;

• Setting success criteria;

• Strategic species selection;

• Application of fertilization and mowing;

• Soil amendment; and

• Soil chemical analysis prior to vegetation.

4.1.3 Case Study Three - Elkview Coal Mining Site (Przeczek, 2003).

Elkview Coal Corporation (Elkview) is located in southeastern British Columbia near the town of Sparwood. The focus of the reclamation program at the Elkview is to re-establish functional ecosystem processes and biological capability (Przeczek, 2003).

4.1.3.1 End Land Use and Reclamation Objective

The focus of the reclamation plan was to ensure that the reclaimed slopes were geotechnically stable, control soil erosion, maintain acceptable water quality, mitigate aesthetic impacts, promote acceptable habitat for a range of wildlife species, and allow for re-colonization of native plant species. Elkview recognized that creating conditions that will promote re-establishment of basic plant communities was the key to the success of the developed CC&R plan.

4.1.3.2 Challenges and Limiting Factors

The Elkview mine is located within the dry cool Montane Spruce and subalpine Fir biogeoclimatic subzones (Braumandl and Curran, 1992). Braumandl and Curran (1992) identified a number of key factors that might limit plant growth on various forested site series in this biogeoclimatic subzones. The primary factors include excessive dry or wet soils, poor nutrients, cold soils and cold air temperature. Conifers planted
between 1999 and 2001 have had poor survival. This poor performance is attributed to winter desiccation. Additionally, reconstructed soils can be limiting factors as these soils tend to have increased soil density, poor porosity, low levels of organic matter and low nutrient levels (Haigh, 2000).

4.1.3.3 Habitat Diversity

Elk and mule deer are featured species for the Elkview reclamation program; however, the reclamation plan for the site encouraged re-establishment of local populations of a wide range of vertebrate and invertebrate species. The plan recognized that there are a number of factors that affect the potential re-establishment of a species into a reclaimed environment and a lack of guarantees that species population will re-establish because of the existence of appropriate habitat (Black et al., 2001). Elkview recognized its limits in creating habitats that will support all the species communities that existed prior to development, the planned measures of reclamation success include how well various vertebrate species use the reclaimed mine area and connectivity of various elements in the reclaimed landscape with the surrounding undisturbed area.

4.1.3.4 Biological Diversity

Management of Elkview is committed to restoration of biological diversity. Office of Technology Assessment [OTA], 1987 defines biological biodiversity as the variety of variability among living organisms and the ecological complexes on which they occur at three basic levels (genetics, species and ecosystems). While reclamation will establish the basic ecological process, as it could take centuries for a complex ecosystem to develop.
4.1.3.5  Soil Capability

Reclamation treatment units were developed and applied at the Elkview mine site. Reclamation treatment units were delineated on the basis of site characteristics that will influence ecological processes and reflect anticipated differences in the development of plant communities, productive soils and suitable wildlife habitats. Reclamation treatment units are simplified capability units providing the framework for developing treatment regimes that focus on the specific ecological factors that are limiting to the establishment of targeted plant communities. They provide a framework for adaptive management by providing context for establishing monitoring programs that will assess if reclamation objectives are being met. Re-establishing functional reconstructed mine soils is the most important objective for ensuring that plant communities become self-sustaining.

4.1.3.6  Revegetation

Revegetation activities were planned to follow re-sloping treatments. Seeding to establish grass and legume-dominated plant communities took place in the fall. Fertilization occurred in the spring following snow melt. Three applications of fertilizer are planned over the next 10 years to ensure that plant communities become self-sustaining. The developed reclamation plan recognizes the importance of establishing trees and shrubs. Native tree and shrub species are planned to be used in the reclamation program.

4.1.3.7  Results-Based Standards

Elkview proposed to use results-based standards for assessing reclamation success as follows:

- Geological stability;
- Minimization and control of surface erosion;
- Vegetation productivity, spatial diversity and species diversity;
• Spatial diversity that promotes connectivity with adjacent undisturbed land;

• Ecological functioning including soil profile development, soil organic matter and nutrients and % of mycorrhizal fungi colonization; and

• Wildlife use – re-establishment and ongoing use by a variety of wildlife species.

Summary of reclamation best practices:

• Setting end land use objectives;

• Identifying challenges and limiting factors;

• Selection of indicator species; and

• Setting reclamation treatment units.

4.2 CASE STUDY ANALYSIS

The case studies that were reviewed for this research indicate that there are a number of direct measures that can be used to assess reclamation success. The table below summarizes the useful benchmarks, targets and best management practices that have been applied in previous case studies. Definitions of benchmarks, targets and BMP are provided in subsections 1.2.1, 1.2.2 and 1.2.3, respectively.
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## Case Study

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CHAPTER FIVE

5.1 CASE STUDY ANALYSIS AND DISCUSSION

This chapter will discuss the lessons learned from the case studies reviewed in Chapter 4 and provide a discussion on the applicability to the AOSR. A management plan has been development for selected best fit reclamation benchmarks and targets and related best management practices.

5.2 PROPOSED MANAGEMENT PLAN

Reclamation of an ecosystem to capabilities similar to those that existed prior to disturbance is a challenging undertaking. This is due to the consequences of mining activities, which result in removal of the basic attributes of an ecosystem (structure, function, complexity, and interconnectedness).

The goal of reclamation should be to establish an ecosystem that is self-sustaining and resilient. This will require complex benchmarks to measure the reclamation success. The CC&R plan should be developed with short and long-term objectives of creating a self-sustaining ecosystem. This management plan has been developed considering that boreal ecosystems develop over a long time. Proper planning that takes into consideration all stages of development (pre-development, project, and post-development) will enable succession processes that will lead to the desired ecosystem complexity. CC&R plans should identify limitations and determine critical aspects, including re-vegetation of areas that have been disturbed by mining and subsequently reclaimed.

There are several aspects that should be taken into consideration when setting reclamation objectives, such as vegetation structure, species diversity, and ecosystem process (Elmqvist et al., 2003), erosion control measures, TLU, esthetics and establishment of suitable post-mining end land uses. Meeting the set reclamation objectives will require a properly managed reclamation program to ensure effective return of the land to an agreed upon post mining end land use. Evaluation of reclamation success should be conducted using the selected and agreed upon benchmarks or indicators.
This research recognizes that reclaiming oil sands is different from other mines that have been successfully reclaimed; however, there are lessons that can be learned from other related mining industries, and incorporated into the reclamation process of AOSR.

This management plan focuses on the application of reclamation benchmarks and targets that have been applied in the case studies reviewed in Chapter 4 on a tailings pond; however, similar principles would be applied to other landforms that have been created as a result of oil sands development in the AOSR. The focus on tailings ponds is primarily due to the fact that tailings ponds will occupy a majority of the closure landscape for oil sands mines and there are current challenges and uncertainties associated with the reclamation process of this landform.

5.3 ESTABLISHMENT OF RECLAMATION GOALS AND OBJECTIVES

The goals and objectives of reclaiming a tailings pond will include stabilization of the site and establishment of a productive plant community based on an applicable and agreed upon end land use. The set goals should be consistent throughout the AOSR to ensure that continuity of landforms across the landscape is maintained.

The following eight step approach in setting benchmarks and targets should be utilized:

1. Key stakeholder mapping;
2. Agreeing on the selected benchmarks and targets;
3. Selecting success indicators to be monitored;
4. Evaluating and assessing baseline data and current state;
5. Planning for adaptive management;
6. Monitoring of results;
7. Reporting to promote accountability; and
8. Implementing the management plan and monitoring and evaluating findings.

Guidelines for successful revegetation developed by the Nevada Division of Environmental Protection (1998) recommends that a reclaimed desired plant community
should be selected and agreed upon by key stakeholders for use in the disturbed land form prior to development. To meet the set reclamation goals, the variable site characteristics will be taken into account. The following key benchmarks and targets selected have been assessed and considered applicable to AOSR. Implementation of the selected targets and benchmarks will need to be assessed on a site by site basis.

5.3.1 Cover Material

Capping of tailings provides a protective layer of soil that is graded to promote runoff that mimics pre-disturbance conditions (Colorado Department of Natural Resources, 2002). The capping layer provides an uncontaminated soil layer in which vegetation can grow. The design should account for potential minor erosion that is prone to occur; however, the selected cap should be stable enough not to disturb the contaminated tailings underneath. In the PMUO case study summarized in Chapter 4 one of the closure criteria included consolidation and covering of the tailings with a random cover material that was appropriate for supporting vegetation re-establishment. To reduce costs, the primary cover material was obtained from the stockpiled overburden material.

Like most tailing ponds, the tailings ponds in the AOSR contain potentially toxic material. Capping design should take into consideration the level of toxicity in the material that is being capped prior to initiation of the capping process. In the case of Idarado mine site reclamation program described in Chapter 4, soil chemical analyses and amendment was conducted prior to re-vegetation activities. Given the toxicity levels that have been reported in the tailings ponds in the AOSR, a complex capping material that contains interlayered material should be used. The appropriate construction season should be optimized, taking into consideration factors such as frost, erosion and animal activities and appropriate measures should be put in place to mitigate potential impacts. Periodic monitoring to identify potential problems and maintenance should be conducted.
Measurement of Reclamation Success

To measure the achievement and success of the reclamation a periodic site visit should be conducted. Monitoring should be conducted for at least 5 years. The site visits should specifically assess the following aspects:

- Surface and groundwater quality in relation to applicable regulatory limits;
- Visual assessment of cover settlement;
- Tailings pond structural integrity monitoring (exposure of tailings material);
- Assessment of drainage (volume of standing water);
- Cover support of vegetation growth;
- Established vegetation control of erosion;
- Geological stability of the reclaimed surface; and
- Soil chemistry indicators.

5.3.2 Revegetation and Vegetation Diversity

Vegetation performance has been used as a key reclamation success indicator, however, there has been a tendency to focus on very few vegetation performance indicators like height growth and site index as reclamation benchmarks (Young, 2000). Vegetation structure can predict ecosystem productivity and habitat suitability, and ultimately the successional pathway (Wang, 2004). Species diversity will promote susceptibility to invasion by native and exotic species and the trophic levels that are required for a resilient ecosystem (Nichols and Nichols, 2003).

Re-vegetation is crucial in reclaiming disturbed land due to the following factors:

- Reduction of soil erosion and storm runoff;
- Provision of habitat and forage for animals;
• Reduction of visual and noise impacts;

• Reduction of reclamation liability;

• Increase of the value of the land by returning it to equivalent capability; and

• Provision of nutrients to the soil cover.

Appropriate revegetation methods should be utilized, taking into consideration site specific needs. Revegetation best management practices reviewed for this research indicate that similar extraction industries are utilizing site specific and non-prescriptive techniques; and the adopted general approach is similar to the approach currently being followed in the AOSR. In the AOSR, the choice has been left to the operator, who is assumed to have enough expertise to make well informed decisions.

Heterogeneity in design development should be adopted since it is likely to promote a landscape that is diverse and similar to a natural landscape. In order to promote vegetation at a larger spatial scale in the AOSR, inclusion of a variety of species and diversity of plots that are designed to ensure connectivity to adjacent natural landscapes will be critical. Tools like Geographic Information Systems (GIS) should be utilized in mapping the desired outcome.

In order to achieve the desired outcomes the following subsections describe vegetation establishment best management practices that should be incorporated.

5.3.2.1 Seeding

Species Selection and Seed Source

Selection of appropriate seed source and proper seeds has been identified as an important aspect as new information on successful reclamation of mines becomes available. It has been observed that the performance of seed sources whose origin is not the same as the area to be reclaimed perform differently (Limstrom, 1964). Work conducted by Limstrom (1964) in the USA shows that yellow poplar from a Mississippi source is more susceptible to frost damage in Ohio than trees from locally collected seeds. When collecting seeds, it is important to also consider resistance to insects and
diseases. Depending on the end land use, it is important to select species that are likely to accomplish the desired objectives. Macyk and Drozdowski, (2008) point out three factors that can influence seedling survival and growth on reclaimed lands; seed source, stock type and species.

Limstrom (1964) recommends that the following questions be included in the process of seed and source selection:

- Is the species suitable to the planting site?

- Is the seed source or variety adaptive to the local climate?

- Are the species and seed source suitable for the product desired?

The Nevada Division of Environmental Protection (1998) recommends that a perennial plant community should be established on a disturbed site to promote stability. Several species could be selected depending on the established reclamation goals and end land use; however, the species should be selected based on site-specific revegetation goals and variable site characteristics for the mining disturbances. When selecting species, major alterations in reconstructed soils and the subsequent effect of this on the site’s capability to establish and sustain the desired vegetation must be considered. Analysis of soil chemistry should also be conducted prior to revegetation. The selected species should have a reasonable chance for success when making the selection, thus it is highly recommended that the selected seed mix be specific to the climate of the site and similar to the native vegetation. The plant community should be diverse and, when appropriate for the site, should include grasses, forbs, shrubs and/or trees. The operators should strive as much as possible to include species that are native to the area, or introduced species where the need is documented for inclusion to achieve the approved post-mining land use. The plant material selection and application should be those that have proven long-term success on previous projects. For the AOSR, results from test plots should be used to evaluate the applicability.

Revegetation best management practices developed by the Colorado Department of Natural Resources (2002) recommend application of mulch over the entire seeded area to protect the seeds from water and erosion while they sprout. Natural plant communities
should be established through succession from pioneer species to climax species (Norman, Wampler, Throop, Schnitzer, and Roloff, 1997). It has been observed that climax species will grow slowly whereas pioneer species grow more rapidly and fill the disturbed area (Norman et al., 1997). Operators should keep in mind that each phase in the plant succession prepares the ground for the next. Thus, nitrogen-fixing legumes, shrubs, and trees will play a crucial role in soil reconstruction. It is not possible to mimic progression during the reclamation phase; however, planning a phased succession for both ground cover and trees allows progression towards climax species (Norman and Lingley, 1992).  

5.3.2.2 Fertilization

It was noted in the case studies that were reviewed that fertilization can improve the performance of the soil that is potentially stripped of nutrient during the mining phase. It is recommended that fertilizer be applied where it is deemed necessary to improve the performance of vegetation re-establishment. Suncor is currently conducting a five year study to determine the benefits of fertilizer application (Macyk and Drozdowski, 2008).

Setting re-vegetation success indicators that are based on long-term data collection should be included in the planning stages. The indicators will include the following standards adopted from the three case studies reviewed;

- Total cover (live vegetation and litter);
- Live cover;
- No single species contributes to the majority of the cover;
- Minimal erosion;
- Reclaimed areas have been successfully utilized by wildlife; and
- Performance of the vegetation has not been impacted by cover settlement.
Monitoring and evaluation of success will be a key component of this plan. For example the Nevada Division of Environmental Protection (1998) recommends that the success of the vegetative growth on a reclaimed site be evaluated no sooner than during the third growing session after all reclamation activities have been completed. Interim progress of reclamation should be monitored as appropriate by the operator and reported to the regulators at agreed upon intervals. Where it has been determined that revegetation success has not been met, the regulator and the operator should meet to decide on the best course of action necessary to meet the reclamation goals. This approach is desirable as it promotes flexibility and allows for collaboration among the involved stakeholders.

It is recommended that regular maintenance on the revegetated land be conducted. This could include regular inspections of the area to identify potential problems that might be caused by erosion, areas of non-growth or noxious weeds. If a problem is identified, prompt action should be taken. The implemented reclamation plan should be monitored and evaluated to ensure that it meets the desired goals and objective of the reclamation program. Vegetation measurements should be employed at least twice per year during the growing season in the first few years of the reclamation program. This will ensure detection of species that are either late or early season dominant and will also allow for accountability of late season germination and over winter survival. A complete plant species composition and cover of individual species should be determined during the inspection. This will allow for a determination of seeded and unseeded species. The monitoring program should include a general assessment of plant health and vigor. Adaptive management principles should be employed at all times.

Mining activities promote harsh conditions that sometimes make it difficult for vegetation to re-establish. The operators should progressively revegetate the disturbed land as mining activities progress. Starting the re-vegetation process early is critical as it allows several seasons to establish vegetation cover. Successful revegetation can potentially be a slow process, so it is important to take the time to monitor and evaluate to ensure that the end land use objectives are being met. Currently, the Alberta government has not set any performance targets; however, this is an instrument is recommended for
measuring compliance. Any targets set should be flexible and take account site specific conditions.

Vegetation diversity will be the targeted benchmark that will not only be important for promoting a variety of wildlife habitats, but also for the resilience it can offer the forest in the face of major disturbances such as insect or disease infestations or fire.

Measurement of Reclamation Success Indicator

Zak (1992) recommends monitoring microbial activities at the functional level to monitor for short term and long-term reclamation success. He also indicates that measures of mycorrhizal species abundance, change over time, and richness can determine reclamation success. The reclamation plan for Elkview utilized this indicator to measure reclamation success. Naeth et al. (1991) recommend the establishment of benchmarks sites to allow for comparison of soil physical properties. They recommend reassessment at 10 year intervals.

To measure the achievement and success of the set reclamation criteria, the following aspects should be assessed through field assessment monitoring activities:

- Percentage of total cover (i.e., live vegetation and litter);
- Percentage of live cover;
- Percentage of one single species of the live cover;
- Percentage of perennials;
- Nutrient and trace element content;
- Species richness and diversity, including variety of wildlife species;
- Native species establishment;
- Soil profile development;
- Percentage of soil organic matter;
• Resilience in case of a natural disturbance like fire; and

• Mycorrhizal fungi colonization.

5.3.3 Habitat Diversity and Connectivity

The Elkview coal mine case study encourages the establishment of local populations with a wide range of vertebrate and invertebrate species. One of the main indicators of high biological diversity is a high level of structural complexity (Wascher, 2000). Assessment of how well different flora and fauna species re-establish and use the created habitat will be a key benchmark for sustainable reclamation. The importance of connectivity of various elements in the reclaimed landscape with the adjacent natural landscape will also be a key indicator.

Measurement of Reclamation Success Indicators

• Permanent settlement of key wildlife species;

• Conducting regular wildlife surveys to determine the presence of key species and continued use of wildlife in the reclaimed area;

• Wildlife movement to adjacent natural landscape; and

• Percent of species in comparison to baseline conditions.

5.3.4 Progressive Reclamation

The Government of Alberta has shown its support of the principle of progressive reclamation. Progressive reclamation is important as it sets the stage for the establishment of a self-sustaining ecosystem. Progressive reclamation:

• Allows operators and regulators to acquire long-term data;

• Allows for identification on potential problem while the mine is still in operation; and

• Reduces final reclamation costs and liability.
Currently, there is no legal requirement for operators in the AOSR to perform progressive reclamation. As such, operators in the region have no incentive for undertaking timely reclamation. Even though operators do develop reclamation timelines and milestones in the CC&R plan, there is a lack of enforcement from regulators. It is recommended that operators and regulators work together to come up with agreeable reclamation timelines that will promote progressive reclamation. Each operator should be required to reclaim a certain percentage of the total disturbed area and report to the regulator at an agreed-upon interval.

**Measurement of Reclamation Success Indicators**

- Percentage of reclaimed area in comparison to disturbed in the set time frame;
- Increased rate of reclamation certification; and
- Percentage area reclaimed during final reclamation activities.

**5.3.5 Monitoring and Evaluation of Reclamation Objectives**

Successful implementation of this management program will require a holistic approach to monitoring that assesses several parameters.

The Government of Alberta has not developed revegetation success indicators. Implementation of reclamation benchmarks and targets like the ones summarized above will aid evaluation of reclamation success evaluation. Until such standards are developed, operators in the AOSR should employ available technical knowledge in making their decision. Success indicators should be determined prior to commencement of the reclamation program, and progress should continue to be monitored including a feedback mechanism and implementation of appropriate change when necessary.

**Measurement of Reclamation Success Indicators**

- Achievement of set reclamation objectives and goals;
- Applicability of set targets and benchmarks to the AOSR;
- How well the principle of adaptive management is employed; and
- Flexibility of the developed management plan.
5.3.6 Regional Reclamation Reference Sites

A reclamation reference site is defined as the condition that is a representative of a group of disturbed sites organized by selected physical, chemical, and biological characteristics (Reynoldson, Norris, Resh, Day and Rosenberg, 1997). For this research reference sites are defined as set reclamation test plots that are used as a benchmark for assessing reclamation success. In the Red Mountain and Telluride case studies, a reclamation field scale test was conducted prior to implementation of the full reclamation program. The field scale testing provides important information that should be used in the planning and implementation of a full-scale reclamation program. To promote the continuity of landforms found in the AOSR, it is recommended that reference sites be established at a regional level. The established test plots will take into account the different biological conditions that exist in the AOSR. Reference sites should be grouped into groups of similar habitat and invertebrate community characteristics. Wright et al. (1984) recommended grouping of individual sites according to faunal characteristics.

Measurement of Reclamation Success Indicator

The following approaches should be used to evaluate reclamation success of the reference sites:

- Use of biotic condition indices with pre-established thresholds;
- Measurement of geographic and physical attributes; and
- Assessment of species composition.
5.4 DISCUSSION

Results of this research show that sustainable reclamation targets and benchmarks can be developed and applied in the AOSR. Targeting biological functionality and diversity at all levels should be a driver in achieving the objective of equivalent land capability and desired end land uses. Implementation of the proposed plan will ensure that end land use and reclamation objectives are achieved, reclamation activities are progressive and the environment is protected for future generations.

Successful implementation of this management plan will require identifying priority areas and applying appropriate benchmarks and targets. Understanding the dynamics of ecological systems will require prolonged periods of time. At a minimum the reclaimed landform (tailings pond) should be monitored annually, however, results are expected to be apparent within a 5 to 10 year timeframe. Further field research is required in assessing if short-term reclamation success indicators are a good measure for long-term ecological outcomes.

5.4.1 Consultation and Collaboration

Given the complexity of the issue, implementation of the identified benchmarks and targets will aid in mitigating disturbance to the environment and ensure sustainable growth. This will require consultation and collaboration amongst the key stakeholders. It is recommended that the following aspects be reviewed and incorporated in the process:

- Improving technical competencies – improved technical understanding will set a basis for the complexity associated with reclaiming the landforms in this region. Collaboration between government, industry, researchers, NGOs and First Nations will be required. Industry and/or government will need to champion and or sponsor these initiatives;

- Improving leadership efforts (industry and government) – the government of Alberta should set reclamation guidelines to streamline the process for industry working in this region;
• Balancing economic benefits with social, environmental, human and wildlife health impacts that are associated with the development of this valuable resource - acknowledge that economic prosperity is sustainable only if the other aspects of the sustainability principle are accounted for;

• Integration of environmental, social and economic disciplines as the impacts are interrelated; and

• Inclusion of First Nations in all phases of the development including reclamation.

5.5 FUTURE RESEARCH

Several areas that are related to sustainability of reclamation in AOSR still require further research. It is recommended that stakeholder in the region assess the needs and set priorities. The following areas require further research:

• **Governance and Leadership:** Clear definition of roles and responsibilities of various government levels - (i.e. municipal, provincial and federal) as well as the roles of industry, First Nations and the NGO groups working in the region and demonstrated leadership from the government and industry;

• **First Nation Traditional Knowledge:** Assessing the applicability of the inclusion principle by drawing on First Nation traditional knowledge in the reclamation process;

• **Research and Development:** Gap analysis and review of uncertainty associated with the scientific knowledge currently available; and

• **Legislation:** Assess the feasibility of developing strong reclamation policies and regulations.
REFERENCES


Canadian Natural Resources Limited [Canadian Natural]. Province of Alberta, Environmental Protection and Enhancement Act. Approval No: 149968-00-00. Edmonton, Alberta.


