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COMPREHENSIVE REPORT ON OPERATIONAL RECLAMATION TECHNIQUES IN THE MINEABLE OIL SANDS REGION

PREPARED FOR
CUMULATIVE ENVIRONMENTAL MANAGEMENT ASSOCIATION (CEMA)

PREPARED BY
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ALBERTA RESEARCH COUNCIL INC.

September 15, 2008

DISCLAIMER

The information in this document was obtained primarily from documents supplied by the mine operators in the mineable Oil Sands, Mountain and Prairie coal mining regions, Alberta Environment, and Alberta Records Center. These documents included "Annual Conservation and Reclamation Reports", approval documents and a variety of publications pertinent to the topic. Information may appear to be more comprehensive for some companies than others, and this is a result of the availability of information at the time of compilation of this document.

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1.0 INTRODUCTION

Surface mining of coal in Alberta has been practiced for the last century. Oil sand extraction began 40 years ago. The associated operational reclamation techniques evolved as a result of the changes in guidelines and regulations that occurred and the research effort that expanded markedly during that time. This report identifies and summarizes reclamation practices that have been used in the mineable Oil Sands region and coal mining industry over the last 40+ years.

1.1 OBJECTIVE

There were two main objectives for this document. These were to:

- Develop a comprehensive report that documents the operational reclamation techniques relevant to reclamation in the boreal forest/mineable Oil Sands region in Northern Alberta, and in the Mountain and Plains coal mines over the same period, and
- Identify the progression of reclamation techniques over time showing how research and experience along with government policy have influenced the development of current reclamation practices.

This document is not intended to be used as a prescriptive manual for undertaking reclamation activities, but is intended to serve as a reference insofar as it describes what techniques and strategies have been used in the mineable Oil Sands, Mountain and Plains Coal mining regions (Figure 1.1). It also provides references to applicable legislation, regulatory approvals, annual reports, and relevant research and literature to guide the reader to more detailed and specific information.

1.1.1 SCOPE AND ORGANIZATION

This document provides a summary of past and present techniques and technologies used for reclamation in the mineable Oil Sands, Mountain and Plains Coal mining regions of Alberta (Figure 1.1). Reclamation, for this document, includes such activities as soil salvage and placement, revegetation with herbaceous and woody species, revegetation, soil monitoring, fertilization, weed management, erosion control and landform design.

The document presents the information in four main sections. The first section provides a brief summary of the regulations and operational reclamation practices in the mineable Oil Sands, Mountain and Prairie coal mines and identifies similarities and differences among them. Section 2 describes the operational reclamation practices in the mineable Oil Sands region in more detail, with company specific information. Sections 3 and 4 describe the operational reclamation practices in the Mountains and Prairie coal mines, respectively, in more detail. Statements that are highlighted in sections 2 to 4 represent key components of the evolution of operational reclamation practices and associated observations.

Figure 1.1. Sketch map of mine locations.

1.2 PHILOSOPHY OF RECLAMATION

Reclamation is an "emotional" issue because land disturbances are highly visible and represent an "image" issue with some history of provoking public response. The philosophy of reclamation has changed dramatically from the 1950s and 1960s. In fact reclamation was largely unheard of in many parts of North America at the time. Initially aesthetics were an obvious concern along with some of the unseen legacies associated with these disturbed areas. Progressively the public realized that land is a limited resource and that one should not sacrifice one resource for another (Adams 1983). Furthermore, surface mining is a temporary land use compared to the long-term uses associated with agriculture, forestry, or recreation.

The 1973 Land Surface Conservation and Reclamation Act had a major impact on the philosophy and approach to reclamation with the introduction of the need for conservation and planning. As a result industry began to hire environmental staff to assist with obtaining approvals for projects, to get the projects on stream and to manage on-site environmental programs. Companies also discovered that it was more expensive to go back and fix problems than to prevent them.

Suncor's initial reclamation goal was "to reclaim disturbed land with vegetation that is erosion controlling, self-sustaining and useful as wildlife habitat and for recreation" (Klym and Shopik 1979). Their current reclamation goal states that "developed lands shall be reclaimed to viable ecosystems compatible with pre-development, including forested areas, wetlands and streams. The reclaimed lands will provide a range of end uses including forestry, wildlife habitat, traditional use and recreation" (Golder 2007).

Albian Sands Energy Inc. which began site construction in 1999 had a reclamation objective "to restore ecosystem processes and services to a level similar to undisturbed ecosystems within a reasonable time scale (Albian Sands 2006).

The above mentioned examples illustrate the difference in philosophy or expectation over a period of 20 to 25 years. In essence it was a shift from just wanting to have something grow, to wanting a cover of defined species at a specified stocking rate and level of productivity. Similar examples could be provided for the Mountains and Plains regions as well. For example in the Plains region in the late 1970s or 1980s the goal would have been "to return the land to productive agricultural use" whereas a current goal would include the return of land to agricultural capability classes that existed prior to disturbance. Similarly the objective of reclamation at the Grande Cache area operations in the early 1970s was "to establish a long-term vegetation cover that is in harmony with adjacent undisturbed areas" (Macyk 1972). This changed in the ensuing years to reflect the proportion of the various species that would comprise this vegetation cover and reflect the importance of wildlife habitat.

This change in approach or "philosophy" can be attributed to the increase in understanding of how reclamation materials function and the associated changes in regulations and approvals. Early operational practice and research demonstrated the value of soil salvage and replacement. Similarly revegetation practice evolved beyond establishment of a green cover to stabilize the site and prevent or minimize erosion.

Adopting the "capability" rather than "productivity" concept for measuring reclamation success represented a major shift in philosophy or approach. This shift demonstrated the commitment to the idea that the cost of assuring the ability of the land to support various uses after reclamation is to be borne as a capital investment in the land rather than as an operating cost by the end land user. The adoption of systems for reclamation planning and measurement of reclamation success represented major advances. For example, acceptance and adoption of the "Soil Quality Criteria for Disturbance and Reclamation" (ASAC 1987) provided a universal approach to measuring the suitability of undisturbed and reconstructed soils. The Land Capability Classification for Forest Ecosystems (LCCS) manual (2006) first introduced in 1996 is intended to facilitate evaluation of land capabilities for forest ecosystems on natural and reclaimed lands in the Oil Sands region. It is based on a level of understanding of natural ecosystems and evolution of reclaimed ecosystems. The companion document "Guidelines for Reclamation to forest Vegetation in the Athabasca Oil Sands Region" (OSVRC 1998) provides guidance for developing revegetation treatments for reclaimed landscapes.

Future advances in reclamation approach will be influenced mainly by the results of current practice and the advances identified through ongoing research programs.

1.3 PROGRESSION OF RECLAMATION TECHNIQUES OVER TIME

The evolution of reclamation practice or progression of reclamation techniques over time is based on the changes in regulations and guidelines and overall government policy combined with research and experience gained through operational practice. The text of this report provides the details pertinent to the various components including approvals, soil handling practices, revegetation practices, and monitoring activities for the different operations or mines in each of the Oil Sands, Mountains and Plains regions.

Figure 1.2 provides a summary of the major regulatory changes as well as "criteria" and "system" based documents used to provide guidance with respect to reclamation practice and mechanisms for measurement of reclamation success. The 1963 Surface Reclamation Act resulted in some limited requirements associated with mining in the Plains region. In 1973 reclamation became an integral component of all types of mining operations when the Land Surface Conservation and Reclamation Act (1973) began to require companies to plan land conservation and reclamation.

The regulatory approvals are the mechanisms used to translate regulations into operational practice. Detailed descriptions of the approvals for each operator within each region are provided in the report. Table 1.1 provides a "generalized" overview for each of the regions as requirements for individual operators within a region differed. For example, in the Plains region at a specific time or year one operator may have had the requirement to replace 0.15 m of topsoil while another had to replace 0.20 m.

During the late 1970s the approvals made reference to removal of organic and mineral material suitable for reclamation in sufficient quantities necessary for reclamation. The reconstructed soil was to have chemical, physical and biological characteristics which permit:

- upland reclamation to a forest environment at least as productive as prior to disturbance in the Mineable Oil Sands region
- upland reclamation to an agricultural use in the Plains
- return of land capability equivalent to that which existed prior to disturbance in the Mountains.

During the 1980s and 1990s minimum and average soil replacement depth requirements dictated the soil salvage practices which followed.

Research projects were initiated largely concurrently with mining operations that were already active or that initiated operations during the 1970s (Table 1.2). Much of this early research focused on the problems or unique conditions of a particular operation. The results of these "research" programs were generally short term when transferred to operational practice because of the need to reclaim areas on an operational scale in a timely manner. As a result monitoring of research efforts continued as operational reclamation was undertaken and the operational areas thus became larger research or demonstration trials.

Formation of the Reclamation Research Technical Advisory Committee (RRTAC) and the Oil Sands, Plains Coal, and Mountains and Foothills reclamation research programs provided for the development and coordination of research to address regional rather than site specific issues or problems.

Table 1.2 provides a list of the major funding agencies and coordinating bodies and a listing of some of the major research programs and projects undertaken in the regions. Many of these reflect programs that were or have been in place for 10 to 35+ years. As well some of them were large and had a broad scope such as the Plains Hydrology and Reclamation program which was conducted over a 15 year period. It resulted in 48 RRTAC publications on a broad range of topics related to mining and reclamation including geochemistry, geology, geotechnical (subsidence), hydrogeology, and reclamation impacts. Many operation specific studies were conducted that are not included in Table 1.2 but are described in the "Soil and Vegetation Monitoring" sections of this document.

The technology synthesis related to soil capping research in the Athabasca Oil Sands Region initiated in 2005 synthesized existing research results for use in landscape and soil capping design (Barbour et al. 2007).

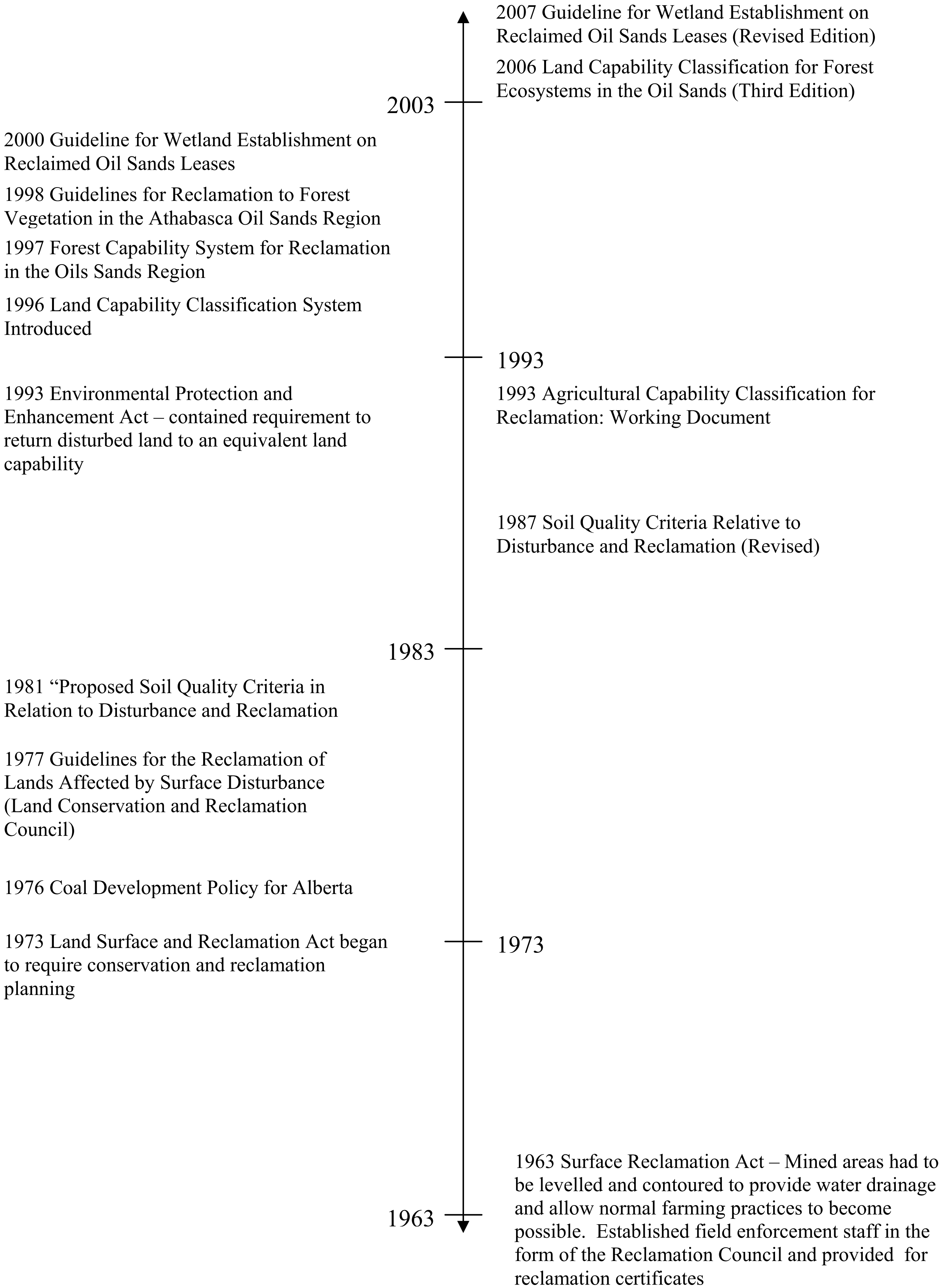

Figure 1.2. Regulation and criteria summary.

Table 1.1. Approval summary for the Oil Sands, Plains and Mountains regions.

Oil Sands Approvals		**Plains Approvals**		**Mountains Approvals**	
1978	Organic and mineral material suitable for soil reclamation be removed in sufficient quantities necessary for reclamation Reconstructed soil to have chemical, physical and biological characteristics which permit upland reclamation to a forest environment at least as productive as prior to disturbance	1977	All surface disturbing activities carried out so that disturbed land would be self-supporting of plant and animal life and as productive as before it was disturbed Operator shall replace root zone soil having a depth sufficient to support agricultural plant growth, in proper sequence, on the surface of the reclaimed lands	1979	Reclamation to be done in accordance with “Guidelines for the Reclamation of Lands Affected by a Surface Disturbance” published in 1977 by the Land Conservation and Reclamation Council Return a land capability equivalent to that which existed prior to disturbance
1984 to 1985	Specific soil depth replacement requirements established including: -incorporate 0.15 m of muskeg or 0.15 m of peat and 0.10 m of clay into tailings sand surfaces -place 0.10 m of peat on overburden surfaces consisting of Holocene/Pleistocene materials. -sodic overburden shall be covered with a minimum of 1.0 m of Holocene/Pleistocene material	1979	All organic and mineral soil above B horizon to be salvaged Soil surface was to have chemical, physical and biological characteristics which would permit upland reclamation to an agricultural use	1979 1981	Various clauses for different operations included: -direct placement whenever possible -replace minimum of 0.30 m of suitable root zone material over all overburden and spoil areas and a minimum of 1.0 m of suitable material over areas which consist of sodic materials -minimum of 0.10 m of suitable subsoil (regolith) shall be placed prior to replacement of topsoil -minimum of 0.30 m of suitable topsoil materials shall be placed on areas designated as topsoil island areas (Cardinal River)
1989	Introduction of “average” rather than “minimum” soil replacement depths and increase in depth of soil replacement required: -Average of 70±10 cm of suitable surface material on tailings sand -Average of 50±10 cm of suitable surface material on all overburden surfaces except for saline, sodic or oil affected areas where 1.0 m of suitable material required	1982 to 1989	All topsoil material (A horizon) was to be salvaged from all lands to be disturbed. Replaced topsoil to be a minimum of 0.15 to 0.20 m Replace minimum of 0.50 m to 1.5 m subsoil (based on availability)		

Table 1.1. Approval summary for the Oil Sands, Plains and Mountains regions cont'd.

Oil Sands Approvals		**Plains Approvals**		**Mountains Approvals**	
1990	Operator will ensure that 60% of disturbed land will be returned to productive forest with remaining 40% oriented to wildlife -suitable soil material profiles with organic content <20% (v/v%) shall have a minimum of 0.15 m of organic soil placed on the surface -on unsuitable quality overburden place a minimum of 1.0 m of reclamation material composed of: ▪ Surface layer with minimum of 0.5 m suitable soil material ▪ Sub-surface layer with minimal of 0.5 m soil with SAR ≤12, salinity ≤8 dS/m and oil content <1%.	1989	Replace 1.5 m of suitable subsoil on lands returned to CLI Class 3 capability and 0.35 m on lands returned to CLI Class 4, 5, or 6	1981	-grass cover to be established yearly for erosion control -fertilizer to be applied until cover becomes self-sustaining -second year after reclamation seedling lodgepole pine and white spruce to be progressively established at 600+ stems/ha
		1991	Replace 1.0 m of suitable subsoil on lands returned to CLI Class 3 capability	1996	Replace all available topsoil to average depth of 0.28 m for a combined topsoil/regolith minimum replacement depth of 0.30 m
1995	Return land to upland ecosystem on disturbed land consisting of 50% productive forest and 20% non-productive forest (including grasslands) Wetland ecosystems on the remaining 30% with a maximum of 20% water bodies	1998	Replace minimum of 0.12 m and average of 0.18 m topsoil on land returned to CLI Classes 2, 3, 4 or 5	1999	Replace surface soil over 1.0 m of spoil, regolith, surface soil having good, fair or poor rating according to Soil Quality Criteria Replace surface soil to minimum average depth of 0.30 m on 80% of area in areas with 0° to 18° slope Replace surface soil to minimum average depth of 0.15 m on 80% of area in areas with 18° to 27° slope -no soil replaced in areas with slopes > 27° Incorporate native seed into seed mixes
1996	Land Capability Classification System introduced Replace suitable soil or mineral topsoil to a minimum depth of 0.10 m with an average depth of 0.20 m on all overburden landforms to achieve soil Capability Classes 2 or 3 and on all tailings sand landforms to achieve soil Capability Classes 3 or 4	1999 to 2007	Salvage all topsoil, conserve all topsoil Replace minimum of 0.12 m to 0.17 m and average of 0.14 m to 0.20 m of topsoil (different operations) Replace minimum of 1.0 m subsoil on agricultural Capability Class 2 or 3 land Replace minimum of 0.35 m subsoil on agricultural Capability Class 4, 5, 6 land		

Table 1.1. Approval summary for the Oil Sands, Plains and Mountains regions cont'd.

Oil Sands Approvals		Plains Approvals		Mountains Approvals	
1999 to 2007	Approvals standardized for all operators with respect to soil handling, revegetation, wildlife and biodiversity: -upland surface soil salvaged to maximum average depth of 0.15 m in a or b ecosites -upland surface soil salvaged to maximum average depth of 0.30 m from sites not a or b ecosites -when salvaging peat/mineral mix emphasis is placed on fine textured underlying materials rather than coarse textured soils -in areas of LCCS class 1-5; 0.50 m of coversoil and subsoil (combined) replaced -when subsoil or overburden with ≥20% clay the coversoil of peat/mineral mix must be an average minimum of 0.30 m -when subsoil, overburden or tailings with ≤20% clay, coversoil of peat/mineral mix must be; class 1 and 2, 0.50 m; class 3, 0.40 m; class 4 and 5, 0.30 m -impervious material, reject, composite tailings, Clearwater overburden and plant development area must be capped with average minimum of 1.0 m of tailings sand or overburden prior to soil placement -land shall be reclaimed so that soils and landforms are capable of supporting a self-sustaining, locally common boreal forest, regardless of end land use -revegetated disturbed land to target establishment of a self-sustaining, locally common boreal forest integrated with the surrounding area			2000	Minimum of 0.30 m of salvaged surface soil on 0.10 m salvaged regolith Minimum of 0.15 m of salvaged soil over 0.20 m salvaged regolith Tree and shrub density > 1000 stems/ha (shrubs dominant) in open forest areas and trees dominant in closed forest areas

Table 1.2. Major projects and agencies associated with reclamation research in the Oil Sands, Plains and Mountains regions.

Oil Sands		Plains		Mountains	
1969	Suncor initial discussions re revegetating tailings sand	1976	Reclamation and Revegetation study at Highvale Mine initiated	1969	Research activities initiated at Cardinal River Coal
1971	First reclamation activities on Tar Island Dyke (Suncor)	1978	Reclamation Research Technical Advisory Committee (RRTAC) formed and Plains Coal Reclamation Research Program (PCRRP) initiated	1971	Research program initiated at Grande Cache Area Operations (McIntyre Porcupine Mines Ltd.)
1973	Formation of Alberta Oil Sands Environmental Study Group (OSESG)				
1975	Formation of joint Alberta/Canada Alberta Oil Sands Environmental Research Program (AOSERP)	1978	Torlea Soil Reclamation Trials initiated at Paintearth Mine	1978	Reclamation Research Technical Advisory Committee (RRTAC) formed
1978	Reclamation Research Technical Advisory Committee (RRTAC) formed	1979	Plains Hydrology and Reclamation Project to examine the impacts of surface mining on regional groundwater, geology, and soils initiated (Resulted in 48 RRTAC publications on topics of Geochemistry, Geology, Geotechnical (subsidence), Hydrogeology and Reclamation Impacts)	1979	Revegetation of Ash Disposal Sites in Grande Cache Area operations initiated (ARC)
1979	RRTAC and industry initiated joint Oil Sands Reclamation Research Program			1979	Native Grasses for Reclamation work initiated (AEC)
1989	Fine Tailings Fundamentals Consortium formed			1984	Coal Association of Canada and RRTAC agree to jointly fund and manage the Mountains and Foothills Reclamation Research Program (MFRRP)
1992	CONRAD is formed				
1998	CEMA is formed				
1998/ 1999	South Bison Hill research site constructed at Syncrude	1979	Plains Soil Reconstruction Project: -Battle River Soil Reconstruction Project initiated in 1979 and -Highvale Soil Reconstruction Project initiated in 1982	1988	Soil capping requirements for coal cleaning wastes (tailings) at Coal Valley Mine initiated
1999/ 2000	CT Demo Wetlands and Terrestrial Sites constructed at Suncor				
2005	Carbon Dynamics, Food Web Structure and Reclamation Strategies in Alberta Oilsands – affected wetlands (CFRAW) project launched	1983	Use of Bottom Ash as an amendment to sodic spoil initiated (Battle River)		
		1983	Changes in physical and chemical properties of reconstructed soils at Paintearth Mine initiated		
2005	Soil Capping Research in the Athabasca Oil Sands Region: Technology Synthesis initiated	1983	Suitability of soil and overburden for soil reconstruction at Montgomery Mine initiated		

Reclamation practice in the mineable Oil Sands, coal mines and other sites where surface disturbing activities occurred, evolved as a result of a number of factors, the first of which was the lack of precedent or "not knowing what would work". Other factors included the nature of the predominant materials, including tailings sand and overburden, and the lack of reclamation materials (i.e. native seed sources) as we know them today. As a result the emphasis in the early 1970s was placed on site stabilization and erosion control. At this time there was a good knowledge base for growing and sustaining agricultural crops. Knowledge related to species selection and the benefits of fertilizer application were established. Similarly, there was a knowledge base regarding methods of reforestation in areas affected by forestry operations.

As a result, much of the initial reclamation practice was adopted/adapted from agricultural practice. Typical practice in Alberta and in virtually all jurisdictions was to select a wide range of grass and legume species to see which ones would establish and persist thereby providing a "cover" and erosion control. For example, Suncor initiated research with Alberta Agriculture in 1971 to determine seeding techniques for reclaiming tailings sands. A variety of agronomic species were utilized in the initial seeding efforts.

Similarly, initial research trials at Grande Cache area operations initiated in 1972 included the use of agronomic grasses and legumes. Operational revegetation initiated in 1974 utilized a seed mix comprised of the species considered most suitable based on the observations from monitoring the trials for the previous two field seasons. Similar approaches were used in the initial stages at all operations in the Mountains region and in the Oil Sands region. Research in the 1970s and into the 1980s emphasized the vegetation component. The soil component was included but the major emphasis in that period was on what vegetation would establish and persist in the different regions. In effect this approach was in response to the need to improve the aesthetics of surface disturbances by establishing some form of cover, preferably green.

Substantial effort was put into site preparation prior to seeding and planting. For example, in the Oil Sands region a variety of implements were used to incorporate peat into tailings sand and other substrates and to ameliorate compaction in different situations and locations. Several implements were either taken directly from agricultural use or modified to make them more "heavy duty".

Agricultural equipment was not practical for use in the Mountain mines, particularly the subalpine and alpine operations, due to the topography and the coarse fragment content of the replaced coversoils. However, a variety of "drag" type implements were generated for the purpose of surface preparation in some instances but mainly for scarification of the surface for the purpose of incorporating broadcasted seed and fertilizer.

The initial practice for tree and shrub establishment also involved the use of a range of varieties that were available for planting and that might be adaptable rather than being "native" to the area. For example, caragana was known to be adaptable, hardy, and excellent for erosion control based on its long-term use in establishment of shelterbelts across the prairies. It proved to be a hardy species for reclamation in the Oil Sands and trials indicated that it would persist at subalpine mine sites as well.

The following provides an overview of the changes that occurred regarding the various aspects of reclamation practice in the different regions.

1.3.1 SOIL SALVAGE

Soil salvage practices evolved rapidly from virtually no salvage prior to 1973 to specific depths and horizons in ensuing years. This reflected the understanding of the value of soil and in particular the surface horizons in re-establishing landscape function. As a result approvals evolved to the requirement of salvaging surface soils from essentially the entire area of proposed disturbance in all regions. This was not always possible in the Mountains region due to slope steepness. Practice in the mineable Oil Sands evolved from peat salvage to overstripping resulting in peat-mineral mixes. This was followed by the salvage of subsoil and parent materials. More recently the salvage of LFH or the surface organic layer and mineral A horizon materials of upland soil to a depth of 0.15 m or 0.30 m depending on ecosite is being practiced.

In the Mountains, salvage generally involved a one-lift operation which included the surface organo-mineral layer combined with the underlying mineral layer over bedrock. This is similar to the LFH overstripping salvage practice in the Oil Sands. In both situations the organic surface layer is mixed with the underlying mineral layer. In the Oil Sands the proportion of mineral component is dictated by the total depth of salvage. In the Mountains the proportion of mineral material is dictated by the depth to bedrock as shown in Plates 1.1 and 1.2. In some instances at the higher elevation mines, mineral material or "regolith" was segregated from the surface or first lift layer salvaged. At the lower elevation mines there was some segregation of "topsoil" and "subsoil" materials.

In the Plains region soil salvage practices evolved from no salvage to the salvage of topsoil only to salvage of topsoil and subsoil. The "Live Root Transplant" technique initiated at the Genesee Mine in 2003 was similar to direct placement of peat-mineral mix or LFH material in the mineable Oil Sands and direct placement of coversoil materials salvaged at the Mountain mines.

Soil salvage in the mineable Oil Sands is generally conducted during the winter months primarily because of ease of trafficability. The normal practice for soil recovery in the Mountains and Plains is to conduct operations in the summer and fall periods when conditions are driest. Winter salvage may be conducted in wet areas.

Soil stockpiling is practiced to some extent in all regions, but primarily in the mineable Oil Sands and Mountains. Direct placement is practiced wherever and whenever possible to reduce soil handling costs and to enhance overall reclamation success. Stockpiling practices have evolved to ensure separate storage of "topsoil" type materials from the subsoil materials.

Plate 1.1. Shallow depth to bedrock.

Plate 1.2. Deeper depth to bedrock.

Soil salvage practices were generally based on the suitability of the soils to be salvaged which was determined by use of the soil quality criteria (ASAC 1987).

1.3.2 Soil Placement

Soil placement requirements dictated soil salvage practices. The initial approvals stated that the depth of replaced soil should be sufficient to provide reclamation to the post-disturbance land use prescribed.

Initial practice in the mineable Oil Sands involved placement of 0.10 m to 0.15 m of peat over overburden and tailings sand and evolved to placement of a peat-mineral mix ranging in thickness from 0.30 m to 0.50 m depending on the clay content of the underlying subsoil, overburden or tailings sands and land capability class.

In the Mountains region there were differences between the lower elevation (Foothills) mines and the higher elevation mines. At the lower elevation mines the practices evolved from replacement of an average depth of 0.30 m root zone material over recontoured spoil to placement of an average of 0.30 m root zone material over non-sodic spoil and 0.50 m to 1.0 m root zone material over sodic spoil.

Some differences were observed for the high elevation mines with the placement of "topsoil" (0.20 m) over regolith (0.20 m) over spoil at one operation. At another operation initial practice was to apply topsoil in all areas; this evolved to placement of 0.30 m on slopes ≤18°, 0.15 m on slopes 18° to 27° and none on slopes >27°. One operation employed the approach of creating "topsoil islands" with a minimum topsoil depth of 0.30 m over 0.10 m of regolith. This was followed by the "rough/mounded" method for soil replacement.

Soil placement requirements and strategies prompted a significant research effort and were often the major theme of numerous reclamation conferences and workshops. The initial focus of the research in the mineable Oil Sands was on determining "how much of what is necessary to grow trees" in the reclaimed areas. Operational practice at the Syncrude operations in the 1990s included the placement of:

- secondary material over tailings sand (Plate 1.3)
- peat mix over secondary over tailings sand (Plate 1.4)
- peat mix (0.20 to 0.50 m) over tailings sand (Plates 1.5 and 1.6)
- peat mix (1.5 to 2 m) over mineral.

In addition a concern that the peat mix caps, especially the thinner ones, would be combusted in the event of a forest fire resulted in the practice of incorporating the peat mix cap into the underlying secondary layer (Plate 1.7). As well there was the concern that the peat-mix cap would decompose over time resulting in the loss of nutrients and nutrient cycling in the soils with the potential for the vegetation cover to regress.

Plate 1.3. Secondary over tailings sand.

Plate 1.4. Peat-mineral mix over secondary over tailings sand.

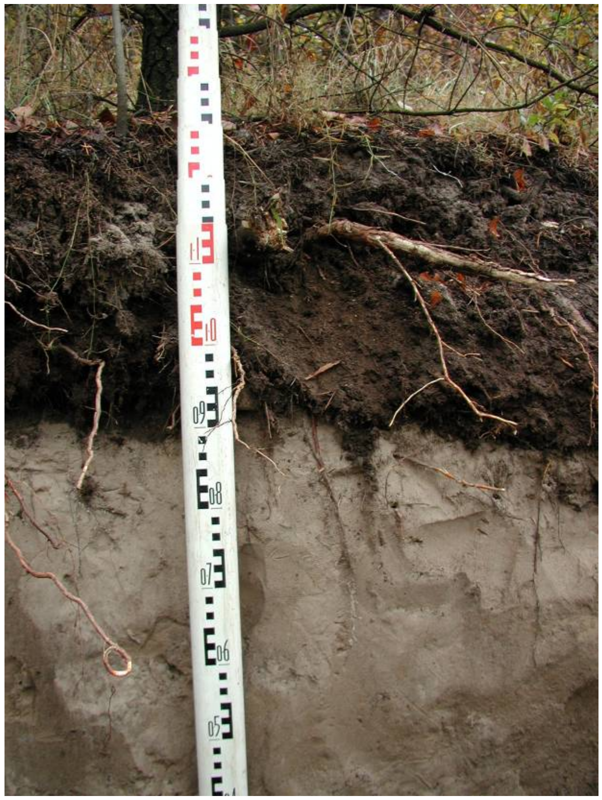

Plate 1.5. 30 cm peat-mix over tailings sand.

Plate 1.6. 40 to 50 cm peat-mix over tailings sand.

Plate 1.7. Peat mix tilled into secondary layer over tailings sand.

The research effort expanded in scope to determine the optimal capping practice when placing peat-mix, LFH, and secondary materials over saline sodic overburden and tailings sand. Numerous projects related to the main topic areas of “soil moisture”, “soil salinity/sodicity”, and “soil nutrients and biological response” were and continue to be conducted. Many of the projects involved detailed monitoring at areas reclaimed prior to 1998. Much of the research related to soil placement or soil covers after 1998 is being conducted in areas of constructed landforms. The “Soil Capping Research in the Athabasca Oil Sands Region Volume 1: Technology Synthesis” (Barbour et al. 2007) provides an excellent review of all of the research related to soil reconstruction in the mineable Oil Sands. This includes a synthesis of the data from studies conducted from the inception of reclamation practice to the research related to the placement of a range of soil covers in areas of saline sodic overburden and tailings sand.

Soil placement activities in the Mountains generated research related to the effectiveness of topsoil or coversoil depth for reforestation. The coversoil layer needed to be deep enough to allow for the planting of container or bare root stock. A field experiment to assess the effect of soil depth or revegetation success using agronomic and native grasses at the Grande Cache area operations concluded that growth or yield was not a function of soil depth (Macyk 1979).

Soil placement research was a major component of the research conducted in the Plains region. The work emphasized determination of appropriate subsoil replacement depths to ensure re-establishment of equivalent capability and depths required for placement over saline/sodic overburden. Major studies completed under the Plains Coal Reclamation Research Program and operator sponsored projects at the Battle River and Highvale sites which generated results that supported and confirmed the requirements spelled out in the respective operator approvals.

In summary it is important to note that current soil placement practices reflect the fundamental importance of the surface cap and the underlying layers (secondary, subsoil, regolith) in providing an adequate reservoir for rooting, soil moisture storage, and nutrient cycling (Plates 1.8 and 1.9).

This emphasis is evident in the approval summary in Table 1.1. Replacement of organic materials or the "topsoil" or "coversoil" was the first requirement for all operations in all regions. This was followed by the placement of a "subsoil" or intermediate layer between the soil cap and underlying spoil, overburden, tailings sand in areas where a source of this material was available. This included materials described as regolith at some Mountain mines and secondary materials in the Oil Sands. In the Plains region the requirement for subsoil placement was at one point up to 1.5 m at some operations, but is currently at 1.0 m for agricultural capability class 2 and 3 lands.

Plate 1.8. Soil cap provides a reservoir for roots, moisture and nutrients in Oil Sands reclamation.

Plate 1.9. Soil cap provides a reservoir for roots, moisture and nutrients in Mountains region.

1.3.3 REVEGETATION

Initial revegetation practice in all regions was adopted from agricultural practice. This meant that practices were directly transferable to the mined areas in the plains region. In some cases the reconstructed areas were seeded directly to cereal grains to resume the cropping practice used prior to mining. In most situations however, the land was seeded to wheat, barley, oats and canola and underseeded with forage species. The land uses included pasture, hayland and cereal grain production. At most operations the land remained in forage for up to five years prior to the return to cereal grain production.

Grass seed mixes were developed for different uses such as “grass mix”, “hay blend”, “riparian mix”, “problem area mix”. Tree planting was done to establish shelterbelts and islands and clump locations of trees and shrubs for visual and wildlife cover purposes established for non-agricultural land use in the region.

Initial revegetation practice in the mineable Oil Sands and Mountains regions was similar in that in both regions mixtures of agronomic grasses and legumes were seeded at relatively high rates (70 to 80 kg/ha) to establish a cover to stabilize the soil, limit erosion, and re-establish soil function. Agronomics were used because they had a proven ability for rapid establishment and were in a sense the only option available, as native materials were not available commercially or in any significant quantities. A variety of seed mixes were developed for different habitat and different landscape positions and aspects. For example in the mineable Oil Sands different combinations of species were used for tailings, dyke slopes and overburden dumps. In the Mountains region mixtures were developed for moister/cooler aspects or drier/hotter aspects. Some of the mixes were described as "standard", "fast growing", "tailings pond", "wildlife" or "reforestation".

Seeding techniques were similar between the two regions with the use of broadcast seeding (aerial, ATV or caterpillar mounted, hand held) and hydroseeding. Hydroseeding included the use of mulches and tackifiers. "Agricultural" or "rangeland" type seeding equipment was used and to some extent continues to be used in the mineable Oil Sands.

Invariably fertilizers were applied to ensure vegetation establishment. Rates of up to 500 kg/ha were applied to amend the nutrient poor tailings, overburden and soil capping materials that were being revegetated at the time.

In fact, some of the early approvals in the Mountains region stated that "a vegetation cover of grasses must be established yearly for quick erosion control" and "fertilize until such time as it becomes self-sustaining". Ultimately operators in the mineable Oil Sands and Mountains regions decreased seeding rates of agronomic grasses and legumes, reduced initial fertilization rates and terminated maintenance fertilization sooner in the programs.

A wide range of agronomic species were used in the initial vegetation cover establishment with species such as alfalfa, timothy, smooth brome, sweet clover, creeping red fescue and crested wheatgrass being used in all three regions. It is interesting to note that in subsequent years practitioners in the Oil Sands and Mountains noted that creeping red fescue was an excellent species for erosion control but it was highly persistent especially when fertilized, limiting native species invasion and the establishment of shrubs and trees. Similarly, the proportion of smooth brome in seed mixtures was reduced or removed entirely at several operations.

The time of year of seeding was evaluated over the years to determine optimum seeding times. Observations indicated that spring and fall seeding were effective. Early spring seeding allowed for a lengthy growing season to ensure establishment and to take advantage of precipitation which is relatively high in June in all regions. Fall seeding has some advantages in that it mimics the phenomenon of natural seed drop in the fall with "scarification" over the winter. Ideally the intent was to seed as late in the season as possible prior to snowfall but this is difficult to predict.

One of the potential disadvantages of a fall seeding in the mountains is that on the more steeply sloping surfaces there can be seed loss due to snowmelt and runoff.

The use of native grasses and legumes evolved with time. In the 1970s when most revegetation activities began in the mineable Oil Sands and Mountains regions there were no commercial sources of native materials. Seed collections were done at all operations to begin small trials with a variety of species, however these collections could not provide even a small fraction of the seed required to meet the needs of the operational seeding programs. In some situations native seed collected was added to the agronomic mix used initially, or broadcast seeded some years later into areas where the initial cover had been previously established.

In the late 1970s a major effort in native species research and production began and as a result seed was commercially available by the mid to late 1990s. This meant that native seed which, was considerably more costly than conventional agronomic varieties, was available in quantities required to meet at least some of the operational seeding requirements. Native were included in operational seed mixes beginning in approximately 1997 in the mineable Oil Sands and Mountains regions. They were also used in the Plains region, particularly for revegetation of areas of non-agricultural land use. Some of the Mountain mines continue to use a combination of non-competitive agronomics and natives in their seed mixes. Species such as alfalfa, alsike clover, white clover, and sweetclover continue to be used to provide a legume component to the cover established. Suitable native legumes are much less available than grasses for this region.

The salvage and replacement of LFH materials in the mineable Oil Sands results in a substantial increase of native species and associated community diversity and species richness compared to the use of peat mineral mixes. The replacement of the single lift coversoil at the Mountain mines was also demonstrated to be a factor in increasing the variety of native species present.

The establishment of shrubs and trees was undertaken concurrently within one or two years of initial cover establishment in the mineable Oil Sands. Early tree planting in the mineable Oil Sands was mainly experimental and was used to determine which species, both native and non-native, would grow best. Syncrude initiated a plant propagation program in 1977 to supply native materials.

It was quickly recognized that the initial agronomic grass and legume initial covers established were impacting the establishment of trees and shrubs. Areas were scarified prior to planting to improve survival and seed and fertilizer application rates were lowered to reduce the density and competitiveness of the initial cover. Furthermore stem girdling by rodents was a major problem in the dense grass and legume covers.

A substantial research effort was undertaken to determine the most appropriate type and size of container for seedling production to maximize survival rate and growth.
In the 1980s it was observed that a barley cover 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. The use of barley or oats or other appropriate initial cover became a standard practice with initial cover crop planting in year 1 followed by tree and shrub planting in year 2 or 3.

The current goal in the mineable Oil Sands is to provide a functionally sustainable forested ecosystem with stems/ha of the different species defined for the different ecosites and capability classes. Plates 1.10 and 1.11 illustrate that with time this goal will be achieved. Several additional illustrations are provided in the following sections of the document. Current emphasis regarding woody species establishment is on the shrub component which is being addressed by the major effort to identify optimal propagation techniques for the most desirable shrubs identified for the region.

The experience in introducing trees and shrubs at the Mountains mines was similar to the mineable Oil Sands experience. Initial planting trials were largely experimental in the early 1970s and emphasized the use of species native to the area. The lack of availability of seedling stock suitable for the conditions and altitude of the operations prompted seed cone and cutting collection programs to allow for propagation of suitable materials. The work included the propagation of materials in different types and sizes of containers and experimentation with time of year of planting and different stocking rates and planting densities. Ultimately spring planting resulted in the best overall survival at the various operations.

The stock was planted primarily into the initial cover at the sites. At some operations, particularly the lower elevation mines, the problem of competition from grass and legume cover was observed. This was not considered a major concern at the higher elevation mines where seedling exposure was a serious problem. Microsite creation such as that provided by rocks, woody debris and microrelief is important. The protection offered by the grass/legume nurse cover is critical to initial survival and growth. In the summer the cover provides an insulating effect for newly planted seedlings by reducing soil and above ground temperatures. In the winter the cover holds snow to provide a protective cover, similar to the barley cover in the Oil Sands. The higher elevation mines can have snowmelt and high winds throughout the winter months which have severe impacts on seedlings. Girdling of trees by rodents was not identified as a major problem, however grazing of seedlings by ungulates is a problem at all operations.

A general recommendation for the region is that tree and shrub planting sites be fully vegetated and self-sustaining prior to planting and have a wide variety of microsites. Plates 1.12 and 1.13 illustrate the revegetation that can be achieved in this region. Several additional illustrations are provided in the following sections of the document.

Direct seeding of conifers including Engelmann and white spruce, lodgepole pine and alder was identified as a technique for establishing woody species for some locations at the Mountain mines.

Plate 1.10. Reclaimed area at Syncrude Southwest Sand Storage facility in 1997.

Plate 1.11. Same area as above in 2007.


Plate 1.12. Planting seedlings into initial cover at Mountain mine site in 1975.


Plate 1.13. Tree cover at above site in 2005.

Native invasion or plant ingress has been observed to a certain extent on most reclaimed sites. This natural appearance of species can be attributed to seed distribution by wildlife, seed dispersal from adjacent undisturbed areas and by the replacement of coversoils containing seed and propagules. The rate of ingress is influenced by factors including distance from the seed source or adjacent undisturbed area, prevailing wind direction and extent of potential microsites in the existing cover.

1.3.4 SUMMARY

In summary, the manner in which reclamation practice evolved in the Plains, Mountains, and mineable Oil Sands reinforces that the fundamental facets of reclamation such as soil handling and revegetation are the same for all regions. This came with the recognition that soil is a vital natural resource that is nonrenewable on a human time scale (Jenny 1980) and that soil serves as a medium for plant growth by providing physical support, water, nutrients, and oxygen for roots. There was also the recognition that a vegetation cover was needed to stabilize the disturbance and with that came the gradual move away from looking for the right plants or the "super plant" that would thrive in these areas to re-establishing the ecosites that existed prior to disturbance. This provided a sense of direction and identified what could be achieved through the combination of manipulation, through different planting prescriptions and natural succession (stand development) processes.

The common lament is that "we should have started work on this years ago and we'd have the answer by now". Unfortunately we weren't asking the questions then that we are now – we were just "crawling" and not "walking or running". All is not lost however, as we still have the opportunity to learn more from the older reclaimed sites even though they were not established to meet a specific objective. Another lament is that "our reclaimed sites are young in comparison to the "mature" control or natural analogues we are using for comparison. Won't it be wonderful when our reclaimed sites reach the 65 or 70 year threshold –just another 25 to 30 years to go for some older sites. Then lets' hope that someone has a good record of what the natural sites were like at 65 to 70 so we can finally make the comparison.

Significant strides have been made in advancing reclamation practice in the past 40 years. Time is so critical when one is dealing with natural systems. In that short span of 40 years we went through a learning process jointly as regulators, operators, researchers, and practitioners. This process included not only the development of reclamation practice but also the development of measures to assess the success of these practices. To put the time factor in perspective, canopy closure occurs at about age 20 for most stands and most trees in the boreal forest of Alberta are not ready for harvest until age 60 to 75 or more.

There are obvious differences between regions and between individual operations within a region to respond to site specific conditions. An obvious conclusion from conducting this review is that there could be more extrapolation of ideas and approaches between regions – much more than has occurred in the past. We just need to soften the attitude that operating in one region makes us different from another.

1.4 RECLAMATION PRACTICES BASED ON CURRENT TECHNIQUES IN THE MINEABLE OIL SANDS

Current reclamation practice reflects optimal practice based on current knowledge and experience, and regulatory requirements. Current landforms that must be reclaimed include tailings sand dykes and plateaus, overburden dumps and dykes, tailings ponds, ancillary areas such as coke and sulphur storage, and infrastructure (roads, pipelines, powerlines). When initial operational reclamation activities and the associated research began, the work was not necessarily directed to a specific landform or landscape design, rather it was aimed at the immediate problem or area(s) of concern. These included tailings dykes and a variety of construction areas.

There are obvious differences in the reclamation techniques for overburden and tailings sand areas compared to fine tailings and wetlands. In light of the fact that reclamation techniques are relatively similar for overburden and tailings sand, with the exception of soil placement practices and to some extent revegetation, they will be discussed together in the generic discussion of soil salvage, soil placement, and revegetation. Separate sections for “tailings” and wetlands follow.

1.4.1 SOIL SALVAGE

Soil salvage is conducted to provide a supply of material for replacement on a variety of landforms. This document provides a comprehensive review of the evolution of soil salvage practices in the mineable Oil Sands, Plains, and Mountains regions. The following represent generic practices currently used in the mineable Oil Sands:

- Salvage of peat or muskeg materials in poorly drained areas with overstripping to include a mineral component specific to texture of the mineral component. Overstripping of fine textured mineral is considered more desirable than coarse textured mineral.
- Salvage of suitable subsoil and parent materials. Most commonly associated with salvage of medium to fine textured till and lacustrine materials. Consideration currently being given to salvaging subsoil and possibly parent materials from sandy soils which comprise a significant portion of the area to be mined.
- Salvage of LFH or surface organic layer with overstripping of underlying mineral A horizon material in upland (moderately to well drained areas). This particular practice includes the benefit of enhancing revegetation potential as well as providing a good soil cap.
- Soil salvage is conducted primarily during winter or frozen ground conditions for trafficability and reduction of potential for compaction.

Parallels to the above mentioned practices in the mineable Oil Sands can be drawn from the Plains and Mountains regions.

- In the Plains region all topsoil or Ah, Ahe horizon material is salvaged so that minimal inclusion of Ae or B horizon material is included. There are no limits on the thickness of suitable subsoil salvaged – salvage is done to produce the volume required to meet replacement requirements.
- In the Mountains region the one-lift salvage of the organic litter combined with underlying mineral to bedrock or unsuitable material is similar to the salvage of LFH in the mineable Oil Sands. Salvage of regolith or subsoil is conducted at some operations.
- Soil salvage in the Plains and Mountains is conducted during the drier periods in the summer and fall. Exceptions are poorly drained areas that may be salvaged under frozen conditions.

1.4.2 Soil Stockpiling

Although direct placement of salvaged soil materials is a desirable and effective practice, it is often not practical, resulting in the need for stockpiling. The protocols related to stockpiling practice include the following:

- Stockpile foundations are stable.
- Stockpiles do not contain any materials that may cause stockpile instability.
- Topsoil materials including topsoil or coversoil material shall be stockpiled separately from subsoil or parent materials.
- Stockpiles are easily accessible and retrievable.
- Stockpiles that remain in place for more than one year shall be revegetated.

Research is underway to determine optimum stockpile size and management practices for storage and "preservation" of the benefits of salvaged LFH materials.

1.4.3 Soil Placement

Initial practice at Suncor was to till a 0.10 m cap of peaty soil into the **overburden or tailings sand** prior to seeding. In subsequent years the thickness of the cap was increased to an average depth of 0.20 m.

Initial practice for **tailings sand slopes** at Syncrude was to incorporate a 0.15 m layer of peat and 0.10 m layer of clayey overburden into the sand. Subsequent practice involved the placement of 0.50 m of material (fair or good suitability) over the sand. The depth of amendment material was later increased to 0.70 m and efforts were made to increase surface organic matter content.

No surface amendment was applied in the initial years of **overburden reclamation** at Syncrude. Subsequently a 0.10 to 0.20 m layer of peat was placed on the surface. The practices were altered in 1984 to include a 1.0 m cap of Fair or Good reclamation material over overburden materials assumed to be saline or sodic. In later years the thickness of the cap was reduced to 0.50 m for non-saline and non-sodic overburden.

Current approval requirements at Suncor involve placement of:

- an average total depth of 0.50 m of coversoil plus subsoil on all reclamation areas of land capability Class 1 through 5
- average minimum depth of 0.30 m of peat-mineral mix over subsoil or overburden of 20% clay or more
- average minimum depth of 0.30 m (Class 4, 5), 0.40 m (Class 3) and 0.50 m (Class 1, 2) of peat-mineral mix used as coversoil immediately over subsoil, overburden, or tailings sand comprised of less than 20% clay.

Current approval requirements at Syncrude Mildred Lake and Aurora South involves placement of:

- total soil cover of 1.0 m (0.80 m suitable overburden and 0.20 m coversoil) on flat and sloped overburden surfaces
- total soil cover of 0.35 m (0.15 m suitable overburden and 0.20 m coversoil) on flat and sloped tailings sand.

Current approval requirements at Aurora North operations where the available soil resources are predominantly sandy and organic involve placement of:

- total soil cover of 1.0 m coversoil comprised of a 1:1 (volume) peat to sand mixture in a one-lift operation on flat and sloped overburden
- total soil cover 0.35 m coversoil on flat and sloped tailings sands.

The above information indicates that there are differences in the soil replacement depths between **overburden and tailings sand** at both Suncor and Syncrude however, the replacement depths are similar for both the flat and sloped surfaces of the respective landforms.

Other considerations include the incorporation of the peat-mineral mix cap into the underlying secondary or subsoil layer to reduce the potential for loss of the soil cap in the event of fire. As well, there is the placement of LFH rather than peat-mineral mix as the coversoil to enhance nutrient levels, plant community diversity, species richness and plant abundance.

It is expected that the practices for the remaining operators in the mineable Oil Sands regarding tailings sand and overburden will be similar to the current practices at Suncor and Syncrude. This includes the practice of placement of 1.0 m of tailings sand or overburden prior to placement of reclamation materials on impervious materials (lean oil sands or rock), reject materials, consolidated tailings, Clearwater overburden, plant area sites and landfills.

The placement of LFH material as a soil cap in the mineable Oil Sands is comparable to placement of the coversoil in the Mountains which has also demonstrated enhanced community diversity by contributing to the observed “native species ingress or invasion”. The placement of the A horizon or topsoil layer in the Plains is a similar practice providing the optimal growth substrate in terms of physical properties (moisture retention, porosity, tilth) and nutrient content and cycling.

The placement of 1.0 m of secondary or subsoil type material over saline/sodic overburden in the mineable Oil Sands parallels a similar practice for the lower elevation Mountain mines and Plains mines. In the Plains the placement is tied to Capability Class with 1.0 m required for Capability Class 3 and 0.35 m for classes 4, 5, and 6.

Determining the best capping practices to return reclaimed land to equivalent capability has been, and continues to be extensively researched. The practices will continue to evolve as research progresses. The "Soil Capping Research in the Athabasca Oil Sands Region Volume 1: Technology Synthesis" (Barbour et al. 2007) provides an excellent review of the work completed to date.

Current and future research and monitoring at the operations located in areas of predominantly sandy soils and muskeg will identify the optimal soil replacement prescriptions and revegetation practices for this large area.

1.4.4 REVEGETATION

Revegetation practices for tailings dykes, overburden areas and ancillary areas are generally similar. Establishment of a rapidly establishing initial cover is critical to minimizing erosion in all areas. It provides protection for seedlings and cuttings by providing shade and trapping moisture in the summer and providing as insulating effect during the winter.

There is potential to use appropriate native grasses and legumes to provide this initial cover particularly in areas with a peat-mineral mix cap. For example some of the wheatgrasses such as slender wheatgrass, tall fescue, and hairy wildrye could be used. Similarly legumes such as vetch would be effective and could contribute to a reduction in the amount of fertilizer utilized.

The practice of introducing trees and shrubs in year 2 or 3 following initial cover establishment is effective. The species planted and the density (stems/ha) of planting has been, and continues to be, addressed in the operational planting programs. The timing of planting of some of the species targeted for specific ecosites is still being addressed. Planting prescriptions by ecosite phase were provided by the Oil Sands Vegetation Reclamation Committee (1998) and are currently under review.

Land use requirements dictate the tree species that are planted to achieve "equivalent capability". Research and operational practice has evolved to the extent that materials native to the area are available, which is evident in the planting programs conducted by the operators. Considerable effort continues in developing propagation techniques for the most desirable shrub species for the region. The use of caragana and other non-native species in the 1970s and 1980s was the result of a combination of the lack of native materials, the adaptability of the non-native materials and the need to establish cover. Caragana proved to be a highly adaptable and persistent species, providing excellent cover and erosion control, but would not be considered for current programs. Hybrid poplar, which is a rapid growing species and excellent for carbon storage, is not considered native to the area but is desirable for a land use that favours fiber production.

As mentioned previously, the focus of revegetation efforts in the mineable Oil Sands has been on establishing target ecosites and planning vegetation programs accordingly. This includes re-establishment of the continuity of vegetation patterns between the reclaimed lands and adjacent undisturbed lands as well as commercially viable forest ecosystems on areas equivalent to what existed in the pre-disturbance state. There is still a great deal of debate about what gets planted and when and whether or not the revegetated sites are on the "trajectory" to resulting in the desired end product. Unfortunately it takes several decades to reach that stage in vegetation establishment. However, much can be, and has been learned from the evolution of vegetation cover in the areas reclaimed over the past 30 years in the mineable Oil Sands. Some of the observations are summarized in the soil capping research synthesis (Barbour et al. 2007).

1.4.5 WETLANDS

Wetland reclamation has been undertaken at Suncor Energy Inc., Syncrude Canada Ltd., and Albian Sands Energy Inc. Most of the information pertinent to wetlands reclamation is associated with research or demonstration rather than operational practice. The work conducted by Suncor was initiated in 1991 and included the building of a series of nine parallel trenches for research purposes. Subsequently, construction of a CT Demo Wetland was completed in 1999/2000 with annual monitoring conducted to date.

Syncrude undertook experimental work in 1985 focussing on capping of MFT (Mature Fine Tailings) and continued with construction of the "Large Scale Demonstration Pond" and other constructed wetlands.

In addition a significant amount of research sponsored by the operators, CEMA and CONRAD is underway. The various projects were designed to address a number of objectives including to:

- Determine if saline wetlands could be used to reclaim mined Oil Sands areas, and whether saline vegetation could grow and accumulate organic mater in natural and reclaimed wetlands.
- Assess conditions present at the origin of wetlands to determine appropriate substrates and revegetation methods for a variety of types of wetlands.
- Determine if constructed wetlands are on a trajectory that is converging on natural systems. There is a project that compares constructed wetlands and a range of wetlands found naturally in analogous portions of the boreal forest.
- Examine and compare the ecology of undisturbed and constructed wetlands (CFRAW). The project examines interactions between macrophytes, phytoplankton, zooplankton, benthic invertebrates, amphibians and waterfowl in wetland ecosystems. In addition, the project will examine how different types of biomass are incorporated into food webs as the constructed wetlands age, and the effectiveness of wetland amendments (e.g. peat) on their productivity and their potential to become carbon-sequestering peat lands.

- Assess the potential of saline vegetation to grow and accumulate organic matter in natural and reclaimed wetlands.
- Develop revegetation techniques for some wetlands species.

The Oil Sands Wetlands Working Group (2000) was formed to develop a preliminary guideline document that identified a number of guiding principles that are essential to wetland development. The guideline presented an "approach" for the establishment of wetlands on reclaimed landscapes at Oil Sands mining operations. The guideline identified five types of wetlands:

- altered wetlands
- opportunistic wetlands
- constructed wetlands
- vegetated watercourses and
- littoral zones.

In October 2003 the Reclamation Working Group held a "Creating Wetlands in the Oil Sands Reclamation Workshop" (Reclamation Working Group 2006) to assist the Wetlands and Aquatics subgroup in the revision of the 2000 Wetlands Manual. The workshop was held to:

- Solicit expert views from leading authorities in a number of disciplines related to the creation and study of wetlands,
- Investigate the challenges of creating a range of wetlands in a reclaimed Oil Sands landscape, and
- Develop recommendations for methods to create a range of wetlands.

The second edition of the wetlands guideline entitled "Guideline for Wetlands Established on Reclaimed Oil Sands Leases Revised (2007) Edition" (Harris 2007) updated the state of knowledge regarding reclamation of wetlands in the Oil Sands region. The document provides a description of the steps involved to create reclaimed wetlands, which include landscape scale planning, building individual wetlands, and monitoring, maintaining and modifying. Key design elements are defined in providing guidance for marshes and open water wetlands, fens and bogs, swamps, building connectivity into wetland complexes and the construction phase in wetlands reclamation.

Since the above mentioned information is readily available in the guideline document it is not repeated in this document. While the guidelines provided are intended for the mineable Oil Sands they do not necessarily reflect the operational practice undertaken to date.

1.4.6 TAILINGS

In addition to wet landscape reclamation of CT (Consolidated Tailings), research studies were undertaken at Suncor Energy Inc. to determine the potential for phytoremediation and dewatering of CT in a dry landscape scenario. The growth of three plant species (reed canary grass, willow and poplar) in four types of CT including capped or uncapped with peat and fine tailings, freeze-thaw fine tailings and weathered and unweathered fine tailings was monitored.

In the early and mid 1990s, Syncrude undertook a broad suite of greenhouse studies with the University of Alberta to look at the effects of CT and CT release water on boreal forest plants (black spruce, white spruce, jack pine, hybrid poplar, willow, dogwood, raspberry, strawberry and bearberry).

The results of these programs indicated that CT water causes drought stress and toxic ion effects, with effects varying between and within species. Hybrid poplar and dogwood demonstrated the greatest resistance but all species exhibited some damage when salinity of solution exceeded 4 dS/m.

The results from this extensive program clearly demonstrated that CT and CT water should not appear in the root zone in upland areas where productive forest is the target of post-closure vegetation.

Concurrent with the greenhouse work, field trials were conducted on a pilot scale CT deposit (U-shaped cell). Although the addition of peat ameliorates the effect somewhat, the conclusion from these field tests confirmed the greenhouse studies which demonstrated that CT should not appear in the root zone in upland areas expected to produce commercial forest. Research to determine depth of sand cap required indicated that any sand cap with a goal of protecting the root zone (top one meter) from CT water would need to be greater than 1.6 m in depth. Additional work, coupled with the evidence from the CT wetlands at Suncor, which Syncrude partially supported, indicated that thriving wetland and riparian plant communities can develop on CT materials and in areas affected by CT water.

In 1998 Syncrude constructed the 40-hectare CT Prototype in order to develop the technology for a full scale CT plant. The CT prototype was partially sand capped in 1998. A one-hectare portion of the sand cap was reclaimed and planted to jack pine, white spruce and aspen, and salt flushing and plant growth were monitored for five years.

The extensive research around CT reclamation has demonstrated that CT and CT waters can appear in the root zone of wetland areas, but they must be isolated from the root zones of upland commercial forests.

1.4.7 BIODIVERSITY

Biodiversity was not a specific or defined goal in the early stages of reclamation. It was implied when the approach to reclamation evolved to establishment of a variety of self-supporting ecosystems suitable for forestry, wildlife habitat and recreation areas. The establishment of predominantly upland and wetland landforms will result in a broad range of ecosites. The return of these ecosites and the associated herbaceous, shrub, and tree species will result in enhanced habitat for a range of wildlife species and the opportunities for traditional use. The opportunity to increase biodiversity will be enhanced by the ability to propagate and introduce a wider selection of native shrubs in the revegetation programs as well as the increase in native ingress that will occur with time.

The information pertinent to "biodiversity" has emphasized wildlife monitoring and management activities. The current approvals for the operations contain a clause regarding biodiversity programs in terms of monitoring and documenting the return of biodiversity in the reclaimed landscape.

2.0 OPERATIONAL RECLAMATION PRACTICES IN THE MINEABLE OILS SANDS

2.1 BACKGROUND

The information herein was obtained primarily from documents supplied by the mine operators in the mineable Oil Sands region and Alberta Environment. These documents include "Annual Conservation and Reclamation Reports", approval documents and a variety of publications pertinent to the topic. A complete list of documents is provided in the reference section.

2.1.1 COMPANY OVERVIEWS

This section provides brief "historical" information for each company and their operations with emphasis on reclamation. Some operations are in the construction or initial mining stage and therefore are currently undertaking soil conservation and limited reclamation activities.

The majority of reclamation activities in the oil sands region have been undertaken by Suncor Energy Inc. (Suncor) and Syncrude Canada Ltd. (Syncrude) and as such, this document primarily focuses on the evolution of reclamation practices at these two mining operations and to a lesser extent Albian Sands Energy Inc. (Albian). Canadian Natural Resources Ltd. (CNRL) and Petro-Canada Oil Sands Inc. (PCOSI) have been issued approvals and initiated construction activities, however very little reclamation, if any, has been undertaken by these operators. As a result, reclamation information provided for these companies is considered proposed and largely conceptual.

2.1.1.1 Suncor Energy Inc.

Oil sands mining activities began in 1967 at Great Canadian Oil Sands (GCOS) approximately 35 km north of Fort McMurray, Alberta. The company became Suncor Inc. Oil Sands Group in 1979 and Suncor Energy Inc. in 1997. Suncor extracts and upgrades oil sands into high-quality refinery-ready crude oil products and diesel fuel. Most of the land disturbed by Suncor's oil sands operation activities is associated with surface mining. At the end of 2006, land disturbance since start-up covered approximately 12,280 hectares on Lease 86/17, Steepbank Mine, Millennium Mine, South Tailings Pond and Voyageur Upgrader (Suncor 2007).

Initially bucketwheel excavators were used to extract the oil sand. In 1992 Suncor changed mining practices and therefore reclamation activities by switching technology from bucketwheel excavators to truck and shovel mining. The Steepbank Mine opened in 1998 and construction of the Project Millennium, an expansion to Suncor's oil sands operation, began in 1999 to increase production capacity. The Firebag in-situ oil sands facility using steam assisted gravity drainage (SAGD) technology was opened in 2004. In July 2007, Suncor received regulatory approval under the Environmental and

Protection and Enhancement Act (EPEA) to construct and operate a third oil sands upgrader (Voyageur) and to expand the North Steepbank Mine.

Reclamation activities at Suncor oil sands project began in 1967, and were first formally recorded in an annual reclamation report for activities completed in 1976 (Shopik 1976). Prior to 1976, activities to stabilize dyke and overburden dump areas were part of the mine plan and were not considered as reclamation of landforms.

The reclamation progression from 1971 to 2006 has resulted in Suncor temporarily or permanently reclaiming approximately 933 hectares of land (nearly 10% of land disturbed) and planting more than three million trees (Suncor 2007 and 2005b).

2.1.1.2 Syncrude Canada Ltd.

Syncrude was incorporated in December 1964. Site preparation at the Mildred Lake Oil Sands operation commenced in December 1973 and production began in July 1978. Located 35 kilometres northeast of Syncrude's base mine (the Mildred Lake facility) the Aurora North Mine started up in July 2001. Aurora South Mine located northeast of the Mildred Lake facility has yet to be developed.

Syncrude produces high-quality, light, sweet crude oil which currently meets more than 13% of Canada's petroleum needs. Syncrude has been reclaiming land since 1975 pursuant to various Approval amendments and changing Approval conditions. Currently, Syncrude has reclaimed approximately 22% of the total disturbed land area (Syncrude 2006b and 2006c). At the Mildred Lake Base Mine site, land reclamation now exceeds disturbance. This trend will continue as the mine reaches the end of its production life and operations shift to the North and South Aurora mining areas. As of 2006, Syncrude had reclaimed, either temporarily or permanently, over 4,600 hectares of land and planted around 4.5 million tree seedlings (Syncrude 2006b and 2006c).

Reclamation research at Syncrude has been ongoing since 1971. The first annual report on revegetation work (Langevin and Lulman 1976) indicated that "techniques and materials used in 1976 were purposely varied such that maximum experience could be gained in the first years of revegetation work". Beginning in 1993, in cooperation with the Fort McKay First Nation, Syncrude developed wood bison habitat to test the viability of reclaimed land to support large animals. More than 300 wood bison now graze on land reclaimed from the mining and tailings operations. Recently, reclamation research has helped gain a better understanding of ecosystem performance at the landform scale through the use of several research watersheds on reclaimed land.

2.1.1.3 Albian Sands Energy Inc.

Albian operates the Muskeg River Mine. The Muskeg River Mine and the Scotford Upgrader together comprise the Athabasca Oil Sands Project - a joint venture of Shell Canada Limited, Chevron Canada Limited (a wholly owned subsidiary of ChevronTexaco Corp.) and Western Oil Sands Inc. The Muskeg River Mine is located approximately 75 km north of Fort McMurray, Alberta on Shell Canada Ltd's Lease 13. Construction of the mine facilities was initiated near the end of 1999 and completed during 2003. Albian received regulatory approval under the Environmental Protection and Enhancement Act to expand the Muskeg River Mine in November 2007.

Albian Sands plans to use several new technologies to return the land to productive equivalent land capability and involve local stakeholders in the development of reclamation plans. Local environmental impacts have been reduced in the design of the project. It is intended that the Mine's overall footprint will be relatively small due to the following measures:

- Tailings management methods have allowed Albian to reduce the size of the tailings pond.
- Progressive land reclamation (filling the mine pit approximately every seven years and replanting vegetation) will minimize effects on wildlife and plants, reduce visual impacts and limit dust issues.

2.1.1.4 Shell Canada Energy Ltd. – Jackpine Mine

The Jackpine Mine – Phase I Oil Sands Extraction and Processing Facility is part of a Shell Canada Ltd. and venture partners Chevron Canada Resources and Western Oil Sands Limited Partnership development in Lease 13. This development is located near the Muskeg River approximately 80 km north of Fort McMurray, Alberta. In 2004 Shell Canada Ltd. received regulatory approval to construct and operate the Jackpine Oil Sand Mining and Extraction Facility. Development activities thus far have included clearing, timber salvage, road construction, site drainage, waste management facilities and stockpiling of material on-site. The Jackpine Mine is designed to produce approximately 200,000 bbl/day of bitumen from the McMurray Formation. The Jackpine Mine is expected to have full production in 2010 and last 22 years.

Due to the early phase of development and limited activity to date, no permanent land reclamation has occurred. Given Shell’s experience at Albian Sands - Muskeg River Mine, efforts have been undertaken to align reclamation practices at the Jackpine Mine with those at Muskeg River, where appropriate. Land conservation procedures that were implemented on site in 2006 included soil salvage and stockpiling, overburden stockpiling, ore stockpiling, surface drainage control, weed control and erosion control. Reclamation material at Shell’s Jackpine Mine has been stripped and stockpiled for future reclamation activities on-site. No permanent soil placement has occurred on-site.

2.1.1.5 Canadian Natural Resources Ltd.

The Horizon Oil Sands Project is a wholly owned and controlled project of CNRL and is located approximately 70 km north of Fort McMurray, Alberta. The project consists of a surface mine, bitumen processing facility with associated tailings ponds, and a heavy oil upgrading facility. Major site development for the project began in 2004 and initial production of synthetic crude oil is scheduled to begin in 2008 with full project development planned for 2011 to 2012. Mining at the Horizon Project is expected to end in 2046 and reclamation is planned for completion by 2050.

Reclamation activities associated with the Horizon Project have been limited in scope because the project is undergoing initial construction. Activities to date have included merchantable timber salvage, clearing & grubbing of non-merchantable trees, conservation of surface soil materials and stockpiling these materials for future reclamation, temporary revegetation for erosion control purposes, and reclamation research.

2.1.1.6 Petro-Canada Oil Sands Inc.

Through a limited partnership agreement, PCOSI will operate and lead development of the Fort Hills mining operation with a 60% interest. Partners, UTS Energy Corporation (UTS) and Teck Cominco each hold 20% interests. Approval for the Fort Hills Project was obtained in 2005 (in response to the True North Application). Construction on-site began in 2007 and startup is scheduled to commence in 2011.

The Fort Hills mining operation will be similar to other major mining projects, such as Albian Sands, in the Athabasca oil sands region. The 2006 Annual Conservation and Reclamation Report (Leskiw 2007) was the first such report for the Fort Hills Oil Sands Project. This report documented results of activities conducted during the previous year in relation to targets set previously for the Fort Hills Project and presented targets and strategies for future activities. Surface disturbance as of 2006 had been confined to trails, cutlines for test drilling and facility sites. PCOSI initiated reclamation on 2.9 ha in 2007.

2.1.2 REGULATORY SUMMARY

The development of reclamation and conservation policy in Alberta can be broken into three stages (Macyk 2000). The first, prior to 1963 can be referred to as the "remedial" stage. The only requirement under the early Coal Mines Regulation Act was that the operator leaves the site in a safe condition.

The "cosmetics" stage came between 1963 and 1968 when companies were required to level the disturbed site so that the landowner could work it later (Macyk 2000). Provisions of the 1963 Surface Reclamation Act stated that mined areas had to be levelled and contoured to provide water drainage and allow normal farming practices to become possible. It also established field enforcement staff in the form of the Reclamation Council, and provided for reclamation certificates. The "modern" era began in 1973 when the Land Surface Conservation and Reclamation Act (LSCR) began to require conservation and reclamation planning (Macyk 2000). This Act applied to all lands within Alberta except those used for residential purposes or agricultural operations. This Act made referral and coordination by government departments mandatory. It also formalized the three committees established under the Land Conservation Regulations including the Crown Mineral Disposition Review Committee, the Exploration Review Committee, and the Development and Reclamation Review Committee. The Act required segregation of topsoil and replacement following the levelling of overburden. The reclamation standards associated with the Act stated that the land must be returned to a level of capability for production at least equal to its previous level.

Under the current (1993) Environmental Protection and Enhancement Act each approval holder has a duty to conserve, reclaim, and obtain a reclamation certificate on specified land (Section 137). This Section states that conservation and reclamation must be carried out in accordance with the terms and conditions in any applicable approval or code of practice, the terms and conditions of any environmental protection order issued to the approval holder regarding conservation and reclamation, the directions of an inspector or the Director, and the Act.

Under the Conservation and Reclamation Regulation, the objective of conservation and reclamation of specified land is to return it to an equivalent land capability. This phrase is currently defined as "the ability of the land to support various land uses after conservation and reclamation similar to the ability that existed prior to an activity being conducted on the land, but that the individual land uses will not necessarily be identical" (EPEA, C&R Regulation 115/1993). The regulations and guidelines associated with the various "Acts" and "Policies" define the expectations associated with achieving reclamation success. However, systems or tools are required to measure or determine reclamation success. The process of adopting and implementing a system for measuring reclamation success continues to evolve and is based on several strategic activities and research efforts.

2.1.3 APPROVALS

Suncor's most recent approval for the construction, operation and reclamation of the Suncor Energy Inc. Oil Sands Processing Plant and Mine was issued in August 2007. Syncrude's current approval for the Mildred Lake, Aurora North and Aurora South Oil Sands Processing Plant and Mine was given in June 2007, and Albian Sands Energy Inc. received a new approval in November 2007 for the Muskeg River Oil Sands Processing Plant and Mine.

The terms and conditions associated with the approvals have evolved from very general requirements to specific measurables. The newest approvals for Suncor, Syncrude and Albian contain much of the same information and requirements. The approvals for these mines are all similar in that they contain very specific soil handling and revegetation clauses. For example, the approvals state that the approval holder shall salvage upland surface soil:

- to a maximum average depth of 0.15 m from all land to be disturbed where ecosite classification as defined in the *Field Guide to Ecosites of Northern Alberta* (Beckingham and Archibald 1996) is A or B and
- to a maximum average depth of 0.30 m from all land to be disturbed where the ecosite classification as defined in the *Field Guide to Ecosites of Northern Alberta* (Beckingham and Archibald 1996) is other than A or B and

- additionally, when salvaging peat-mineral mix priority shall be placed on the salvage of finer textured underlying mineral soils rather than coarse textured soils, unless otherwise authorized in writing by the Director.

In terms of soil replacement the approvals state that:

- The approval holder shall place an average depth of 0.5 m of coversoil and subsoil combined, on all reclamation areas of land capability Class 1 through 5.
- When peat-mineral mix is used as coversoil immediately over subsoil or overburden of 20% clay or more, the peat-mineral mix shall be placed to an average minimum depth of 0.3 m.
- When peat-mineral mix is used as coversoil immediately over subsoil, overburden, or tailings sand comprised of less than 20% clay, the peat-mineral mix shall be placed:
    - Class 1 – average minimum 0.5 m
    - Class 2 – average minimum 0.5 m
    - Class 3 – average minimum 0.4 m
    - Class 4 – average minimum 0.3 m and
    - Class 5 – average minimum 0.3 m.
- The following materials will be capped with an average minimum of 1.0 m of tailings sand or overburden prior to placement of reclamation material:
    - impervious materials such as lean oilsand or rock
    - reject from the oil sands conditioning and transport system
    - composite tailings
    - clearwater overburden and
    - the plant development area.

General clauses related to land reclamation state that the land shall be reclaimed so that the soils and landforms are capable of supporting a self-sustaining, locally common boreal forest, regardless of the end land use. The approval holder shall revegetate disturbed land to target the establishment of a self-sustaining, locally common boreal forest integrated with the surrounding area.

In terms of revegetation the approval holders are to develop a plan regarding establishment of forest ecosystems and wetland ecosystems re:

- incorporation of vegetation and vegetation communities of traditional value that are characteristic of the locally common boreal forest
- re-establishment of the capability for long term biodiversity consistent with the Biodiversity Program to be submitted
- re-establishment of the continuity of vegetation patterns, where practicable, between the reclaimed lands and adjacent undisturbed lands
- establishment of the continuity of vegetation patterns, where practicable, between the reclaimed lands and the lands adjacent lease holders
- establishment of commercially viable forest ecosystems on areas equivalent to the pre-disturbance areas of commercially viable White Spruce Mixedwood, Deciduous, White Spruce and total Coniferous ecosite phases.

Reclamation requirements in earlier approvals were company specific and are summarized below.

2.1.3.1 Suncor Energy Inc.

Suncor's 1978 Development and Reclamation Approval stated that "disturbed lands shall be reclaimed with gentle slopes to primarily a forest use compatible with the predisturbed terrain, providing habitat for wildlife and with possibilities for recreation. Dyke slopes shall be revegetated primarily for erosion control with possibilities for forest and wildlife use". Suncor was required to institute a program of field trials during the 1979 growing season to determine the appropriate mixture of soil making materials required to produce a suitable reconstructed soil, in terms of both quality and quantity. This reclamation field trial program was to be conducted for a minimum of five growing seasons after which Suncor was required to submit a proposed design for a reconstructed surface soil.

A 1983 amendment stated that the operator shall salvage and store, for the purpose of reclamation, all in situ Type 1 muskeg soil and that storage sites must have stable foundations and be protected from wind and water erosion.

A 1984 amendment introduced specific soil depth replacement requirements including:

- For tailings sand surfaces, the Operator shall incorporate 15 cm of Type 1 muskeg into the recontoured surface.
- For overburden surfaces, the Operator shall incorporate 15 cm of Type 1 or Type 2 muskeg soil into the recontoured surface.
- Oversize reject from the extraction plant shall be placed at least one meter below the base of the replaced soil surface.
- Clearwater material that was sodic (SAR > 10) shall be covered with a minimum of one meter of Holocene/Pleistocene material.

The amendment stated that through appropriate conservation of soil materials, spoil placement, backfilling and recontouring, soil replacement, revegetation, and reclamation research the reclaimed surface at Suncor's lease shall have characteristics and properties (topography, drainage, soils, vegetation) that will result in the return of a land capability that is equivalent to or better than that which existed prior to disturbance (D&R approval NO. OS-1-79 1984). Final slopes of dykes and discard sites at Suncor were to have no slope angle steeper than 2.5:1 (22°) between benches and were to be suitably terraced to minimize soil erosion and to assist in stabilization and revegetation. Suncor was required to obtain soils and plant growth data to monitor the long term adequacy of the materials handling and reclamation procedures utilized.

A 1990 amendment required that the operator ensure that 60% of the disturbed land be returned to productive forest, as defined by the Alberta Forest Service, and that the Alberta Forest Service regeneration standards were met on the lands. The remaining 40% could be oriented to a wildlife capability which could be integrated into the productive forest lands.

The 1996 Development and Reclamation Approval included more detailed or specific soil replacement and revegetation requirements and the Land Capability Classification System was introduced. In terms of soil replacement, the approval stated that:

- The approval holder shall replace suitable soil or mineral topsoil to a minimum depth of 10 cm with an average depth of 20 cm on all overburden landforms to achieve soil capability classes 2 or 3.
- The approval holder shall replace suitable soil or mineral topsoil material to a minimum depth of 10 cm with an average depth of 20 cm on all tailing sand landforms to achieve soil capability classes 3 or 4.
- Oversize reject from the extract plant, reject from the oil sand conditioning and transport system, and Clearwater overburden material shall be capped with at least 1.0 m of either tailing sand, overburden material or suitable soil material.

In terms of revegetation, the approval stated that:

- The approval holder shall return disturbed land west of the Athabasca River to a revegetated condition compatible with the surrounding area including:
    - commercial forest on 60% of the disturbed land stocked with trees to meet the standards of a commercial forest as defined by the Timber Management Regulations
    - non-commercial forest on the remaining 40% of the disturbed land or
    - an alternative land use as otherwise authorized in writing by the Director.
- The approval holder shall return disturbed land east of the Athabasca River to a revegetated condition compatible with the surrounding area including:
    - forest ecosystem on 65% of the disturbed land containing an equivalent predisturbance area of commercial forest having equivalent productivity as determined by site indices as outlined in the *Alberta Vegetation Inventory Standards Manual*
    - non-commercial forest on the remaining 35% of the disturbed land;
    - re-establishment of equivalent wildlife habitat or
    - an alternative land use as otherwise authorized in writing by the Director.
- The approval holder shall reclaim disturbed land within the river valley east of the Athabasca River taking into consideration the values outlined in the *Fort McMurray – Athabasca Oil Sands Subregional Integrated Resource Plan*, Publication No. 1/358, ISBN. 0-86499-749-3, May 7, 1996.

2.1.3.2 Syncrude Canada Ltd.

The initial (1978) approval stated that:

- Organic and mineral material suitable for soil reclamation be removed in sufficient quantities necessary for the reclamation of the lands to the approved post-disturbance land use.
- Depth of replaced soil was to be at least sufficient to provide reclamation to the post-disturbance land use prescribed in the Application.
- The reconstructed soil was to have chemical, physical and biological characteristics which would permit upland reclamation to a forest environment at least as productive as it was prior to disturbance.

A 1983 amendment made reference to the reclaimed land surface having characteristics and properties that will result in the return of a land capability that is equivalent to or better than that which existed prior to disturbance. **The "better than that which existed prior to disturbance" component was removed in a 1984 amendment.**

A 1985 amendment introduced specific soil depth replacement requirements including:

- For sloped tailings sand surfaces, the Operator shall amend the surface with 15 cm of peat and 10 cm of clay and incorporate these materials to a depth of 30 cm.
- For overburden surfaces consisting of Holocene/Pleistocene materials, the Operator shall amend the surface with 10 cm of peat in order to improve soil structure.

A 1989 amendment introduced the approach of "average" rather than "minimum" depths and an increase in depth of material replaced:

- The Operator shall replace an average of 70 ± 10 cm of "suitable surface material" on all tailing sand surfaces.
- The Operator shall replace an average of 50 ± 10 cm of "suitable surface material" on all overburden surfaces, except for saline, sodic or oil affected materials which shall be covered with a minimum of one meter of suitable surface material.

A 1995 approval for the Mildred Lake Oil Sands Mine included more detailed and specific soil replacement and revegetation requirements. In terms of soil replacement the approval holder shall replace suitable soil material on upland ecosystem areas as follows:

- A minimum of 60 cm and an average of 70 cm on tailings sand surfaces.
- A minimum of 40 cm and an average of 50 cm shall be placed on suitable quality overburden surfaces.
- Suitable soil material profiles with an organic content less than 20% (v/v%) shall have a minimum of 15 cm of organic soil placed on the surface.

On unsuitable quality overburden surfaces the approval holder shall place a minimum of one meter of reclamation material composed of:

- a surface layer with a minimum of 0.5 m of suitable soil material
- a sub-surface layer with a minimum of 0.5 m of soil with an SAR ≤ 12, salinity ≤ 8 dS/m and an oil content < 1%.

In terms of revegetation and land use the approval holder shall return the disturbed land to:

- an upland ecosystem on 70% of the disturbed land, consisting of 50% productive forest and 20% non-productive forest (including grasslands)
- a wetland ecosystem on the remaining 30% of the disturbed land with a maximum of 20% waterbodies.

The September 2001 approval for the Mildred Lake Plant and Mine contained a clause related to the return of disturbed land to a minimum post-disturbance land capability class. As well, the approval holder shall replace coversoil to a minimum depth of 0.10 m, with an average depth of at least 0.20 m, on all disturbed land reclaimed as land capability class 1, 2, 3 and 4.

2.1.3.3 Albian Sands Energy Inc. – Muskeg Mine

The 1999 approval pursuant to the Environmental Protection and Enhancement Act for construction, operation and reclamation of the Muskeg River (Lease 13) Oil Sands Project included the following terms pertinent to reclamation:

- The approval holder shall salvage sufficient coversoil to reclaim disturbed land to achieve the approved amount of land to land capability classes 1 through 5.
- The approval holder shall directly place salvaged coversoil on contoured portions of the disturbed land whenever possible.
- When coversoil is stockpiled, the approval holder must ensure stockpile foundations are stable, do not contain any materials that may cause stockpile instability are easily accessible and retrievable, and are managed to control weeds.
- The approval holder shall replace coversoil to a minimum of 0.10 m with a minimum average depth of 0.20 m on all disturbed land reclaimed as land capability class 2, 3 or 4.
- The approval holder shall replace coversoil on all disturbed land reclaimed as land capability class 5 as authorized in writing by the Director.
- With the exception of replaced topsoil, including the litter layer, the approval holder shall ensure all replaced coversoil has an organic content between 40 and 70% on a per volume basis.
- The approval holder shall ensure oversized reject from the extraction plant, reject from the oil sand conditioning and transport system, and Clearwater overburden be capped with at least 0.80 m of tailing sand or overburden prior to placement of coversoil, unless otherwise authorized in writing by the Director.
- The approval holder shall restore moose wildlife habitat to levels equivalent to that which existed prior to disturbance.
- The approval holder shall re-establish a diversity of wildlife habitats consistent with pre-disturbance site characteristics and the surrounding undisturbed land.

2.1.3.4 Shell Canada Energy Ltd – Jackpine Mine

The 2004 approval pursuant to the Environmental Protection and Enhancement Act for construction, operation and reclamation of the Shell Jackpine Oil Sands Project – Phase I included the following terms pertinent to reclamation:

- The approval holder shall salvage coversoil to reclaim disturbed land to achieve the approved amount of land to land capability classes 1 to 3.
- The approval holder shall replace coversoil to a minimum depth of 0.10 m with an average depth of at least 0.20 m on all disturbed land, reclaimed as land capability class 2, 3 and 4.
- The approval holder shall directly place salvaged coversoil on contoured portions of the disturbed land whenever possible.

- When cover soil is stockpiled, the approval holder must ensure stockpile foundations are stable, do not contain any materials that may cause stockpile instability, are easily accessible and retrievable, and are managed to control weeds. Stockpiles that have remained for more than 1 year shall be revegetated, unless otherwise authorized in writing by the Director.
- The approval holder shall ensure oversized reject from the extraction plant, reject from the oil sand conditioning and transport system, Clearwater overburden, and consolidated tailings (CT) be capped with at least 1.0 m of tailing sand or overburden prior to placement of coversoil, unless otherwise authorized in writing by the Director.
- The approval holder shall submit a Revegetation Plan to the Director within 12 months of commencement of operations. The plan shall comply with the *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region*, 1998 and shall include, at a minimum, all of the following:
    - forest ecosystems and wetland ecosystems on disturbed land and
    - commercially viable forest ecosystems.
- Within 12 months of commencement of operations, the approval holder shall submit a Biodiversity Program to the Director. This program shall include:
    - a plan and schedule to monitor and document the return of biodiversity in the reclaimed landscape and to evaluate and compare changes in biodiversity on reclaimed sites and in the region and
    - a plan for participating in programs to monitor the cumulative effects on biodiversity in the region.

2.1.3.5 Canadian Natural Resources Ltd.

The 2004 approval pursuant to the Environmental Protection and Enhancement Act for site clearing for the Canadian Natural Resources Limited Horizon Oil Sands Processing Plant and Mine included the following terms pertinent to reclamation:

- The approval holder shall construct all structures and slopes to be geotechnically stable with minimal erosion.
- The approval holder shall replace coversoil (A horizon topsoil including LFH and/or peat-mineral mix) to a minimum depth of 0.10 m with an average depth of at least 0.20 m on all disturbed land, such that the appropriate reclaimed land capability classes defined in the Horizon Project Approval will be achieved.
- The approval holder shall cap the following materials with at least 1.0 m of tailings sand or overburden prior to replacement of coversoil, oversize reject from the extraction plant; reject from the oil sands conditioning and transport system, Clearwater overburden; and nonsegregating tailings (NST), unless otherwise authorized in writing by the Director.
- All borrow areas developed by the approval holder within the plant shall be reclaimed as outlined above.
- The approval holder shall submit a Revegetation Plan to the Director within 12 months of commencement of operations, unless otherwise authorized in writing by the Director.

- The Reforestation Plan shall comply with the *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region*, 1998 and shall include the following information:
    - forest ecosystems and wetlands ecosystems on disturbed land:
        - incorporation of vegetation and vegetation communities of traditional value and that are characteristic of those communities on adjacent undisturbed lands
        - re-establishment of the capability for biodiversity in the long term
        - re-establishment of the continuity of vegetation patterns, where practicable, between the reclaimed lands and adjacent undisturbed lands
    - commercially viable forest ecosystems:
        - on areas equivalent to the pre-disturbance areas of commercially viable White Spruce Mixedwood, Deciduous, White Spruce and total Coniferous ecosite phases.

2.1.3.6 Petro-Canada Oil Sands Inc.

The 2002 approval pursuant to the Environmental Protection and Enhancement Act for construction, operation and reclamation of the Fort Hills Oil Sands Processing Plant and Mine included the following terms pertinent to reclamation:

- The approval holder shall salvage coversoil to reclaim disturbed land.
- The approval holder shall conduct direct placement of salvaged coversoil on contoured portions of the disturbed land under final reclamation whenever possible.
- When cover soil is stockpiled, the approval holder must ensure stockpile foundations are stable, do not contain any materials that may cause stockpile instability, are easily accessible and retrievable, and stockpiles are managed to control weeds. Stockpiles that have remained for more than 1 year shall be revegetated, unless otherwise authorized in writing by the Director.
- The approval holder shall replace coversoil to a minimum depth of 0.10 m with an average depth of at least 0.20 m on all disturbed land, reclaimed as land capability class 1, 2, 3, and 4.
- The approval holder shall submit a Revegetation Plan to the Director within 12 months of commencement of operations.
- The approval holder shall participate in a Land Capability Classification System (LCCS) Research Program.
- The approval holder shall participate in a Regional Wildlife Assessment Program.
- The approval holder shall submit a Biodiversity Program to the Director within 12 months of commencement of operations, unless otherwise authorized in writing by the Director.
- The approval holder shall submit or cause to be submitted a Wildlife Monitoring Program to the Director within 6 months of commencing ditching and draining for mine preparation.

2.2 DRY LAND RECLAMATION

2.2.1 SOIL SALVAGE

2.2.1.1 Suncor Energy Inc.

Annual reporting of reclamation work at Suncor Oil Sands sites began in 1976 (Golder 2007). Information regarding specific soil salvage operations during the 1970's was not documented in detail.

Peat has been salvaged since the beginning of operations at Suncor. It was determined in 1978 that hauling of peat to the reclamation site from peat and overburden removal operations saved considerable time and money. Furthermore, the peat was then available for placement directly on reclamation areas in the spring, stockpiling at strategic locations for future use, or depositing in overburden waste dumps. It was also determined that for soil placement on tailings sand slopes, peat should be mixed with underlying mineral layers at salvage, creating a final peat dressing mixture with a 2.5 to 1 ratio of peat to mineral. Material handling operations (excavation, haulage and placement of soils) generally occurred in winter and were seen to provide sufficient mixing of the mineral overburden (usually clay and silt) and organic soil (usually peat) material to promote plant growth. Peat materials less than 0.6 m in depth were more difficult to strip and not usually salvaged for reclamation.

After 1979, a mix of 25 to 50 % mineral to peat was used. Before salvage, if the peat was underlain by fine mineral material it was designated "Type 1" peat and used for reclamation of tailings sand structures. If the peat was underlain by coarse mineral layers it was designated "Type 2" peat and used in reclamation of overburden dumps. Field research at this time showed that high organic matter content was favourable in reclamation treatments; therefore applying peat with minimal incorporation provided improved moisture supply, nutrients and regeneration of native vegetation.

The focus of muskeg soil excavation and placement since 1984 has been to utilize and apply undisturbed muskeg deposits (*insitu* muskeg soil) from reserves in front of the overburden advance directly to reclamation areas rather than to storage stockpiles. Stockpiled material was used only when mine advances provided insufficient soils for reclamation activities. Prior to 1983, muskeg soil had been excavated and placed in stockpiles for future use (Suncor 1984).

During the reclamation programs of 1983 and 1984, the source of the muskeg soil changed to deposits located in unmined areas where disturbance was minimal. The undisturbed material was excavated during the winter months when *insitu* seeds and roots are dormant and placed directly on the reclamation sites. The material was then spread in the following spring.

As of 1992, the desired ratio of organic to mineral components was adjusted closer to 2:1 and the definition of Type 1 and 2 reclamation soil amendments changed slightly. Type 1 soil (stockpiled peat with an overburden content of approximately 40% by volume) was used for reclamation of tailings sand areas as well as some overburden areas, and Type 2 soil (sand overlain with peat) was used on areas of overburden soil with higher clay contents.

Experience demonstrated that a 60:40 ratio was a better growing medium. To achieve the best reclamation results it was recommended that the stripping operations be conducted to ensure the salvaged soil material contained at least 50% organic material, ideally 60 to 70% (Suncor 1997). As a minimum thickness of 1 m was considered necessary to effectively carry out the soil salvage operations, a peat layer with a minimum depth of 50 cm in the salvaged soil was required. Soil amendments with <50% organic matter were not normally salvaged for reclamation. In areas where the peat thickness was >50 cm, the stripping depth was increased accordingly.

The organic/mineral ratios do not apply to true mineral soil salvage, where the focus is on the leafy, fibric and humic (LFH) and A horizons.

In 1996, with the development of *The Land Capability Classification for Forest Ecosystems in the Oil Sands Region* (Leskiw 1996) the reference to Type 1 and Type 2 muskeg soil was dropped by Suncor. Instead, soil criteria as defined by the report (Leskiw 1996) were used to measure the return of capability in the post reclamation landscape.

Soil salvage methods in accordance with EPEA Amending Approval (94-01-37) for the Voyageur Upgrader site and North Steepbank Extension changed relative to previous practice (Suncor 2007). For upland a (lichen) and b (blueberry) ecosites, Suncor is required to salvage the LFH and available mineral A horizon to a maximum depth of 15 cm. Other upland ecosites (c – mesic Labrador tea ecosite and, d – low bush cranberry ecosite) will have LFH and mineral A horizon salvaged to a depth of 30 cm.

Subsoil salvage depths for each soil type are as follows:

- a and b ecosites – range from 50 to 70 cm
- other ecosites (c, d) – range from 50 to 70 cm
- transitional soils (e – dogwood, f – horsetail, and g – hydric Labrador tea ecosites) – range from 30 to 60 cm
- organic soils (deep peat) no subsoil salvage.

At the Voyageur Upgrader site, there will be separate stockpiles for the various suitability classes of both topsoil and subsoil so that mixing of surface soils and subsoils and qualities of different soils is minimized. Soil stockpiles will be created and segregated for the following types:

- Topsoil
    - Good – Fair
    - Poor (coarse textured)
    - Poor (fine textured)

- Subsoil
  - Good – Fair
  - Poor (coarse textured)
  - Poor (fine textured)
- Peat – Mineral mix

Soil salvaged form the North Steepbank Extension will require only a few small stockpile areas because direct placement is planned for most salvaged materials to Steepbank Mine reclamation areas.

Completed stockpiles will be sown with an annual barley crop cover to minimize soil loss due to the action of wind and water.

2.2.1.2 Syncrude Canada Ltd.

Reclamation of lands disturbed by Syncrude has been underway since 1976. Initial approvals (September 1978) stated that "organic and mineral material suitable for soil reclamation shall be removed by the operator in sufficient quantities necessary for the reclamation of the lands to the approved post-disturbance land use and have slopes less than 2:1 (27º)" (Syncrude Canada Ltd. 1978).

Soil salvage activities at Syncrude consisted of the selective removal of muskeg (Plate 2.1), usually to a stockpile (Plate 2.2). They also include the removal, loading and hauling of suitable (generally top 2.0 m) of Holocene/Pleistocene (regolith) material (Plate 2.3) for direct placement on reclamation sites (Syncrude 1985 and 1986). Historically, muskeg deposits greater than 2.0 m deep were identified for salvage and suitable regolith material was identified by test pit sampling and laboratory analyses. Activities were completed during winter.

Plate 2.1. Peat material in salvage area at Syncrude Canada Ltd.

Plate 2.2. Salvaged peat in peat mix stockpiles at Syncrude Canada Ltd.

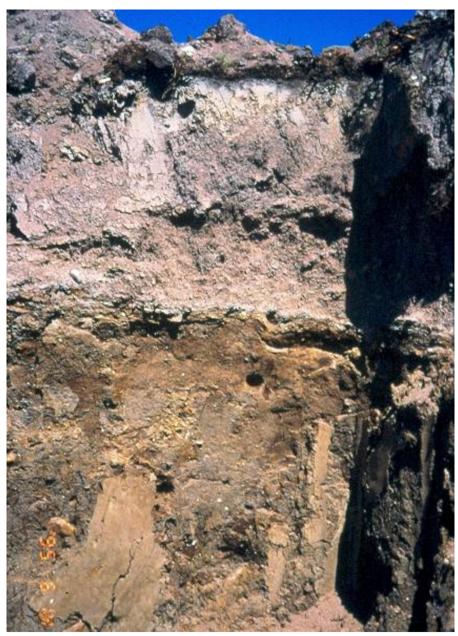

Plate 2.3. Soil and geological material salvaged to provide "secondary" replacement material at Syncrude Canada Ltd.

Soil salvage methods remained the same until 1990 when a test model was developed to determine the quality of overburden material on Syncrude leases. The model was developed through auger and test pit sampling, analysis of samples, and logging of lithology. Geostatistics were applied using the sample locations and data to predict quantity, quality, and location of reclamation material site-wide. The model was refined annually by inclusion of new data from step-out drilling which increased the density of sample sites in the areas to be stripped of overburden in the medium term. This model was then used to delineate and quantify the volumes of cover soil and overburden material available for use within overburden strips to fulfill the requirement for reclamation capping material (Syncrude 1991).

Since the development of the model, Syncrude conducts winter overburden auger and sampling programs with the objective of characterizing the overburden resource on an annual basis (Syncrude 2006a). Generally, sample sites are densely spaced within the one to five-year overburden stripping limits (100 meter spacing or less) and more sparsely spaced beyond 5 years (200 meters spacing or greater). Geologic data collected include geographic position (northing, easting and elevation), facies, depth and qualifier. Samples for physical and chemical analyses are collected discretely by facies in five-foot intervals. The analyses include pH, electrical conductivity (EC), sodium adsorption ratio (SAR), particle size distribution (percents sand, silt and clay), textural class (e.g., sand, loam, clay loam) and percent oil for select samples (Syncrude 2006a).

The model classifies coversoil as any topsoil or organic soil that meets the coversoil criteria. Overburden is defined as the material below coversoil and above bituminous sand. It is divided into two groups: suitable and unsuitable. Poor quality material according to the soil quality criteria is considered unsuitable and is not used for reclamation (Table 2.1).

Table 2.1. Overburden suitability for reclamation at Syncrude.

	Good	**Fair**	**Unsuitable**
pH	4.0-7.5	7.6-8.0	>8.0
EC (dS/m)	≤ 2.0	2.1-4.0	>4.0
SAR	≤ 4.0	4.1-7.0	>7.0
Oil (%)	<1.0	<1.0	≥1.0
Texture class			C,HC
Geological source	Holocene, Pleistocene	Holocene, Pleistocene	Cretaceous

Syncrude reclamation material suitability criteria are consistent with criteria for evaluating the suitability of surface material for revegetation in the Northern Forest Region outlined in the S*oil Quality Criteria Relative to Disturbance and Reclamation* (ASAC 1987).

Prior to overburden removal, the surface soils and subsoils are characterized by the above parameters and surveyed according to the Canadian System of Soil Classification (CSSC) at a scale of 1:20 000. Other criteria for suitable material include:

- Pleistocence (mineral) material to be salvaged to a maximum depth of 3 meters
- Holocene (organic) material to be salvaged to depth of occurrence
- upper 0.5 meters may be salvaged from all area
- poor material below organic material salvaged to a maximum of 30%.

In 1992 and 1993, suitable *in-situ* reclamation materials were characterized into three main types including direct placement material, secondary placement material, and muskeg/topdressing material and were salvaged accordingly.

From 1995 to 1997, Syncrude adjusted the salvaging methodology because of difficulties encountered with a thin upper layer of heavy textured lacustrine till material found in most upland areas. This material had a tendency to form a heavy textured layer which resisted incorporation of organic material and presented an added erosion hazard. However, when salvaged with the underlying sandy loam outwash till, it created a matrixed material suitable for reclamation. Because this strategy resulted in deeper salvage, it was classified as secondary material which required topdressing at the reclamation site.

The process of salvage and placement is performed annually, typically in the winter months of November to late March to ensure trafficability of wet organic deposits and to minimize compaction of placed soil covers (Plate 2.4). With additional controls on a suitable substrate and proper placement methods it can be done in the summer.

Currently, Syncrude salvages organic soil (peat and muskeg) to the underlying mineral contact. Areas not salvaged for peat are candidates for topsoil salvage (shallow soil or LFH) (Plate 2.5). The boundaries between suitable and unsuitable overburden materials are typically chemical, making salvaging to visual contact in the field impossible. The maximum salvage depth is predetermined through the suitability evaluation. Source pits have a design volume. To ensure required placement volumes and design depths are met, the number of truck loads going to each site is monitored. Salvaging operations are generally done two years in advance of mining operations and the materials are stockpiled.

Plate 2.4. Soil salvage operations at Syncrude Canada Ltd.

Plate 2.5. LFH layer salvaged (foreground) at Syncrude Canada Ltd.

2.2.1.3 Albian Sands Energy Inc. - Muskeg River Mine

Coversoil is excavated from peat that is overstripped to include sufficient underlying mineral soil to generate an approximate 70:30 peat/mineral mix. On excavation the coversoil is stored in reclamation material stockpiles for future reclamation or placed directly on prepared areas to a minimum depth of 0.2 m.

In 2005 and 2006, soil was salvaged in 2 lifts. The top lift consisted of a shallow stripping material layer (material from the top 25 cm of the natural soil profile) and a peat/mineral layer (all materials suitable for reclamation below the top lift). Each lift went to separate areas of the stockpile. Approximately 141,000 m^3 of shallow stripping material and 626,000 m^3 of peat/mineral material was salvaged for roughly 767,000 m^3 of material in total. Net stockpile volumes totalled more than 7.8 million m^3 of material by the end of 2006 (Albian 2007).

2.2.1.4 Shell Canada Energy Ltd. – Jackpine Mine

Soil salvage activities commenced in 2006 with testing and selection of suitable soils and excavation and stockpiling of material for future reclamation (Shell 2007). Soil testing was conducted on muskeg to ensure that only suitable material was sent to the reclamation stockpiles. Reclamation stockpiles were composed of an organic material and mineral material mix.

Soil salvage techniques were consistent with Muskeg River Mine techniques. However, frozen ground conditions resulted in the undesirable lifting of mixed chunks (sometimes in excess of 1 m^3) of organic and mineral soil. Given this circumstance and the limited time available for soil salvage, Shell determined that a single lift technique was the only viable option. Salvaged materials were placed into reclamation material stockpiles.

Reclamation material stockpiles were constructed in alternating lifts of weaker, higher organic materials, and stronger, higher mineral content materials. This allowed heavy equipment to access the stockpiles because the organic portion of the reclamation materials has inherently weak strength. To ensure geotechnical stability, the piles were constructed no higher than 20 m.

2.2.1.5 Canadian Natural Resources Ltd.

Surface soil salvage practices on the Horizon Project are consistent with those prescribed in *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region* (OSVRC 1998). Salvaged reclamation material is currently stockpiled for future use. As areas become available for permanent reclamation, reclamation materials will also be directly placed on these areas.

Peat-based soils that are greater than 0.2 m in depth (i.e., peaty-phase gleysols and organic soils) are typically over-stripped beyond the peat-mineral contact, which results in a peat-mineral mix used for reclamation. This process is commonly referred to as "muskeg salvage". Areas of peat-based soils are selectively targeted for the following reasons:

- Salvage of peat-based soils is necessary for achieving the soil volume requirements for reclamation over the life of the project.
- The peat-based soils are located within areas where removal is required to ensure geotechnical stability of structures.

Across all peat-based material, the over-strip quantity is typically calculated to be 58%, and this gives an approximate mix of 60% peat material and 40% mineral mix in the stockpiles. No excavation of peat is conducted where the designed use and depth of peat allow it to remain in place with facilities constructed on the peat (e.g., roads). Circumstances where surface soils are not salvaged are the following:

- removal is not necessary for meeting the soil volume requirements for reclamation now or throughout the life of the Horizon Project and/or
- surface soils are located within the area of a constructed landform (e.g., overburden waste area) but their removal is not required for geotechnical purposes.

Overburden materials will be selectively handled during overburden stripping operations so that they can be used for subsoil fill material over Clearwater Formation overburden. Subsoil material that is less saline and less sodic than Clearwater Formation materials will be salvaged from overburden and used to cover any areas of Clearwater Formation overburden.

2.2.1.6 Petro-Canada Oil Sands Inc.

Based on 2007 reporting for 2006 (Leskiw 2007) it was reported that surface disturbance to date had been confined to trails, cutlines for test drilling and facility sites. No major soil salvage activities have occurred on site. Soil salvage activities will comply with the most current approval conditions.

2.2.2 SOIL PLACEMENT

2.2.2.1 Suncor Energy Inc.

Early reclamation areas on Suncor's oil sands mine site in the 1970s included Tar Island Dyke (TID), East-West Dyke and Waste Dumps 5, 7, and 11. The main focus of early reclamation activities was to stabilize and prevent erosion of berm slopes and provide cover on waste dump areas (Golder 2007). Sites were prepared by levelling berms at a constant elevation and contouring them slightly towards the upslope. Peat was then spread over these areas to a depth of 0.10 m. This was done to force ponding and infiltration of water, to control runoff, and prevent the creation of alluvial fans.

The first operational scale reclamation work began in 1971, when 0.10 to 0.30 m of peat was tilled 0.30 m into the tailings sand of the TID over a 14 ha area (Golder 2007). A D6 bulldozer and attached Rotovator (Plate 2.6) were used to mix the tailings sand and peat. Results were variable due to variability in the spreading thickness of the peat.

It was determined in 1978, that for soil placement on tailings sand slopes, peat should be mixed with underlying mineral layers at salvage, creating a final peat dressing mixture with a 2.5 to 1 ratio of peat to mineral (Golder 2007). On overburden areas, peat (free from mineral incorporation) was spread to an average depth of 0.15 m, with a minimum depth of 0.10 m. The increase in the application depth was made in an attempt to eliminate areas where insufficient soil amendment was placed. Final seedbed preparation followed muskeg application with fertilizer and muskeg being incorporated into surface substrates to a depth of up to 0.30 m (Shopik and Klym 1979). These material handling procedures were found to be sufficient to create a mixture of mineral and organic materials with properties conducive to plant growth (Klym and Shopik 1980).

After 1979, a mix of 25 to 50% mineral in peat was used (Suncor 1989). Field research at this time showed that high organic matter content was favourable in reclamation treatments; therefore applying peat with minimal incorporation provided improved moisture supply, nutrients and regeneration of native vegetation (Suncor 1989). A chisel plow (Plate 2.7) was used rather than a Rotovator to achieve this minimal incorporation, with a harrow (Plate 2.8) used to mix fertilizer and the barley nurse crop.

Since 1984, the preferred method has been to move topsoil in front of the overburden advance directly to reclamation areas rather than to storage stockpiles, and to use stored soils only when mine advances provided insufficient soils for reclamation activities. The undisturbed material which was excavated during the winter months when *insitu* seeds and roots are dormant was placed directly on the reclamation sites. In the following spring, the muskeg soil was spread on the reclamation site to a minimum depth of 0.10 m, with an average depth of 0.20 m. The result of using partially frozen *in situ* pockets of topsoil was noteworthy because native seeds and root fragments transferred with the soil became established and grew rapidly on the reclamation sites (Suncor 1991).

As of 1985, soil preparation involved placing a 0.15 m top layer of soil material (peat or topsoil), with fertilizer incorporation to a depth of 0 to 0.15 m depending on the tillage instrument used (e.g., harrows, Klodbusters, chisel plows), with chisel plowing the preferred method where possible (Suncor 1986). Following incorporation of the topsoil, the area was then packed and imprinted with the Suncor Land Imprinter.

Research from 1991 on tailings sand showed that spreading soil amendments over the reclamation area without incorporation into the underlying material was the most suitable reclamation method, as it permitted survival of root fragments and seeds suspended in the soil and allowed better growth and survival of a diverse community of natural vegetation with little erosion (Suncor 1992).

As of 1992, the desired ratio of organic to mineral components was adjusted closer to 2:1 and the definition of Type 1 and 2 reclamation soil amendments changed slightly (Suncor 1993). Type 1 soil (stockpiled peat with an overburden content of approximately 40% by volume) was used for reclamation of tailings sand areas as well as some overburden areas, and Type 2 soil (peat overlain with sand) was used on areas of overburden soil with higher clay contents. Soil amendment was placed on reclamation areas in spring at average depths of 0.20 to 0.29 m (Suncor 1993).

Plate 2.6. Rotovator used at Suncor Energy Inc. before 1979.

Plate 2.7. Chisel plow used At Suncor Energy Inc. after 1979.

Plate 2.8. Harrows being pulled by an All Terrain Vehicle after seeding at Suncor Energy Inc.

Peat hauling and spreading was generally conducted from mid-February to mid-July. Soil spreading was generally conducted from late March to early July. Spreading the muskeg soil amendment onto the parent material without blending had given the best ecosystem establishment results (Suncor 1994). Results showed that this was an improvement over previous methods as a more diverse natural plant community became established on these sites and erosion was not a problem. This "capping" method permitted the survival of a greater percentage of the root fragments and seed suspended in the muskeg soil. Following application of fertilizer and a barley nurse crop the muskeg soil was mixed with harrows which results in minimal mixing of the amendment with the spoil (Suncor 1995).

The development of the Land Capability Classification System (LCCS) in 1996 (Leskiw 1996) provided a more quantifiable system of soil criteria, with the result that references to Type 1 and Type 2 soils were discontinued (Suncor 1997). The LCCS is based on quality rather than quantity of reclamation soil amendment to ensure that reclaimed areas will have similar soil capability as predisturbance levels (Golder 2007).

2.2.2.2 Syncrude Canada Ltd.

Syncrude's initial approvals (September 1978) required soil to be placed on the surface of the recontoured lands at depths at least sufficient to provide reclamation to the post disturbance land use prescribed. The reconstructed soil was to have chemical, physical and biological characteristics which permitted upland reclamation to a forest environment at least as productive as it was prior to disturbance.

During the initial years (1978 to 1983) of reclamation at Syncrude, tailings sand slopes were reclaimed by capping with a nominal 0.10 m layer of clayey overburden followed by a 0.15 to 0.20 m layer of peat and incorporating these amendments into the sand to a depth of 0.10 to 0.20 m using a cultivator and discs or a Rotovator (Syncrude 1980 and 1983). Sites were then levelled and harrowed to create a good seedbed. Spoil or overburden piles were contoured prior to "topsoiling"; which included the hauling, dumping and spreading of material (0.15 to 0.20 m topsoil and sandy loam clay material) and then incorporation to a depth of 0.25 to 0.40 m into the substrate with a Rome plow or heavy duty cultivator. A mouldboard plow was used to alleviate compaction in some areas (Plates 2.9 and 2.10).

The second reclamation approach evaluated at Syncrude began in 1983 when 35 cm of muskeg material was applied as opposed to the standard 0.10 to 0.15 cm application (Syncrude 1983). Clay was also added in some areas at various depths (Holocene/Pleistocene material). Soil reconstruction was followed by a fertilizer application and either contour plowing with a Kello-Bilt deep plow (Plate 2.11), seedbed preparation with spike-tooth harrows or offset discs or soil incorporation with the Alberta Agriculture Rotoclear (Plate 2.12).

Plate 2.9. Mouldboard plow used to alleviate compaction at Syncrude Canada Ltd.

Plate 2.10. Soil following plowing with mouldboard plow at Syncrude Canada Ltd.

Plate 2.11. Kello-Bilt deep plow used for contour plowing in the 1980s at Syncrude Canada Ltd.

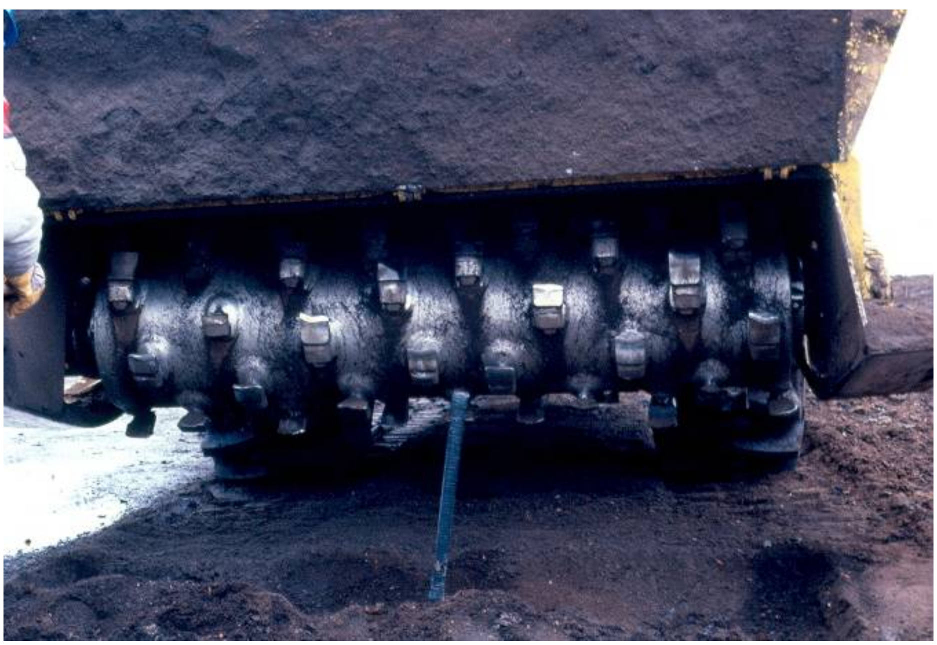

Plate 2.12. Rotoclear used for soil incorporation at Syncrude Canada Ltd.

The next reclamation approach evaluated at Syncrude began in 1986 when the amendment material was applied as a single 0.50 m cap on tailings dykes and greater than 0.50 m caps on overburden dumps. To meet the criteria in their Approval which stated that the replacement depth of 0.10 m of clay and 0.15 m of peat be incorporated to a depth of 0.30 m, Syncrude placed a greater mean depth of each material. Amendment material used for reclamation was rated as having either Fair or Good reclamation suitability based on criteria set out by the Soil Quality Criteria Working Group (ASAC 1987). After placement, the area was prepared by generating prominent ridges (0.30 to 0.50 m high parallel to the contour on slopes) (Plates 2.13 and 2.14). The furrows created by this equipment were believed to create sufficient erosion control on most slopes so that seeding of a grass/legume mixture would be unnecessary (Syncrude 1986).

Plate 2.13. Photo of fall planting in sloped area with ridges at Syncrude Canada Ltd.

Plate 2.14. Photo of ridges and tree cover at Syncrude Canada Ltd. 20 years after planting.

Operational testing of the heavy duty bedding disc/ridger between 1987 and 1991 confirmed that it did not create furrows sufficient to provide erosion control on slopes as steep as 25 to 35%, and in these instances alternative erosion control methods were required (Syncrude 1991). The effectiveness of a winged subsoiler for reducing compaction and assisting with incorporation of organic amendments was evaluated and proven in 1991.

Subsequent reclamation of tailings sand and overburden involved an increase in the depth of the amendment material to 0.70 m and efforts were made to increase organic matter content (Syncrude 1991). For example, if the reclamation material placed on the site had less than 20% organic (peat) by volume, a nominal 0.15 m top dressing of higher organic peat (50 to 100% by volume) material was placed at the surface. The thickness of the lower material was reduced to 0.55 m such that the total amendment thickness was maintained at 0.70 m.

Syncrude redefined the definitions of suitable reclamation materials in 1992 and characterized them into 3 main types (Syncrude 1993):

- Direct placement material was material containing a suitable balance of mineral and organic. This material was salvaged and placed without further amendment.
- Secondary placement material (Plate 2.15) was predominantly mineral material, considered deficient in organic matter when salvaged at the depth specified. After placement, this material is amended with 0.10 to 0.20 m of topdressing material (Plate 2.16).
- Muskeg/Topdressing was predominantly muskeg (organic) material considered deficient in mineral material (Plate 2.17). Use of this material in permanent reclamation included placement depths of 0.10 to 0.20 m as amendment material

and 1.0 m for reclamation of poorly drained areas. Subsequent mixing into the secondary material using tillage equipment (Plates 2.18, 2.19 and 2.20) took place during the next field season.

The definitions of these reclamation materials have since been updated and are currently defined as (Syncrude 2004):

- **Direct placement material contains a suitable balance of mineral and organic. This material is salvaged and placed without further amendment.** The limits for the in-situ organic component are 40 to 70% (v/v). Except for ideal situations, Syncrude rarely employs this direct placement strategy, favouring placement of mineral material followed by organic topdressing. This ensures adequate organic matter at the surface.
- **Secondary Placement is predominantly mineral material, considered deficient in organic matter when salvaged at the depth specified. After placement, this material is amended with 0.10 to 0.20 m of top dressing/peat material, which may then be mixed into the secondary material by tillage equipment.**
- **Peat/topdressing is predominantly organic material, considered deficient in mineral material.** Use of this material in permanent reclamation includes placement depths of 0.10 to 0.20 m as amendment material and up to 1.0 m deep for reclamation of poorly drained areas. The material is usually taken directly from in-situ, but may come from a stockpile source (historically this material was stockpiled). Post treatment cultivation may be required to avoid a peaty surface deduction during assessment.

Plate 2.15. Cross section of secondary material over tailings sand at Syncrude Canada Ltd.

Plate 2.16. Cross Section of peat mix over secondary over tailings sand at Syncrude Canada Ltd.

Plate 2.17. Cross section of peat mix over tailings sand at Syncrude Canada Ltd.

Plate 2.18. Disc incorporating peat mix into underlying secondary material at Syncrude Canada Ltd.

Plate 2.19. After disking peat mix into secondary material at Syncrude Canada Ltd.

Plate 2.20. Peat mix and secondary over secondary material at Syncrude Canada Ltd.

An additional category was added in 2003:

- **LFH is surface organic matter from beneath upland forest stands (Plate 2.21) and is used for its value in providing vegetation propagules appropriate to upland situations.**

Plate 2.21. Cross section of replaced LFH layer at Syncrude Canada Ltd.

The preferred equipment for site preparation from the early 1990s until 2003 was the heavy duty offset disks. High productivity, low maintenance, flexibility for either herbaceous revegetation or reforestation and achievement of desired results for soil mixing and surface roughness have contributed to this preference (Syncrude 2003). Depending on the site, seedbed preparation may have also involved harrowing prior to seeding. Heavy duty offset disks are used presently to disk areas of wind blown sand, to relieve compaction and to mix organic surface material into the underlying mineral material (Syncrude 2007). Such use is balanced against the desirability of maintaining natural emergence of plant material from replaced soil materials.

Syncrude's current soil cover designs (reclamation soil prescriptions) meet or exceed minimum criteria outlined in Syncrude's operating approvals (Syncrude 2007). Tables 2.2 and 2.3 provide a list of the thicknesses of suitable overburden and coversoil placed on each of the different substrate materials at the Mildred Lake and Aurora south operations, and Aurora North operations. Some soil covers are two-lifts (i.e., two layers of reclamation material: suitable overburden and coversoil) and others are one-lift (i.e., coversoil only). Soil materials for reclamation are either directly placed from operations at the mine advance or taken from stockpiles**. Soil replacement operations are generally conducted in the winter (Plate 2.22).**

Plate 2.22. Winter soil placement at Syncrude Canada Ltd.

Table 2.2. Soil placement thicknesses by substrate for Mildred Lake and Aurora South Operations.

Landform	**Suitable overburden (m)**	**Coversoil (m)**	**Total soil cover (m)**
Borrow pits	0.00	0.20	0.20
FGD Waste	0.80	0.20	1.00
Coke storage	0.15	0.20	0.35
Overburden (flat)	0.80	0.20	1.00
Overburden (sloped)	0.80	0.20	1.00
Sand-capped CT	0.15	0.20	0.35
Tailings sand (flat)	0.15	0.20	0.35
Tailings sand (sloped)	0.15	0.20	0.35
Thickened tailings	0.15	0.20	0.35
Wetlands (excluding lakes)	0.15	0.20	0.35

Table 2.3. Soil placement thicknesses by substrate for Aurora north operations (Syncrude 2007b).

Substrate	**Suitable Overburden (m)***	**Coversoil (m)**	**Total soil cover (m)**
Borrow pits	0.0	0.20	0.20
Overburden (flat)	0.0	1.00	1.00
Overburden (sloped)	0.0	1.00	1.00
Sand-capped CT	0.0	0.35	0.35
Tailings sand (Flat)	0.0	0.35	0.35
Tailings sand (sloped)	0.0	0.35	0.35
Thickened tailings	0.0	0.35	0.35
Undisturbed	0.0	0.0	0.00
Wetland (excluding lakes)	0.0	0.2	0.20

*Where suitable overburden is available, prescriptions similar to Mildred Lake's are considered.

Since 2003, after the reclamation material has been spread, an area undergoes further seedbed preparation with a series of tasks appropriate to each location (Syncrude 2003a, 2004a, 2005a, 2006a, and 2007a):

- Contouring and levelling is done by pulling a section of I - beam (large piece of pipe) behind a large tractor. This prepares the ground for fertilization by smoothing out the surface and breaking apart large clumps of peat.
- Other than to minimize erosion by seeding with a barley nurse crop, further seedbed preparation would not be done on areas about to be reforested (this helps to preserve micro-topography features, which aids seedling planters in selecting sites and enhances invasion of native trees and shrubs after planting).
- Disking of pasture areas using heavy duty offset disks is sometimes done as a next step to incorporate the fertilizer into the rooting zone (done less often now because of the possibility of mixing substrates with reclamation materials).
- If disking occurs on a pasture area, a final levelling or contouring is done to break apart clumps brought to the surface during disking.

- Harrowing is done by dragging a combination pipe and chain system behind a tractor prior to seeding.

Slightly different reclamation soil cover designs are required for operational reclamation at Aurora North because the available resources are predominantly sand and organic soils (Syncrude 2007b). Currently, overburden structures are reclaimed with a 1:1 (volume) peat to sand mixture in a one-lift operation to ensure sufficient available water holding capacity for revegetation success. **Current and future research and monitoring of reclamation at Aurora North will likely identify the new suitable reclamation prescription.**

2.2.2.3 Albian Sands Energy Inc. – Muskeg River Mine

The type of soil and placement prescription at Albian depends on the landform of the area, soil available, desired ecosite, desired land capability and results of ongoing research efforts. There has been limited soil placement activity at the Muskeg River Mine due to the stage of development, however, the following activities have occurred.

In 2003, suitable topsoil material was placed over exposed parent material and compacted, exposed oilsand with variable depths of 0.50 m at the bottom of the slope and approximately 0.10 m at the top of the Athabasca River Water Intake Site (Albian 2004). Large coarse woody debris was then scattered throughout the reclaimed area to provide microhabitat and surface stabilization. Reclamation of a 1 ha area was also completed with a coversoil thickness of approximately 0.2 m adjacent to the Muskeg River Bridge.

Direct placement of soil occurred in two layers over a base of tailings sand and on the toe of an overburden dump in 2005 (Albian 2006). The first layer consisting of a mix of peat (approximately 70%) and mineral (approximately 30%) was placed at a depth of 0.7 m and the second layer of shallow stripping material taken from the top 0.25 m of the natural soil profile, was placed in piles at the top of the reclamation areas in sufficient volume to cover the peat/mineral layer to a depth of approximately 0.2 m. After the peat/mineral layer thawed, it was spread and smoothed.

No direct soil placement activities occurred in 2006 (Albian 2007).

2.2.2.4 Shell Canada Energy Ltd. – Jackpine Mine

The Jackpine Mine is currently under construction and therefore no reclamation of disturbed land had occurred at the time of preparation of this document.

2.2.2.5 Canadian Natural Resources Ltd.

The Horizon Project is currently under construction and therefore no reclamation of disturbed land had occurred at the time of preparation of this document.

2.2.2.6 Petro-Canada Oil Sands Inc.

The Fort Hills Project is currently under construction and therefore no reclamation of disturbed land had occurred at the time of preparation of this document.

2.2.3 SOIL MONITORING

2.2.3.1 Suncor Energy Inc.

Soil characteristics in reclaimed tailings and waste overburden areas along permanent transects have been routinely monitored by both in-house staff and external personnel at sites reclaimed between 1971 and 2007. The program consists of regular annual soil sampling from areas reclaimed within the past three to four years and a detailed assessment and sampling of older reclaimed areas completed in the fifth year. On reclaimed sites, three layers are sampled per transect at most sites including the amended layer (0 to 0.15 m), the layer immediately below the amended layer (0.15 to 0.30 m) and the 0.45 to 0.60 m layer. Samples were taken from three locations and bulked to form one composite sample per layer per transect. The trends observed in the various matrices associated with the soil replacement programs based on measurements completed in 2003 are provided (Suncor 2004).

Tailings sand (amended layer – 0 to 0.20 m)

- Generally soil pH has shown minor changes over time with fluctuations occurring within a range of 1.5 pH units. Soil pH at the older sites was moderately acidic to moderately alkaline, while in the intermediate-aged and newer reclaimed sties, pH was more neutral to slightly alkaline (Suncor 2004).
- Electrical Conductivity (EC) has fluctuated over time, but has always been lower that 3.0 dS/m. Since 1998, EC's have been less than 2.5 dS/m, with the exception of the recently reclaimed sites where EC's are slightly higher (Suncor 2004).
- Organic carbon (OC) content and total nitrogen content have followed similar patterns over time and have shown no evidence of decline. OC content was greater than 4% at the older sites while it was between 2 and 5% in the recently reclaimed sites in 2003 (Suncor 2004).

Tailings sand (subsoil layer – 15 to 30 cm)

- Subsoil pH values have fluctuated within a range of 1.5 pH units. In 2003, pH ranged from about 6.0 to 7.6, indicating moderately acidic to slightly alkaline conditions (Suncor 2004).
- EC was relatively stable over time and there was evidence of increase at only one site. All measured ECs indicate negligible subsoil salinity in the oldest reclaimed sites while the intermediate-aged and newest reclaimed sites are slightly saline (Suncor 2004).
- Subsoil organic carbon contents have typically been less than 1%, but 2003 data have indicated that levels in the intermediate aged and particularly the newer reclaimed sites had greater amounts of OC, with levels as high as 3 to 4% (Suncor 2004).

Overburden (amended layer – 0 to 20 cm)

- Soil pH fluctuated within a range of 0.5 to 2.0 pH units over time, depending on the location (Suncor 2004).
- EC values were consistently negligible to slight.
- Sodium Adsorption ratio (SAR) values were generally consistent over time and have indicated non-sodic conditions (Suncor 2004).
- Bitumen content has not followed any consistent trend among sites and has always been less than 2.5% (Suncor 2004).
- OC content and total nitrogen content have generally followed similar stable patterns over time. The highest organic carbon content in 2003 was found in several of the more recently reclaimed sites (Suncor 2004).

Overburden (subsoil layer – 20 to 50 cm)

- Subsoil pH generally maintained a consistent range over the monitoring period (Suncor 2004).
- EC generally declined at most sites.
- Based on EC, salinity at the sites is always within the slightly saline to negligible range (Suncor 2004).
- SAR values have either shown large initial deceases followed by consistent levels, or have been consistently low over time (Suncor 2004).
- OC content has remained relatively stable over time. In 2003, the majority of sites had subsoil OC content greater than 2% (Suncor 2004).

It was concluded that the reclamation sites were not being affected by the chemical characteristics of the underlying tailings sand or overburden wastes (Suncor 2004).

The assessment of land capability for forestry, based on the LCCS for Forest Ecosystems (Leskiw 1998) was a new addition to the comprehensive monitoring program that has been in place at Suncor since 1971. At each location, auger inspections are made to assess overall variability of material type and capping depth. Based on these inspections a representative site is chosen for excavation of a pit for detailed soil inspection and sampling (average 1 pit for 5 ha). The LCCS rating is calculated for each pit and an average calculated for each reclamation area (Suncor 2004).

2.2.3.2 Syncrude Canada Ltd.

The land reclamation monitoring program at Syncrude operations includes assessing the effectiveness of the capping program and capability assessment. Regular monitoring of the areas where reclamation material has been placed to evaluate the performance of each capping program as well as the potential of the reclamation area. In 1998 the *Land Capability Classification for Forest Ecosystems in the Oil Sands Region* (Leskiw 1996) was republished and accepted for use for the evaluation of reclamation success. Since the adoption of the LCCS in 1998, reclamation material placement has been assessed the year after placement to allow sufficient time for differential settling of the soils and for high moisture levels from entrained snow to equilibrate (Syncrude 2007a). As well, since reclamation of a large area pre-dates the application of the LCCS, and was completed under varying standards, Syncrude has developed a program to audit historically reclaimed lands. Syncrude's 1998 Annual Report presented the classification of pre-existing soils and of soils developed from 1978 to 1995 (Syncrude 1999).

The assessment program is based on reclaimed soils being delineated into manageable polygons in two phases. The first phase involves the delineation of polygons prior to field data collection; this is based on the consideration of known information regarding the reclamation planning activities of an area, including source material characteristics, placement variables and landscape topography/position. The second phase consists of further delineating polygons (i.e., splitting a polygon) if a soil or landscape variation is evident during the field investigation (Syncrude 2007a).

An inspection density of one location per hectare has been established, which met accepted intensity for post-disturbance reclaimed soils that are "selectively handled" (Leskiw 1998). A minimum inspection density of 1 per every 5 ha is accompanied with a pit (hand shovel) investigation to collect soil structure and consistence information necessary for input to the LCCS. The objective of having auger inspection locations is to collect information on soil material type and capping depth. Pit investigation locations are inspected in greater detail to determine soil and landscape capability (Land Capability Class) (Table 2.4) (Syncrude 2007a).

Table 2.4. Soil and landscape information collected at each pit and/or auger location as outlined in the Canada Soil Information System (Agriculture Canada 1982).

Soil Information at Auger Locations	Soil Information at Pit Locations	Landscape Information at Pit Locations
Horizonation/soil (prescription) type or parent geological material	Primary and secondary structure	UTM co-ordinates
Depth	Consistence	Slope position
Field hand texture	Horizon Boundary	Slope type and percent
Color	Coarse fragment volume	Aspect
Presence of hydrocarbon odor	Mottles	Drainage class
Significat inclusions	Root descriptions	Primary water source
	Calcareousness	Approximate water table depth
		Key vegetation species

Soil samples within a polygon are sampled by horizon and composited across the polygon from each investigation location. Sample horizons correspond to the principle layers outlined in the LCCS manual (Leskiw 1998). If anomalies such as variable soil material type and depths are present within a polygon, additional discrete samples are collected (possibly a step-out assessment conducted).

Soil samples are characterized based on the soil chemical and physical data required to determine soil capability (Leskiw 1998). Soil samples collected are analysed for all, or a portion of, the following:

- total organic carbon (TOC), percent organic matter, total nitrogen and carbon:nitrogen (C:N) ratio
- electrical conductivity, sodium adsorption ratio, saturation percent, main soluble ions and theoretical gypsum requirement
- soil pH in water
- percent oil in soil
- soil texture or particle size and
- bulk density.

A substantial amount of "soil monitoring" that is occurring within the realm of reclamation research is applicable to the operational regime. The extent of this activity was made evident in the completion of the technology synthesis relative to "*Soil Capping Research in the Athabasca Oil Sands Region*" (Barbour et al. 2007). Numerous projects related to the main topic areas of "soil moisture", "soil salinity/sodicity" and "soil nutrients and biological response" were synthesized down to FACT SHEETS and synthesis documents with a final distillation to "key messages".

One of the studies included in the technology transfer is the "Evaluation of Long-Term Changes in Reconstructed Soils at the Operations of Syncrude Canada Ltd." conducted by the Alberta Research Council (ARC) since 1992. This program has compiled the most comprehensive long term data set for undisturbed and reconstructed soils available in the region. The emphasis has been on tracking changes in soil physical properties (volumetric water content, bulk density, infiltration rate and penetration resistance) (Plates 2.23 and 2.24), chemical properties (pH, percent saturation, EC, SAR, soluble ions and total C and N) and biological properties (microbial biomass carbon, functional diversity) of soils reconstructed using different replacement techniques compared to control or undisturbed soils (Macyk et al. 2004, Macyk et al. 2007a, Macyk et al. 2007b).

The results of the work provide "multiple lines of evidence that there is no deterioration of soil parameters with time and no major differences between natural and reclaimed sites with respect to parameters of concern" (Barbour et al. 2007). Another major study conducted by the ARC involved determining the depth of rooting and distribution of roots (Plates 2.25 and 2.26) in soil reconstructed by different soil replacement techniques compared to undisturbed soils (Macyk and Richens 2002).

Plate 2.23. Soil moisture and density measurement at Syncrude Canada Ltd.

Plate 2.24. Infiltration measurement at Syncrude Canada Ltd.

Plate 2.25. Root assessment at Syncrude Canada Ltd.

Plate 2.26. Root distribution in peat mix over tailings sand at Syncrude Canada Ltd.

The results provided evidence that:

- Rooting patterns are similar in the reconstructed and undisturbed sites.
- Rooting was not inhibited by the different soil reconstruction materials. There was no evidence at any of the sites that there was a rooting restriction between the peat and the underlying secondary or tailings sand. Similarly there was no restriction to rooting in areas where secondary material was placed over tailings sand.
- Root distribution is concentrated in the peat mix cap at reconstructed sites which is similar to distribution of roots in LFH horizons of natural soils.

Another monitoring project to provide a measure of carbon assimilation in natural and reclaimed areas and an evaluation of "ecosystem health" is currently underway. This project emphasizes measurement of soil respiration, leaf area index and biomass carbon assessments for reconstructed and control (undisturbed) soils and ecosites. Preliminary results of the work conducted to date indicate that the carbon pool is greater for all reconstructed sites with a peat mix or LFH cap than natural sites, especially "mature" natural sites that are 70 years of age or greater (Macyk et al. 2007c).

2.2.3.3 Albian Sands Energy Inc. – Muskeg River Mine

Soil monitoring is done on all areas where soil is placed at Albian Sands. Field and laboratory results are used to determine a Land Capability Class using the LCCS (Leskiw 2006).

Albian recognizes the desirable properties of both peat-mineral mixture and LFH (mixed with shallow salvage soil) soil covers. However, most of Albians' soil cover materials (peat mineral mixture or LFH) are characterized by a coarse sandy texture (i.e. sandy, sandy loam, or loamy sand), low available nutrients (i.e. available nitrogen and phosphorus are under detection limit), and quick wet dry cycles after precipitation. These factors create challenges for reclamation activities at Albian Sands' Muskeg River Mine.

To alleviate these problems, fertilization of reclaimed sites and Hydrogel application are being investigated at Albian. Fertilization and Hydrogel application may hasten nutrient release, increase growth rates of planted trees, and encourage rapid development of a vegetation ground cover (Albian 2004). Over the long term, these two treatments may accelerate reclamation and assist in achieving a pre-disturbance level of ecosystem function. However, there is a limited understanding of the impact of fertilization and Hydrogel application on the capability of reclaimed lands to support tree growth, or the effects of fertilization on the establishment of nutrient cycling in the reclaimed landscape. The objectives of the project are to:

- Determine the effects of fertilization on nutrient (nitrogen and phosphorus) cycling in a and d target ecosites (as described in Beckingham and Archibald 1996) in the early stage of land reclamation.
- Examine the effects of fertilization and Hydrogel application on tree growth in the early stage of land reclamation.

- Investigate the potential impact of fertilization on long-term land capability by assessing changes in soil properties and processes, in a way consistent with the LCCS.

A field trial was initiated in 2005 to assess the capabilities of LFH material (Albian 2006). One of the trials with 5 cm shallow stripping material over 0.05 to 0.10 or 0.15 to 0.20 m peat mineral mixture over 1 m tailing sands was evaluated. Another trial with 0.25 m stripping material over 1 m peat mineral mixture over overburden was established. These sites and the benefits for operational reclamation will continue to be assessed.

In August 2006, a study was initiated at Albian Sands to assess soil physical and chemical parameters and quality of reclamation materials being stockpiled (Albian 2007). Stockpiles of reclamation material can remain intact for ten years or more before they are used for land reclamation. There is potential that the stockpiled soil may decrease in quality due to natural degradation processes that may occur during storage. Over time, material decomposition has the potential to change soil chemical and physical parameters, but this has not been quantified to date.

2.2.3.4 Shell Canada Energy Ltd. – Jackpine Mine

The Jackpine Mine is currently under construction and therefore no reclamation or monitoring of disturbed land had occurred at the time of preparation of this document.

2.2.3.5 Canadian Natural Resources Ltd.

Soil inventory information including mapping intensity and the collection of soil data for land capability assessments will be conducted in accordance with the specifications outlined in the Alberta Environment publication *Land Capability Classification System for Forest Ecosystems in the Oil Sands Region*, 3rd Edition (Leskiw 2006).

2.2.3.6 Petro-Canada Oil Sands Inc.

Soil mapping intensity and presentation of land capability assessments will be conducted in accordance with specifications outlined in *Land Capability Classification System for Forest Ecosystems in the Oil Sands*, 3rd Edition (Leskiw 2006).

2.2.4 REVEGETATION

2.2.4.1 Herbaceous Revegetation

2.2.4.1.1 <u>Suncor Energy Inc</u>.

Early programs to establish ground cover on reclaimed areas at Suncor involved agricultural species of grass and legumes that were seeded with the primary goals of providing soil stability and limiting erosion. Temporary reclamation areas that would likely be disturbed again in the future were seeded to establish herbaceous cover for erosion control, however little initial soil preparation was performed (Klym and Shopik 1979). Seeding methods were dependent on the size and shape of the area, accessibility, and erodibility factors. Methods included hydroseeding, aerial (helicopter/bucket or fixed wing) broadcasting and hand-broadcasting (Plates 2.27 to 2.30).

Plate 2.27. Aerial broadcasting with helicopter at Suncor Energy Inc.


Plate 2.28. Fixed wing aircraft for aerial broadcasting at Suncor Energy Inc.

Plate 2.29. Hydroseeding at Suncor Energy Inc.

Plate 2.30. ATV seed broadcaster at Suncor Energy Inc.

In the late 1970s a grass-legume mixture containing a variety of agricultural grasses, alfalfa and clover was seeded at 27 kg/ha on tailings sand slopes using a Brillion grass seeder. On overburden areas, an initial nurse crop of barley was either hand or aerially seeded at 50 kg/ha, followed by hydroseeding with a slurry consisting of Silva-fibre mulch, fertilizer (17.5-16-16), barley, grasses (crested wheatgrass, pubescent wheatgrass, brome grass, creeping red fescue and tall wheatgrass) and legumes (alfalfa, alsike clover, white clover and yellow sweet clover).

Hydroseeding was conducted during the April to July period to optimize legume establishment (Suncor 1978). Although hydroseeding was effective on both new areas and previously reclaimed areas that did not perform well, problems with accessibility and access to water were encountered.

Seed mixtures remained similar through 1979 with three separate mixtures for permanent tailings and dykes slopes, permanent overburden waste dump slopes and non-permanent overburden dyke slopes (i.e., slopes not yet at their final contour). The most important criteria for selection of grass and legume mixtures, as well as appropriate application rates, were performance of previously seeded areas, soil conditions, erodibility, seed availability and seeding methods**. Research with native grasses began in the late seventies with slender wheatgrass, Canadian wildrye, rough fescue, and mana grass.**

Monitoring studies of herbaceous cover in 1979 found that brome grass was the predominant species on tailings sand slopes, while fescue and wheatgrass predominated on overburden waste dumps (Klym and Shopik 1980). Legume growth was poor on tailings sand areas, but much better on waste dumps. Vegetation performance overall was related to soil type and consistency in seed application. In particular, poor vegetation growth on tailings sand areas and overburden areas with increased sand content appeared to be due to lack of nutrients (Klym and Shopik 1979). Prior to 1979, a barley nurse crop was used on reclamation areas to establish initial cover. This practice was discontinued on all areas with the exception of temporarily reclaimed areas in 1979 to see if this would enhance woody plant establishment and native plant invasion. Withholding fertilizer was found to encourage fescue, wheatgrass and legumes in all areas, and though this caused slight decreases in productivity, cover levels remained acceptable (Klym and Shopik 1980).

By 1980, the establishment of woody plants and the invasion of native species had been added to the criteria for selecting seed mixtures and application rates (Klym 1981). At this time, legume species were eliminated from the seed mixtures for temporary reclamation areas due to poor establishment in these areas, likely due to the presence of lean oil sands (Klym 1981). Grass seed mixtures continued to be used in these temporary areas to achieve the primary objective of erosion control.

By 1982, agronomic grasses like bromegrass and legumes were eliminated from all mixes for overburden areas to reduce the vigorous competition with woody plant seedlings (Klym 1982). A 1982 study by Hardy Associates Ltd. found several trends associated with increasing age of vegetation cover on reclamation areas. Total vegetation cover on all seeded areas (both tailings and overburden) with peat-amended soil and annual fertilizer application increased to 100% or greater after two to three years. After this, living cover levels remained constant, but dead cover continued to increase for two to three years (Hardy 1982). Initially, legumes were very abundant but declined to less than 10% in successive years, while invasive native species cover (predominantly mosses) rarely exceeded 10% of total cover even after ten years.

On older reclaimed sites that had not received annual fertilizer treatment for the previous five years, the vegetation quantities were similar to the fertilized areas. However, the species composition was different, with a higher proportion of legume and native species compared to grasses. Though percentage cover levels were similar, total biomass levels were much lower on the unfertilized areas (Hardy 1982). Plots excluded from maintenance fertilizer after ten years showed increased legume and native species composition (decreased grass) with total cover remaining the same. Legume cover was found to be higher on overburden areas than tailings sand slopes, however, overall vegetation species compositions were very similar.

In 1984, to enhance seedling establishment, ground covers were altered by using lower seeding rates, non-agronomic species on tailings sand, nurse crops on overburden, lower fertilization rates and maintenance periods (Suncor 1985).

Though seed application methods were dependent upon logistics, topography and the type of seed being used, helicopter seeding was used extensively on all overburden and some tailings sand reclamation areas starting in 1985. Hydroseeding was reduced to a few small tailings sand slope areas and the coke pad (Suncor 1986). Seed application rates were reduced and seed mixes formulated to enhance establishment of woody plants and native species.

In 1985 maintenance fertilizer was applied to the reclaimed areas to further enhance plant establishment for the next two years after reclamation on overburden materials and for the next three years on tailings sand areas. Application rates for maintenance fertilizer were dependent on soil characteristics, cover performance, and objectives (Suncor 1986). In 1987 fertilizer was applied to the reclamation areas and incorporated into the substrate to a depth ranging from 0 to 15 cm depending on both the tilling equipment (harrows and klodbuster) and the depth of the amendment layer (Suncor 1988). The area was then packed with the Suncor land imprinter. The strategy was to manipulate fertilizer rates and duration of maintenance periods to optimize woody seedling survival and erosion control.

Areas seeded with agronomic species continued to be dominated by these species, even on reclamation sites over 20 years old, thus producing a very different composition of ground cover composition than in adjacent forest areas (Golder 2007). Native species were common only in areas that had not been seeded with agronomic species. By 1992, barley nurse crops were used on all permanent reclamation areas seeded by helicopter at 62 kg/ha. This was found to enhance woody seedling survival and native species invasion as well as to stabilize reclaimed areas from wind and water erosion (Suncor 1994). Following seeding, harrows were used on all new reclamation areas to provide a light soil covering for the seed. Temporary reclamation areas were hydroseeded with a grass-legume mixture at 62 kg/ha combined with barley at 124 kg/ha (Suncor 1994). Barley was applied in late spring (May). In 1996 most areas were seeded with barley with a fixed wing aircraft, although a truck and hopper were also used (Suncor 1997).

Assessments of vegetation cover on older reclamation areas showed no appreciable differences in cover levels between sites seeded with agronomic species compared to sites seeded with barley (Suncor 1994 and 1996). However, cover on agronomic sites was almost exclusively the original seeded species, whereas the areas seeded with barley showed a broad species diversity with many native herbaceous species. The component of native species increased with the age of the site (Suncor 1995).

Since 2002, areas of newly reclaimed lands have been seeded with an annual barley cover in late spring to early summer and harrowed to provide light soil cover. The seed was applied at 75 kg/ha (Suncor 2003, 2004, 2005a, 2006a, 2007a). Barley has been found to increase tree survival on reclaimed sites by providing shade and trapping moisture in the summer, especially during the critical first year of seedling establishment, and trapping snow to provide insulation from damaging winter conditions (Suncor 2005).

2.2.4.1.2 Syncrude Canada Ltd.

Initial revegetation at Syncrude involved three seed mixes used to provide cover for three broad habitat categories: dry, south facing, well drained slopes, moist to wet sites, and well drained, moist sites (Tables 2.5 to 2.7) (Langevin and Lulman 1976). Leguminous seed was pre-inoculated with nitra coat and Rhizobium bacteria to aid in establishment. Seeding was completed by helicopter and bucket on large remote areas with rough surfaces, hydroseeding on steep inaccessible areas that required mulch, and broadcasting with a cyclone seeder mounted on an ATV for small areas. Seed was incorporated into the seedbed with harrows or cultivators. Species selected were agronomic grasses and legumes and the most prominent and vigorous species in plots were assumed to be indicative of the most suitable plants for further revegetation (Langevin and Lulman 1976, Dai and Langevin 1977).

Table 2.5. Mixture for steep slopes in 1976 (dry, south facing slope, well drained sites).

Species	Percent in Mix
Crested Wheatgrass	10
Smooth Bromegrass	20
Slender Wheatgrass	15
Timothy	5
Rhizomatous Alfalfa	10
Alsike Clover	5
Hard Fescue	15
Canada Bluegrass	10
Single Cut Red Clover	10

Table 2.6. Mixture for steep slopes in 1976 (moist to wet sites).

Species	Percent in Mix
Creeping Red Fescue	5
Smooth Bromegrass	10
Timothy	5
Russian Wild-rye	15
Streambank Wheatgrass	20
Mixed Blossom Sweet Clover	5
Rhizomatous Alfalfa	15
Bird's-foot Trefoil	15
Meadow Foxtail	10

Table 2.7. Mixture for level ground in 1976 (well drained, moist sites).

Species	Percent in Mix
Creeping Red Fescue	5
Smooth Bromegrass	20
Slender Wheatgrass	20
Timothy	10
Mixed Blossom Sweet Clover	5
Rhizomatous Alfalfa	5
Bird's-foot Trefoil	10
Pubescent Wheatgrass	15
Sainfoin	10

The common species mix used for all areas included streambank wheatgrass, slender wheatgrass, timothy, Russian wildrye, mixed sweet clover and rhizomatous alfalfa (Dai and Langevin 1977). The use of sweet clover was discontinued in 1977 from most revegetation mixes, however it was still used on dry, south facing escarpments.

In 1979, materials utilized for revegetation and application techniques employed were based on site specific characteristics (Syncrude 1980). Vegetation and soil evaluations were carried out on monitoring plots established on revegetation sites. Five seed blends were developed for use in the 1979 program, which included milkvetch, and yellow alfalfa in addition to the species used previously. Subsequent seed mixes used the same species in different amounts and combinations with orchard grass and highland bentgrass being added to the list in 1981 (Syncrude 1981). Seeding rates varied among primary reclamation sites and maintenance reclamation sites. Primary reclamation sites received seed at a rate of 35 to 179 kg/ha and maintenance reclamation sites received seed at a rate of 56 to 112 kg/ha (Syncrude 1980).

Seeding of high rates of agronomic grasses led to difficulties getting woody plant species to establish, therefore seeding rates were reduced to 10 to 65 kg/ha for primary reclamation sites and 18 to 75 kg/ha for maintenance sites in 1980 (Syncrude 1981).

Seed mix composition in 1982 was based on site specific edaphic and climatic factors as well as past performance, land use and reforestation compatibility. Species included slender wheatgrass, crested wheatgrass, Russian wild rye, timothy, red clover, alfalfa, orchardgrass, smooth bromegrass, bird's-foot trefoil, creeping red fescue, Canada bluegrass, and highland bentgrass. Drill seeding (Plates 2.31 and 2.32) was performed on a trial basis in 1980 and was used extensively by 1982 (Syncrude 1982). **Drill seeding produced a more uniform vegetative cover with more vigorous plants than broadcast seeding despite seeding rates of less than 6 kg/ha (Syncrude 1982). Areas which were inaccessible were seeded aerially by helicopter at decreased rates of 11 kg/ha, as research had shown this to be sufficient to provide surface erosion protection.**

Plate 2.31. Drill seeder at Syncrude Canada Ltd.

Plate 2.32. Brillion grass seeder at Syncrude Canada Ltd.

A strip seeding project (Plate 2.33) was established in 1983 to evaluate woody plant establishment on various herbaceous cover seeding patterns. Strip seeding was conducted by seeding one strip and leaving the strip next to it unseeded. Different treatments evaluated included: a 3 m unseeded strip between two 1 m drill seeded strips of grasses and legumes; a 1 m unseeded strip between 1 m drill seeded strips; and an entire plot drill seeded. The 3 m unseeded strip between 1m drill seeded strips treatment preformed well and was subsequently used operationally on all drill seeded sites (Syncrude 1984).

Plate 2.33. Strip seeding project at Syncrude Canada Ltd.

In 1984 the objective of the revegetation program changed. The new objective was to develop a vegetative cover which provided erosion control but which did not hinder woody plant establishment and the development of methods to promote woody plant establishment (Syncrude 1984). As a result the seed mixes were reduced in the number of species and some areas were not seeded to allow native species to emerge from the reclamation materials.

From 1986 to 1989 permanent reclamation areas were not seeded, which resulted in a significant amount of erosion in some sloped areas (Syncrude 1990). Consequently, beginning in 1990 reclaimed slopes of tailings sand or overburden were seeded with an annual barley or oat crop (Plate 2.34) whereas relatively level areas were not seeded. Exceptions to this approach were the large areas of relatively level overburden and tailings sand that had been revegetated with species that provided forage for bison and temporary reclamation sites which were seeded with a mix of creeping red fescue, Canada bluegrass and red clover (Syncrude 1990).

Plate 2.34. Barley cover at Syncrude Canada Ltd.

A research project was established in 1991 to assess the feasibility of bison ranching as an end land use (Plates 2.35 and 2.36) (Syncrude 1991). The species used in the initial bison pasture seeding program included alfalfa, smooth brome, creeping red fescue, Regar meadow brome, intermediate wheatgrass, and Russian wildrye.

Annual barley was seeded aerially at a rate of 50 kg/ha into a disked and harrowed seedbed (Syncrude 1991). Application rates later dropped to 25 to 35 kg/ha and reclamation sites were harrowed after seeding for incorporation (Syncrude 1996). Revegetation with a cereal crop reduced the need for seeding of grass and legumes, thereby producing a less competitive environment for tree seedling establishment. Decreased herbaceous vegetation also reduced the amount of habitat available for rodents and consequently reduced the amount of seedling damage by rodents.

In 1993 Syncrude decided to allow areas that had been capped with reclamation material one year for settlement to ensure proper drainage control prior to revegetation (Syncrude 1994). In 1995 seeding methods changed from aerial broadcasting of the cereal nurse crop to ground broadcasting with a tractor and Herd 1200C broadcaster (Syncrude 1996). Barley was seeded on areas that were to be reforested at a future date. Seeding of perennial species occurred for permanent and temporary reclamation and included slender wheatgrass, intermediate wheatgrass, Russian wild rye, birdsfoot trefoil, alsike clover, and timothy (Syncrude 1996).

Plate 2.35. Bison pasture during the growing season at Syncrude Canada Ltd.

Plate 2.36. Bison pasture in fall at Syncrude Canada Ltd.

Operational seeding activities in 1997 varied from previous years in that there was some large scale use of native grass seed (Syncrude 1998). The native species were chosen based partially on past experience, availability, and desired properties. The native species used operationally included fringed bromegrass, Junegrass, tufted hairgrass, fowl bluegrass, and rocky mountain fescue. Awned wheatgrass and tickle grass were added to the mix in 1999 (Syncrude 2000). Subsequently, seeding rates and species mixes for revegetation remained similar (Syncrude 2001a, 2002a, 2003a, 2004a, 2005a, 2006a, 2007a).

2.2.4.1.3 Albian Sands Energy Inc. – Muskeg River Mine

Permanent revegetation of disturbed lands has only recently begun at Albian Sands, however temporary revegetation and small scale permanent revegetation has occurred. **Revegetation at the Muskeg River mine consists of broadcast seeding a variety of upland native grasses (Albian 2007a).** Species used for reclamation are listed in Tables 2.8 and 2.9.

Permanently reclaimed areas are revegetated once the soil stabilizes and seedlings become available. Narrow areas are expected to revegetate naturally from adjacent vegetation communities as well as from the roots and seed sources within the direct placement material.

Table 2.8. Custom seed Mix A used at Albian Sands (Albian 2007a).

Species	Composition (%)
Fringed bromegrass	25
Ticklegrass	15
Canada wildrye	20
Junegrass	10
Fowl bluegrass	20
Rocky mountain fescue	10

Table 2.9. Wilco Landscape Contractors Ltd. seed mix used at Albian Sands (Albian 2007a).

Species	Composition (%)
Fowl bluegrass	15
Rocky mountain fescue	12.5
Tufted hairgrass	5
Mountainview Junegrass	10
Ticklegrass	20
Walsh western wheatgrass	12.5
Canada wildrye	17.5
Perrenial ryegrass	7.5

2.2.4.1.4 Shell Canada Energy Ltd. – Jackpine Mine

No revegetation had occurred at the Jackpine Mine at the time of preparation of this document.

2.2.4.1.5 Canadian Natural Resources Ltd.

Permanent reclamation and revegetation of disturbed land has not begun on the Horizon Project, however, temporary revegetation of constructed structures and facilities has occurred (CNRL 2007). This includes roadside ditches, diversion ditches, embankments, pipeline rights-of-way and reclamation material stockpiles.

The native grass seed mixes currently approved by Alberta Sustainable Resource Development (ASRD) are shown in Tables 2.10 and 2.11. Fertilizer may be applied in areas where a cover crop is necessary. When this situation occurs, a standard N-P-K-S blend of 10-30-15-4 will be used (CNRL 2007).

Table 2.10. Seed mixes used by CNRL at the Horizon mine for temporary reclamation and winter seeding (composition %).

General Purpose Mix	Low Growing Mix	Low Growing Winter Mix
Tufted hairgrass (25)	Tufted hairgass (15)	Tufted hairgrass (15)
Awned wheatgrass (10)	Awned wheatgrass (5)	Awned wheatgrass (5)
Hairy wild rye or Canada wild rye (20)	Hairy wild rye or Canada wild rye (15)	Hairy wild rye or Canada wild rye (15)
June grass (25)	June grass (25)	June grass (25)
Fowl bluegrass (20)	Fringed bromegrass (20)	Fringed bromegrass (15)
	Fowl bluegrass (20)	Fowl bluegrass (15)
		Cover crop – perennial common ryegrass (10)

Table 2.11. Seed mix for the permanent water intake road and utilities corridor.

Species	Composition (%)
Awned wheatgrass	30
Mountain bromegrass	25
Sheep fescue	25
Fringed bromegrass	5
Fowl bluegrass	5
Tufted hairgrass	5
Streambank wheatgrass	5

2.2.4.1.6 Petro-Canada Oil Sands Inc.

Revegetation will not commence for several years at the Fort Hills Project, as per the Conservation and Reclamation Plan (Leskiw 2007). When reclaimed soils are ready for revegetation, either LFH transplant material will be applied, or shrubs will be planted in accordance with revegetation guidelines (currently being revised).

2.2.4.2 Trees and Shrubs

2.2.4.2.1 Suncor Energy Inc.

Early tree planting attempts on reclamation areas in the 1970s were mainly experimental. Many of the planting programs were focused on determining which tree species would grow best in the reclamation soil medium, and a wide variety of both non-native and native tree species were used (Shopik 1976). Species included Manitoba maple, caragana, Russian olive, acute willow, basford willow, laurel willow, mixed willow species, Canadian buffaloberry, Siberian elm, green ash, poplar and American elm (Klym and Shopik 1979, Golder 2007).

Early ground penetration methods for reclamation areas receiving seedling stock involved breaking the sod to a depth of 0.15 to 0.20 m to reduce vegetative competition from existing cover species. Difficulties were encountered with this method, such as poor planting medium leading to root desiccation and reduced survival.

Bareroot seedling stock was acquired from the federal tree nursery at Indian Head, Saskatchewan or the Provincial tree nursery at Oliver, Alberta in early spring. The stock was stored in trenches lined with frozen peat and covered with plywood and spruce boughs until late May or early June when it was hand-planted using a 2 by 2 m spacing grid, yielding about 2,200 stems/ha. Overburden areas were then hydroseeded following planting. Early problems included low survival of small seedlings leading to recommendations to use older planting stock for the future (Shopik 1976).

Observations in 1978 indicated that tree planting without establishment of herbaceous ground cover was a viable planting method despite increased potential for soil erosion. This method resulted in reduced competition for nutrients and water between woody and herbaceous species and reduced levels of rodent damage (Plate 2.37) on seedlings as no cover habitat was available (Klym and Shopik 1979).

Plate 2.37. Girdling of woody species at Suncor Energy Inc.

The objectives of the program for 1979 included both the operational stocking of reclaimed areas as well as the evaluation of outplanting methods, species and propagation techniques. Based on this, a variety of seedlings and cuttings were planted on various reclaimed sites on the lease. “Fill in” stock was also planted in poor-performing older reclamation areas (Klym and Shopik 1980).

Trials were conducted at this time to determine the establishment of stock in areas of dense cover (well established cover older than two years) versus minimal or sparse cover less than two years of age on both tailings sand dyke and overburden dump areas. **It was found that reducing the grass-legume cover greatly increased seedling survival, and as a result the application of agronomic (grass-legume) ground cover to overburden waste dump slopes was discontinued in 1980 to encourage establishment of woody species and invasion of native plants (Klym and Shopik 1980).** A nurse cover was applied to these areas for initial erosion protection.

Difficulties were encountered in the use of wild seedlings to establish native shrub species (e.g. raspberry and alder) and the use of larger, containerized stock was recommended. By 1980, most planting stock consisted of seedlings reared from seeds and cuttings collected in Fort McMurray oil sands areas (Klym 1981).

The objectives of the program in 1981 were to return disturbed land to wildlife habitat and aid in species selection for future reclamation programs (Klym 1982). Trees were planted in an offset grid pattern (Plate 2.38) to eliminate downslope rows and reduce the potential for erosion. Reduced seedling survival due to drought conditions was noted in 1981. The highest survival rates were in overburden areas with sparse cover (Plate 2.39) (Klym 1982).

Plate 2.38. Trees planted in an offset grid pattern at Suncor Energy Inc.

Plate 2.39. Trees growing with minimal herbaceous cover at Suncor Energy Inc.

By 1983, species used in the afforestation program included: pine, white spruce, tamarack, hybrid poplar, paper birch, shrubby cinquefoil, chokecherry, rose, raspberry, buffaloberry, blueberry, silverberry, dogwood, saskatoon, willow and alder (Suncor 1984). Species survival was increased when trees were planted in the period with the highest precipitation. Seedling stock was reared by several companies over the years from seed and cuttings collected around the Fort McMurray area.

In 1983, only a nurse crop of annual barley was seeded where seedlings were being planted (Plate 2.40). Based on the results of afforestation assessments and lysimeter studies the time of planting was changed from spring to fall planting to further enhance survival rates (Suncor 1984).

Plate 2.40. Seedling planted in a barley nurse crop.

In 1985, a comparative assessment was done on seedling survival between stock planted in previous years, and for stock planted in different types of soil and ground cover compositions (Suncor 1986). Seedlings planted in 1984 showed good growth rates and increased stocking densities due to the establishment of ‘volunteer’ shrub species (e.g., raspberry, bog birch and cinquefoil). For 1983 plantings, seedling survival was low in areas with dense vegetation cover. Seedlings planted in barley had the highest survival and growth rates, with those in agronomic grass-legume and native grasses showing similar results for most species. Poplar showed higher survival in the native grass mix, while green alder, bearberry, and chokecherry had 100% greater growth rates in agronomic grass cover areas with fertilizer application (Suncor 1986). For 1982 plantings, poplar, chokecherry and rose had the highest survival in reclaimed overburden areas, while dogwood, white spruce, and poplar had the highest survival in tailings sand areas. For areas replanted in 1981, jack pine, lodgepole pine, walker poplar and chokecherry showed the highest survival in overburden areas, while saskatoon, paper birch, shrubby cinquefoil and dogwood had the highest survival rates in tailings sand (Suncor 1986).

For the 1990 program, species consisted of white spruce (one and two year old seedlings), poplar, lodgepole pine, saskatoon, wild rose, raspberry and willow (Suncor

1991). As a trial in fall 1990, three year old white spruce with top growth >46 cm were planted in areas with herbaceous cover competition too dense for small seedling survival. Poplar and willow cuttings were inserted into the soil in reclaimed areas to quantify the potential for this technique to be incorporated into future afforestation programs.

In 1991, the species used were reduced to white spruce, pine, poplar and dogwood (Suncor 1992). In 1992, species included white spruce, lodgepole pine, poplar, dogwood, gooseberry and raspberry. Another trial with three year old spruce seedlings with spring planting as opposed to fall was established (Suncor 1993).

In September 1992, Suncor began to use the Alberta forest service establishment survey as criteria for assessing reclaimed land that could develop into merchantable timber stands. The success of tree planting on reclaimed areas in producing a forest composition suitable for the forest industry was evaluated (Suncor 1993). Species used for afforestation on overburden areas included white spruce, jack and lodgepole pine, poplar, rose, willow, dogwood, saskatoon, bogbirch and raspberry. Species used for tailings sand areas included jackpine, lodgepole pine, poplar and willow (Suncor 1993).

In 1993, larger sized spruce seedlings reared in 1 gallon (4.4 L) containers and 1+1 bareroot stock were obtained for outplanting in areas where tree survival had been marginal due to competition from the dense agronomic grass cover (Suncor 1994).

In 1994, a plug/transplant (1+1) became the preferred stock for fill-in planting application (Suncor 1995). Changes in the planting program were made due to the high level of survival of the plug/transplant (1+1) seedlings combined with the high cost of the gallon sized container seedlings. Seedlings grown in styroblock 415B containers were also used for fill in planting, although not in areas with dense grass mats on older reclamation sites.

A tree rooting study was initiated in 1994 to examine the influence of the underlying parent material on root system development for trees planted on reclamation sites (Suncor 1995). Lodgepole pine, white spurce and balsam poplar were all shown to exhibit adequate root systems on reclaimed tailings sand and overburden areas, though the white spruce trees showed lower tree height and increased root mass on tailings sand compared to overburden and undisturbed areas.

The programs for 1995 to 2000 saw minor changes which were related to supplier of the seedlings.

Slope aspect was found to influence cover density values, with the highest ground cover and tree densities found on the northeast slopes and lowest on the south facing slopes (AGRA 1996). It was difficult to assess the influences of site characteristics other than slope aspect due to changes in reclamation materials and methods over time. In 1995, older reclamation areas showed pine dominated communities on north to east aspect slopes of Tar Island Dyke with poplar dominated stands on the east to southeast orientations (AGRA 1996). Substantial areas of sparse tree cover existed, and overall tree cover was much less dense (300 to 900 stems/ha in areas seeded with agronomic ground cover; 1,500 to 3,000 stems /ha in nonseeded areas) than in adjacent natural mixed wood forest stands (4,000 to 5,000 stems/ha). Overall, grasses and legumes provided the majority (50 to 100%) of the vegetative cover on Suncor's reclamation areas, with tree cover only 10% on seeded areas and 20 to 30% on unseeded areas; whereas cover on natural areas was mainly provided by trees (55 to 90%) (AGRA 1996). Shrub communities were uncommon except for willow stands around seepage points and caragana in several locations (AGRA 1996).

In 2001, the afforestation program used a species mix and density suitable for developing a d2 (lowbush cranberry, aspen-white spruce) or d3 (low-bush cranberry, white spruce) ecosite phase plant community on all reclamation areas that had tree planting (Suncor 2002). Seedlings were planted by contractors in mid to late July and consisted of white spruce, aspen, balsam poplar, white birch, Saskatoon, pincherry, alder, rose and blueberry. A variety of native seeds were collected from previously reclaimed sites at Suncor or from the Fort McMurray area, to propagate the tree and shrub seedlings for future programs (Suncor 2003, 2004, 2005a, 2006, 2007a). The first successful germination of low-bush cranberry was achieved in 2002 which was expected to be useful for future planting programs to make up for shortcomings in shrub availability (Suncor 2003).

The sources of seedlings and planting schedules remained the same for 2002 to 2006, however a slightly different species mix was used each year:

- 2003 White spruce, (412 B and 1+1) jack pine (412B) aspen (615A) white birch(415D) dog wood (415D) low-bush cranberry (415D) rose (415D) alder (415D) blueberry (412) (Suncor 2004)
- 2004 Barley, white spruce, aspen, white birch, low-bush cranberry, pincherry, Saskatoon, choke cherry, alder, blueberry (Suncor 2005a)
- 2005 White spruce, aspen, jack pine, white birch, buffaloberry, low-bush cranberry, pincherry, black currant, gooseberry, saskatoon, chokecherry, rose, alder, blueberry (Suncor 2006)
- 2006 Same as 2005 with the addition of beaked hazelnut as a shrub species (Suncor 2007a).

2.2.4.2.2 Syncrude Canada Ltd.

Reforestation at Syncrude began in 1977 with the goal of establishing a permanent self-supporting and maintenance free plant community (Dai and Langevin 1977). In the first year 22,000 nursery seedlings and 24,000 willow cuttings were obtained as bareroot stock from the Prairie Farm Rehabilitation Administration Nursery (Indian Head, Sask) and Oliver Provincial Tree Nursery (Oliver, AB). Seedling species included Manitoba maple, walker poplar, vernirubens poplar, American elm, Siberian elm, balsam poplar, and caragana. Nursery seedlings were treated with fungicide to control mold and willows were treated with rooting hormone to improve root development. Seedlings were planted 2.0 m apart in parallel rows 1.0 m apart and offset half-way between planting locations of the previous row to prevent erosion. Seedlings were planted using

Swedish tree planting mattocks or drain spades at a density of approximately 8,650 stems/ha (Dai and Langevin 1977).

The primary objective of the native plant propagation study initiated in 1977 was to determine techniques for propagation of trees and shrubs native to the Fort McMurray area which had potential for Syncrude's reclamation program (Dai and Langevin 1977). Species in the program included green alder, saskatoon, common bearberry, bog birch, red-osier dogwood, wolf-willow (silver berry), shrubby cinquefoil, pin cherry, choke cherry, common rose, prickly rose, willow, Canada buffaloberry, snowberry, blueberry and lowbush cranberry. Research into the propagation of these species involved both the vegetative and seed aspects (Syncrude 1980).

Problems with seedling establishment were recognized in 1978 and ameliorative measures were assessed (Syncrude 1978). These methods included use of herbicide, cultivation and use of larger planting stock. Species used for reforestation included white spruce, basford willow, caragana, sandbar willow, balsam poplar, jackpine, trembling aspen, lodgepole pine, paper birch, speckled alder, snowberry, shrubby cinquefoil, green alder, low-bush cranberry, and red-osier dogwood. Northwest poplar, chokecherry, Siberian larch, bur oak and green ash were added to the program in 1980 (Syncrude 1981).

The first large scale reforestation program began in 1980 when 92,000 tree and shrub seedlings were planted (Syncrude 1981). All seedlings were raised in the Syncrude greenhouse (Plate 2.41) in Spender-Lemaire Hillson containers and included white spruce, jack pine, trembling aspen, green alder, saskatoon (Plate 2.41), caragana (Plate 2.41) and red-osier dogwood (Plate 2.41). Areas being planted were first scarified using a Kello-bilt deep tillage subsoiler (Plates 2.42 and 2.43) or Kello-Bilt deep plow (Syncrude 1981). Tree and shrub planting was carried out manually by contractors with shovels at a planting density of 5,000 stems/ha. No two adjacent rows contained the same species (Plates 2.44 to 2.46). In 1982 silverberry (Plate 2.47) and buffaloberry were added to the species being grown in the Syncrude greenhouse for reforestation and white birch, sea buckthorn, tamarack, black spruce and willow were obtained from outside sources for planting in spring (Syncrude 1982). Species with relatively good survival included jackpine, prickly rose, saskatoon, and chokecherry. Different container sizes were also evaluated in terms of seedling survival (Plate 2.48) (Syncrude 1982).

a)

b)

c)

d)

Plate 2.41. a) Syncrude greenhouse b) Saskatoon propagation c) Caragana at Syncrude Canada Ltd. d) Red-osier dogwood propagation.

Plate 2.42. Kello-built deep tillage subsoiler at Syncrude Canada Ltd.

Plate 2.43. Soil surface after deep tillage at Syncrude Canada Ltd.

Plate 2.44. Rows of dogwood and jack pine at Syncrude Canada Ltd. ten years after planting.

Plate 2.45. Rows of dogwood and jack pine at Syncrude Canada Ltd. twenty years after planting.

Plate 2.46. Rows of aspen and white spruce at Syncrude Canada Ltd. twenty years after planting.

Plate 2.47. Silverberry propagation.

Plate 2.48. Seedlings grown in different container sizes at Syncrude Canada Ltd.

Seed collection was ongoing for various tree and shrub species including saskatoon, trembling aspen, pin cherry, red-osier dogwood, white spruce and buffalo berry and was conducted annually to provide sufficient propagules for desired greenhouse production.

Small mammal (mostly meadow vole) girdling caused poor seedling survival therefore various methods including rodenticides, repellents, supplementary feed,

and reduction of non-woody plant cover were used to reduce rodent populations. None of these methods proved to be effective. Vexar seedling protectors (Plate 2.49) were evaluated and found to decrease mortality rates, however were never used operationally (Syncrude 1985, 1986, 1987, and 1988).

Plate 2.49. Vexar seedling protector used at Syncrude Canada Ltd.

The strip seeding project which was designed to evaluate woody plant survival on various herbaceous cover seeding patterns demonstrated that jackpine and green alder survival was highest on plots with no herbaceous cover (Plate 2.50) (Syncrude 1986). Subsequently, a pre-planting herbicide project was established to test the use of Afolan F and glyphosate to create a 2 m wide vegetation free strip in the ground cover where woody plants could be seeded. Glyphosate resulted in lower vegetation cover and thus better seedling survival, although agronomic grass species quickly invaded the area (Syncrude 1986).

Plate 2.50. Seedling grown in strip with no herbaceous vegetation at Syncrude Canada Ltd.

Seedling production was contracted out in 1992. The only seedlings grown in the Syncrude greenhouse by 1994 were for research purposes (Syncrude 1995). Planting densities in 1992 were reduced to 2000 stems/ha and species consisted mainly of white spruce and trembling aspen planted in a 1:1 ratio (Syncrude 1993). There was both a spring and fall planting due to supply. Spring planting consisted of aspen, spruce and larch and fall planting consisted of pine, aspen, spruce and larch. Siberian larch (Plate 2.51) was planted in separate blocks and not mixed with other species. Willow cuttings and willow wattles (interwoven twigs) were planted on slopes severely affected by water erosion.

Plate 2.51. Siberian larch planted at Syncrude Canada Ltd.

Hybrid poplar (Plate 2.52) was evaluated as a tree species for land reclamation in 1993 (Syncrude 1994). **In 1995 multiple end land uses, such as agro-forestry, where the land supports grazing ungulates during the early stages of the forest rotation cycle was tested. White spruce seedlings were planted one year before grazing commenced. This was found to be an ineffective land management strategy after only one year (Syncrude 1996).**

Plate 2.52. Hybrid poplar at Syncrude Canada Ltd.

Since the early 1990's, reforestation of permanent reclamation sites has been carried out over a two to three year period after surface preparation (Syncrude 2006e). A short lived agronomic species such as barley is sown in the first year to assist with erosion control, provide shade for moisture retention, and assist in trapping snow for improved moisture conditions the following year. In year two, naturally invading annual plants carry on functions of the barley crop. Planting of tree seedlings is normally done in the second or third year with the species determined by factors such as availability, reclaimed site characteristics and regulatory expectations.

Tree species such as jack pine, aspen and white spruce and shrubs such as willow and dogwood are planted with species selection dependent on the topography and ecosite conditions of the newly reclaimed areas. In general, southerly facing slopes are planted with jack pine and northerly exposures with white spruce and aspen (Syncrude 2006e).

The shrub planting program was implemented in 2000 to provide the necessary plant biodiversity throughout several areas, and help with the establishment of various ecosites on reclaimed lands. Shrubs also provide shade for white spruce and are beneficial food and shelter requirements for a variety of wildlife species. In 2001 there were 3 species of shrubs planted including green alder, Labrador tea, and common blueberry. Alberta Nurseries and Seed Ltd. provided the shrub species. Initially problems were encountered controlling the densities and locations of shrubs planted but were worked out in upcoming planting seasons. Pincherry, common wild rose, and prickly rose have since been added to the shrubs being planted.

The goal of Syncrude's reforestation program in 2003 was to provide a functionally sustainable forested ecosystem. Accomplishing this goal required an understanding of the complexity specific to reclaimed sites and their succession through ensuing vegetation communities. Thus, the assessment for the 2003 tree plant resulted in identification of a variety of potential ecosites. The ecosites prescription resulted from interpretation of the localized moisture and nutrient regimes as presented in the Forest Soils Capability Manual (LCCS; Leskiw 1998).

Species selection since 2003 has been dependent on topography, slope position, aspect, nutrient regime, and the texture of the underlying materials. Planting is conducted to best match the species composition of the ecosite existing in similar conditions on natural landforms (Syncrude 2006e). Species composition is designed to accelerate the process of natural succession towards desired vegetation types (ecosites). The microenvironments change as woody cover develops on a reclamation area, providing favourable conditions for successional species. The planting program is designed to ensure that the plant species that are capable of taking advantage of these conditions are present. Four to six species are typically planted to supplement the natural processes of woody plant establishment. The planting prescription is typically 2,000 stems/ha of trees and 500 stems/ha of shrubs (Syncrude 2006e). Planting is usually done in the fall when the stock is dormant and less prone to physical stress and able to take advantage of spring melt water, although spring planting has been successful in the past (Syncrude 2006e).

Seed sources for some of the shrub species are not available and the development of commercial supplies of these species are currently being developed. The shrubs that continue to be of interest for planting are pincherry and chokecherry, low bush cranberry, saskatoon, prickly rose, red-osier dogwood, green alder, buffaloberry, and blueberry.

Syncrude maintains a seed collection program that follows provincial guidelines drafted in 2003. Seed is collected within the central mixedwood sub region of the boreal forest natural region. Timing and quantity of seed collected is based on inventories and forecasted planting plans. Optimal time for harvesting cones, catkins and/or berries varies among species.

2.2.4.2.3 Albian Sands Energy Inc. – Muskeg River Mine

Permanent revegetation efforts undertaken in 2006 consisted of interplanting shrubs and trees on existing reclamation areas (Albian 2007a). Common blueberry, bog cranberry and jack pine were planted on the Shallow Stripping Material Test Area. White spruce and trembling aspen were also planted.

Albians' revegetation program involves planting mature trees (white spruce, trembling aspen and jackpine) in the spring in clusters and shrubs (buffaloberry, dogwood, pin cherry, bog cranberry, blueberry and alder) randomly between trees. Transplanting vegetation from surrounding areas to bare reclamation sites enhances the rate and diversity of revegetation. Cattails were transplanted into low, wet areas and forest floor island transplants were established on upland areas (Albian 2007a).

The white spruce and Aspen seedlings were obtained from overstock at Smoky Lake Nursery from seed collected from the Fort McMurray area. Green alder and prickly rose seedlings were also planted from seed collected in 2000 on the Muskeg River Mine site (Albian 2004).

Common bearberry and paper birch seeds were collected in 2003 (Albian 2004). Buffaloberry, common bearberry, common blueberry, bog cranberry, low bush-cranberry, choke cherry, bunchberry, green alder and jackpine were collected in 2006 (Albian 2007a). Seeds were shipped to growers for treatment, registration, storage and subsequent seedling production for use at Albian Sands.

2.2.4.2.4 Shell Canada Energy Ltd. – Jackpine Mine

No trees or shrubs have been planted at this stage of development at the Jackpine Mine.

2.2.4.2.5 Canadian Natural Resources Ltd.

No trees or shrubs have been planted at this stage of development at the Horizon Project.

2.2.4.2.6 Petro-Canada Oil Sands Inc.

No trees or shrubs have been planted at this stage of development at the Fort Hills Project.

2.2.4.3 Revegetation Monitoring

2.2.4.3.1 Suncor Energy Inc.

Suncor uses two monitoring programs for assessing the survival, growth and performance of woody stemmed vegetation on reclaimed sites (Suncor 2004). **The primary monitoring program (vegetation assessments) is used to assess reclaimed areas from a period of one to four years after the initial tree planting has been completed.**

Planted and non-planted (ingress) woody stemmed species are evaluated. For reclaimed sites that are performing less than favourably management treatment plans such as fill-in planting are implemented. Reclaimed areas expected to develop into a merchantable forest stand are to have 1,200 stems/ha at the end of the assessment period (Suncor 2004).

The second monitoring and assessment procedure is the regeneration establishment survey, which is conducted on all reclaimed areas (Suncor 2004). It is completed on reclamation sites four to eight years after harvesting for coniferous, coniferous-deciduous and deciduous-coniferous sites and three to five years for deciduous sites. The Alberta Land and Forest regeneration surveys are used to determine how effective the reclamation operations are in producing a forest species composition which meets the criteria set for the forest industry (Suncor 2004). Reclaimed sites that do not meet a total stocking percentage of greater than 80% are scheduled for fill-in planting to increase the level of stocking (Suncor 2004). This is important in assessing the performance of reclamation areas against an accepted standard. Other woody stemmed species in the plot are also noted to help illustrate the diversity of woody stemmed plants found on the reclamation sites.

Suncor has completed assessments of trends in vegetation cover on an annual basis. The information provided below is based on a summary completed in 2003 (Suncor 2004).

Long-term vegetation trends for tailings sand sites seeded with grasses and legumes:

- Percent cover of seeded grasses and legumes has fluctuated from year to year between 20 and 130%, but over the entire monitoring period cover has been greater than that of native grasses and forbs.
- Dominant grass species were fescue followed by brome.
- Over time, legume cover has varied among sites, but has generally followed similar patterns characterized by an increase after reclamation, a subsequent decline and then again a trend of increasing growth (legume cover typically less than grass cover).
- Alfalfa and sweet clover are dominant legumes.
- Patterns of cover of native invading grasses and forbs and planted trees and shrubs have been consistently low, although tree cover appears to be exhibiting an increasing trend over the past 10 years which may be a reflection of successful in-fill tree planting.
- Total living cover at all sites has increased over time (Suncor 2004).

Long-term trends for tailings sand sites seeded to barley:

- Percent cover of native grasses and forbs in the older sites increased rapidly when the sites were young and being colonized by weedy species, but subsequently declined and more recently appears to have levelled off.
- Early fluctuations in cover may be related to fluctuations in precipitation and temperature, and may also be related to wind-blown sand from adjacent tailings sand deposits covering emerging vegetation.

- Percent cover in more recently reclaimed sites (1997-2000) exhibited similar trends of rapid increase when the sites were young and also subsequently declined.
- In 2003, native grasses and forbs comprised between 10 and 60% cover in the older sites and between 30 and 60% cover at the newer sites (Suncor 2004).
- The dominant species are strawberry, sow thistle, and dandelion in the older sites and sow thistle, pigweed, wild barley, and fireweed in the newer sites.
- Grasses and legumes, which may have invaded from other locations where they were seeded appears to be exhibiting an increasing trend.
- In 2003, seeded grass and legume cover in the older sites was between 15 and 45% while cover in the newer sites ranged between 35 and 70% and was dominated by sweet clover.
- Shrub cover has remained consistent at levels less than 10% while tree cover in the older sites has experienced an increase in the 5 years prior to 2003.
- Total living vascular cover has generally reflected native grass and forb cover and litter cover has increased over time.

Long term vegetation trends for overburden sites seeded to grasses and legumes:

- Percent cover of grasses has fluctuated from year to year, but has increased slightly from the 30 to 60 % range in 1998 to the 40 to 100% range in 2003.
- Creeping red fescue, brome and alfalfa were the dominant seeded grasses and legume species present in 2003.
- Shrubs have provided minimal cover with virtually no variability over the entire 27 year monitoring period, while tree cover was similarly low until 1998 and has subsequently increased at selected sites which may be due to in-filling programs.
- Due to limited invasion of native grasses and forbs at these sites until recently, trends in total living cover reflect primarily the seeded grass and legume cover.
- Percent litter cover has increased at all sites over time and has stabilized around 90%.
- Total cover ranged from 193 to 267% and most cover was provided by living vegetation (Suncor 2004).

Long term vegetation trends for overburden sites seeded to barley:

- These sites have experienced similar trends to sites seeded to grasses and legumes (Suncor 2004).
- Typically native grasses and forbs have rapidly colonized the sites and have had the largest increase in percent cover following reclamation. This trend is followed by an increase in the invasion of seeded grasses and legumes from nearby seeded sites.
- The dominant native species at these sites in 2003 were sow thistle and fireweed with lesser amounts of strawberry and sedge (Suncor 2004).
- Dominant invading grass and legume species include wheatgrass, bluegrass, sweet clover and alfalfa.

- Shrub cover increased initially and then appears to have stabilized since the early 1990s with some sites experiencing minimal cover and others with shrub cover in the 20 to 40% range.
- Tree cover has increased substantially at all sites since the 1990s and now ranges between 10 and 100%.
- Litter, total vascular and total cover followed similar trends of increases in cover, followed by a period of stabilized values and more recently increases at all sites.
- Cover data for the younger sites showed a stable or slightly decreasing trend in the cover of native grasses and forbs, as well as shrubs. Invasion of seeded grasses and legumes from adjacent sites as well as tree cover have contributed to an increasing trend since the mid 1990s. The dominant native grass and forb species in 2003 were sow thistle, fireweed and reedgrass (Suncor 2004). Dominant invading grass and legume species included bluegrass and sweetclover. Litter cover in 2003 ranged from 40 to 90% and the range of cover values for total living vascular cover was similar to older sites at 60 to 170% (Suncor 2004).

2.2.4.3.2 Syncrude Canada Ltd.

Syncrude's monitoring program is aimed at documenting the effectiveness of operations within the reclaimed environment including changes and trends over time for comparison against biological and regulatory standards. This program has been ongoing since 1977 (Syncrude 2006e).

Twenty five "permanent plots" were established in revegetation areas to monitor species composition, percent cover, and biomass by 1978 (Syncrude 1980). The most vigorous species in the plots were smooth brome, followed by slender wheatgrass, Canada bluegrass, timothy and sweet clover. As a result of monitoring, sweet clover was removed from the revegetation program due to its weedy characteristics. It was determined that areas reclaimed with grasses and legumes were difficult to get shrubs and trees to establish. Tree and shrub survival was greater in treatments which were ploughed (likely due to the mitigating effect of ploughing on rodent damage) before planting and this practice was adopted operationally in 1981 (Syncrude 1981). Herbicides were required as a supplementary vegetation control technique because grasses recovered quickly.

Woody plant species which had shown the best survival by 1980 included saskatoon, trembling aspen, shrubby cinquefoil, and lodgepole pine. Native herbaceous species were found on reclaimed areas, however their percent cover was low and there were very few species.

In 1981 evaluations of seeding techniques, rates and fertilizer rates for controlling density and species composition of ground cover on tailings sand dykes was initiated (Syncrude 1982). Results showed that grasses became less abundant when fertilizer was discontinued and native species colonization was occurring very slowly. Low lying, wetter areas were more favourable for both native herbaceous vegetation and woody species. Common species found in these areas included willow, aspen, balsam poplar and prickly rose. This research led to the following changes in operational reclamation practices (Syncrude 1982):

- decreased seeding rates of agronomic grasses and legumes
- elimination of smooth brome grass from most seed mixtures
- reduced initial fertilization rates and
- earlier termination of maintenance fertilization.

Smooth brome continued to be the dominant grass species in the monitoring plots in 1982 followed by slender wheatgrass, creeping red fescue, alfalfa and sweet clover (Syncrude 1982). Small mammal girdling was causing poor tree and shrub survival therefore various methods of rodent control were investigated. The only effective method determined was the elimination of a dense vegetative cover to reduce their habitat and food supply.

Monitoring showed that successful establishment of woody plants on reclaimed areas depended on the type and condition of planting stock, planting time, planting quality, and site and weather conditions at the time of planting. Sizes of planting stock and planting time were evaluated. As a result larger tree seedlings grown in larger containers and fall planting became the standard reforestation practices at Syncrude (Syncrude 1991).

In 1991 monitoring of areas previously amended with 50 cm of regolith material were showing problems with soil moisture, revegetation and woody seedling survival; a new methodology was therefore explored by testing the placement of 10 cm of muskeg topdressing in areas deemed deficient in organic matter (Syncrude 1992). Operational practices subsequently changed with respect to soil prescriptions.

Evaluating the suitability of native grasses for erosion control and co-establishment with woody species began in 1993 (Syncrude 1994). Native species replaced agronomic grasses for initial ground cover on reclaimed sites based on this initial evaluation.

Because of the amount of time required to produce productive forest stands, several of the programs which were initiated as research programs are currently maintained as long term monitoring projects and data is collected on the plots intermittently. Seedling plantations are assessed one year after planting and then at five year intervals. During summer, numerous permanent assessment plots (20 m x 20 m) established at the time of planting are used to assess tree growth, survival, and ingress into planted areas. In addition, the provincial regeneration survey is also completed as a means of ensuring reforestation success by meeting Alberta’s regeneration standards.

Beginning in 2000 the Alberta Research Council began evaluations of the carbon storage of the various reclamation scenarios at Syncrude. This work indicates that substantial storage occurs in areas with grasses, legumes and other herbaceous species. Alfalfa has demonstrated the highest sequestration rates of all species (native and non-native), while buffaloberry, had the highest CO_2 sequestration rate of all native species assessed (Macyk and Faught 2002). The ARC also continues to monitor plots established in 1993 to evaluate selected grass cultivars for co-establishment with trees and shrubs (Macyk 1998). They also continue to monitor plots established in 1997 to evaluate the suitability of commercially available native grasses and legumes for revegetation (Macyk 2006).

Following a very successful LFH demonstration program, in 2004 Syncrude commenced a comprehensive research project with the University of Alberta to look at seed banks, optimal placement depths and handling techniques (e.g. storage, islands) for their upland LFH resource (Syncrude 2006e). Albian Sands, Suncor and CNRL joined the research program in 2005 to look at the use of LFH to re-establish a and b ecosites. In 2006 the study was further expanded to include an LFH stockpile study.

In 2006, Syncrude was joined by Suncor, CNRL, Albian Sands, Imperial Oil and Petro-Canada in continuing the existing long-term research and development program addressing propagation techniques for native species of concern to local communities with Wild Rose Consulting (Syncrude 2006e).

2.2.4.3.3 Albian Sands Energy Inc. – Muskeg River Mine

Vegetation monitoring at Albian Sands includes tree height measurements and root collar diameter measurements for each species planted, overall vegetation cover by species and vegetation type and species composition (Albian 2007a).

The reclamation research areas established in 2005 had more species initially than other plots in their first year of monitoring (Albian 2006). As well, the plot with the thicker placement depth of peat/mineral layer at the Shallow Stripping Material Test site had a higher number of species established (Albian 2006). Initial tree root collar diameter and height were measured one week after planting. Albian will continue to monitor species composition and tree growth in the future.

Tree growth (height and diameter) was also measured at reclamation areas planted before 2006 and was found to have increased for both white spruce and trembling aspen (Albian 2007a).

Albian has initiated a study to examine the potential use of brush/slash mulch material as a source of nutrients, native seed, and erosion prevention amendment (Albian 2006). Traditionally, oilsands companies have employed a combination of brush piling and subsequent burning to remove these brush materials following tree removal. The objectives of this study are to:

- Compare and contrast the techniques of mulching with slash vs. simulated slash piling with subsequent burning.
- Characterize the impacts of mulch on soil properties and potential for suitable reclamation material.
- Quantify the effect of mulching on seed viability within slash piles and within surface soil material.

2.2.4.3.4 Shell Canada Energy Ltd. – Jackpine Mine

No revegetation monitoring has been conducted at the Jackpine Mine due to the stage of development.

2.2.4.3.5 Canadian Natural Resources Ltd.

No revegetation monitoring has been conducted at the Horizon Project due to the stage of development.

2.2.4.3.6 Petro-Canada Oil Sands Inc.

No revegetation monitoring has been conducted at the Fort Hills Project due to the stage of development.

2.2.5 FERTILIZATION

2.2.5.1 Suncor Energy Inc.

Early fertilizer regimes at Suncor were based on the maintenance of grass and legume covers used to prevent erosion on reclamation areas. Fertilization methods have evolved over the years and have included hand broadcasting, hydroseeding and aerial broadcasting (using helicopters or fixed-wing aircraft). The choice of method was dependent on economic as well as logistical factors such as the size and accessibility of the area to be fertilized (Golder 2007).

In 1977, newly reclaimed overburden areas received starter applications of fertilizer (14-14-7) at 112 kg/ha, and were klodbusted in order to work the fertilizer into the seedbed (Shopik and Klym 1978). Tailings sand areas received starter applications of fertilizer (17.5-16-16) at 112 kg/ha. Maintenance programs on previously reclaimed areas consisted of aerial applications of fertilizer at 673 kg/ha for tailings sand and overburden areas. Aerial application was found to be effective for large areas, but it was difficult to achieve the desired application rate on smaller sites.

Starting in 1978, starter fertilizer was applied in two stages during the first growing season on both tailings sand and overburden reclamation areas. A fertilizer blend with low nitrogen content relative to phosphorus and potassium (6-24-24) was applied and incorporated prior to seeding, and a nitrogen fertilizer (34-0-0) was applied later in the season. The rate of fertilizer application depended on criteria including cover objectives, soil test results, and the growth and condition of the plants. Soil analyses resulted in fertilizer rates being reduced in half by 1978 (Klym and Shopik 1979).

Starting in 1981, application of maintenance fertilizer was discontinued for reclaimed overburden sites older than three growing seasons and tailings sand sites older than five growing seasons based on results from soil and vegetation analyses and monitoring (Klym 1982).

The preferred method of fertilizer application in 1985 was aerial broadcasting by helicopter when the size and shape of the area allowed it. Fertilizer was incorporated into the substrate where possible, in two applications (Suncor 1986). The first application was applied in early summer using 6-24-24 at 350 kg/ha on tailings sand and 10-30-10 at 300 kg/ha on overburden areas. The second application was applied one to two weeks later for tailings sand and three to four weeks later for overburden using 10-30-10 at 55 kg/ha for both tailings sand and overburden. Maintenance fertilizer was used for only two years on overburden and three years on tailings sand to enhance plant establishment.

Maintenance fertilizer was applied in 1989 by helicopter on both tailings sand and overburden areas. The general fertilizer types and rates were 34.5-0-0 at 100 kg/ha and 6-24-24 at 200 kg/ha for tailings sand areas and 34.5-0-0 at 200 to 300 kg/ha and 13-16-10 at 100 kg/ha for overburden areas (Suncor 1990 and 1993). For repair areas, 6-24-24 fertilizer was applied at 100 kg/ha using a hydroseeder (Suncor 1993).

From 1991 to 1995, 23.5-25-8 fertilizer was applied to newly reclaimed areas at rates between 300 and 400 kg/ha using a helicopter. Maintenance fertilizer (31.5-16-5) was applied at 200 kg/ ha to previously reclaimed areas by helicopter during the same period (mid-May to mid-June) as starter fertilizer (Suncor 1992, 1993, 1994, 1995, 1996).

All aerial fertilization in 1996 was done using a fixed wing aircraft. The fertilizer regimes in 1996, 1997 and 1998 were the same as in 1995 (maintenance areas: 31.5-16-5 fertilizer applied at 250 kg/ha; newly reclaimed areas: 23.5-25-8 fertilizer applied at 300 kg/ha) (Suncor 1997, 1998, and 1999). Application methods for maintenance fertilizer changed slightly in 1999 from aerial broadcasting to hand spreading depending on the size, shape and accessibility of the reclamation area.

Fertilizer regimes for 2000 to 2006 included application of maintenance fertilizer to previously reclaimed overburden and tailings sand areas using a 31.5-16-5 fertilizer mix applied at 250 kg/ha and a 23.5-25-8 fertilizer was applied at 300kg/ha to newly reclaimed areas. Fertilizer was applied in early July by fixed-wing aircraft, with the exception of a few small areas where either a D4 Cat or ATV 4x4 quad with a mounted seed hopper unit was used (Suncor 2007a).

In 2005, a new five year study of the benefits of starter and maintenance fertilizer on newly reclaimed tailings sand and overburden areas was initiated. Preliminary trails saw the application of 21.5-16-5 fertilizer at 300 kg/ha to a newly reclaimed tailings sand area on Dyke 5 and a newly reclaimed overburden site on the Millennium tailing corridor slope, with monitoring and results to be reported in the future (Suncor 2006, 2007a).

2.2.5.2 Syncrude Canada Ltd.

Initial fertilizer selection and application rates for reclamation at Syncrude were determined from soil nutrient analyses, herbage production on monitoring plots, fertilizer nutrient availability and the stage of site development (Syncrude 1980). Fertilization regimes were different for primary treatment sites (areas receiving fertilizer for the first time) than maintenance areas. Primary treatment sites received two applications of fertilizer at a rate between 200 and 760 kg/ha to ensure plants did not encounter stress conditions due to low nutrient levels. Maintenance areas received fertilizer applications with more soluble forms of nitrogen and phosphorus at a lesser rate of 112 to 504 kg/ha annually until a self sustaining ground cover developed. The following fertilizers were used:

- urea: 46-0-0
- ammonium nitrate: 34-0-0
- monoammonium phosphate: 11-28-0
- potassium chloride: 0-0-60.

Fertilizer was generally applied aerially with a helicopter and hopper attachment. Hand operated broadcasters (Belly grinders) and an All Terrain Vehicle (ATV) with electrically operated broadcasters were also used. Harrows were drawn by the ATV over the reclamation surface to incorporate the fertilizer into the soil on primary treatment sites.

Research in the early 1980s showed that the use of high seeding rates of agronomic species of grasses and legumes in combination with moderately high rates of fertilizers led to the development of a dense ground cover and created conditions which were difficult to establish woody vegetation. **High maintenance fertilizer rates promoted the growth of smooth brome, and exceedingly competitive grass species, at the expense of other species.** This research led to changes in the operational reclamation practices at Syncrude, including reduced initial fertilization rates and earlier termination of maintenance fertilization (Syncrude 1983).

Slow release fertilizers were used once fertilizer rates were reduced nearly in half to promote the growth of native annuals prior to establishment of woody seedlings. Sulphur coated urea and triple coated superphosphate were the main forms of nitrogen and phosphorus and soluble potassium chloride was the potassium source. Incorporation of fertilizer blends was accomplished on most primary treatment sites with a heavy duty cultivator drawn by a crawler tractor (Syncrude 1990).

In 1993 Syncrude started using a bulk fertilizer system (Syncrude 1994). This system allowed for the purchase of pre-mixed fertilizer blends. The blends for permanent, temporary and temporary pasture reclamation are given in Tables 1.12 and 1.13. Fertilizers were generally applied by aerial broadcasting, however maintenance fertilization of the buffalo pastures was done by ground broadcasting using a tow type spreader. In the case of permanent reclamation fertilizer application was followed by offset disking for incorporation.

The majority of the fertilizing after 1995 was carried out using a tractor and tow type fertilizer spreader. This change from previous years was made primarily due to the fact that ground application gave more complete coverage of areas (Syncrude 1996). Fertilizer was purchased pre-mixed and the blends for permanent, temporary and maintenance applications changed slightly (Tables 2.12 and 2.13).

Table 2.12. Fertilizer blend for permanent and temporary reclamation at Syncrude Canada Ltd. (Syncrude 1994 and 1996)

Nutrient	Nitrogen	Phosphorus	Potassium	Sulphur
Analysis (1993)	9	30	15	3
Application Rate (kg/ha)		500		
Analysis (After 1995)	10	30	15	4
Application Rate (kg/ha)		250-350*		
Rate of Release		Medium – Slow		

*350 kg/ha is permanent rate (1995 and 1996 permanent rates 500 kg/ha). Temporary rate varies between 250-350 kg/ha.

Table 2.13. Fertilizer blend for pasture reclamation at Syncrude Canada Ltd. (Syncrude 1994, 1996, and 2002)

Nutrient	Nitrogen	Phosphorus	Potassium	Sulphur
Analysis (1993)	4	19	38	0
Application Rate (kg/ha)		275		
Analysis (After 1995)	23	13	18	0
Application Rate (kg/ha)		225-300		
Analysis (After 2001)	34	6	9	0.2
Application Rate (kg/ha)		200-250		
Rate of Release		Medium - Slow		

2.2.5.3 Albian Sands Energy Inc. – Muskeg River Mine

Fertilization at Albian Sands – Muskeg River Mine is currently being researched (Albian 2007a). There is a limited understanding of the impact of fertilization and Hydrogel application on the capability of reclaimed lands to support tree growth, or the effects of fertilization on the establishment of nutrient cycling in the reclaimed landscape. Therefore a field study has been established. The objectives of this project are to:

- Determine the effects of fertilization on nutrient (nitrogen and phosphorus) cycling in a and d target ecosites (as described in Beckingham and Archibald 1996) in the early stage of land reclamation.
- Examine the effects of fertilization and Hydrogel application on tree growth in the early stage of land reclamation.
- Investigate the potential impact of fertilization on long-term land capability by assessing changes in soil properties and processes, in a way consistent with the LCCS.

2.2.5.4 Shell Canada Energy Ltd. – Jackpine Mine

No operational fertilization has been conducted at the Jackpine Mine due to the stage of development.

2.2.5.5 Canadian Natural Resources Ltd.

No operational fertilization has been conducted at the Horizon Project due to the stage of development.

2.2.5.6 Petro-Canada Oil Sands Inc.

No operational fertilization has been conducted at the Fort Hills Project due to the stage of development.

2.2.6 WEED MANAGEMENT

2.2.6.1 Suncor Energy Inc.

Weed management at Suncor focuses on the control of noxious weeds including scentless chamomile, common tansy, spreading dogbane and Canada thistle as well as invasive weeds such as bindweed and Russian thistle. Weeds are identified annually during the summer and are manually pulled, bagged and burned. This is normally followed by a minor application of herbicide (Telar, 2,4-D or Enhance) by an approved contractor using backpack and truck applicators (Suncor 2004).

2.2.6.2 Syncrude Canada Ltd.

A weed control program has been established at Syncrude since 2002 when two species of noxious weeds, scentless chamomile and common tansy, were identified on the Syncrude Mildred Lake site (Syncrude 2007a). Subsequently, Canada thistle, was identified and is being controlled. There are no known restricted weeds presently on the Syncrude leases. Managing weeds on site depends on a variety of factors including species, severity, and land use. Various methods have been employed to control/eradicate these weed species, including hand pulling and disposal and various herbicides. Each species is treated differently. Common tansy requires individual treatment of each plant present due to its special distribution. The chemicals used to treat common tansy have included "Telar-Toss-N-Go Bags", Telar, and 2,4-D. Scentless chamomile and Canada thistle have been controlled with: "Telar-Toss-N-Go Bags", Tordon 101, Telar, and Enhance. Tordon 101 is used on areas where reforestation is not planned because this chemical has a residual effect and reduces propagation in following years. The other chemicals are not residual and do not impede the growth of other plants (Syncrude 2003a, 2004a, 2005a, 2006a, 2007a).

In addition to treatments for noxious weeds, there has been some herbicide application for pasture management. The pastures are sprayed in order to control weedy species that are not palatable to bison and some that are classified as noxious. This application is in concert with application of a foliar fertilizer. The herbicide used is Target+. As well, Vantage has been sprayed to kill grass prior to reforestation (Syncrude 2003a).

2.2.6.3 Albian Sands Energy Inc. – Muskeg River Mine

The weed management program includes weed surveillance and identification (annual/periodic weed surveys), treatment when required, monitoring and weed education and awareness. Any restricted weeds detected are removed, disposed of and reported (Albian 2006).

Trace amounts of common tansy and scentless chamomile plants were observed in 2005 and were hand picked and disposed of. The areas where these weeds occurred had previously been sprayed with Tordon 101 in 2004 (Albian 2006). These two weed species were observed again in 2006 and were hand picked and disposed of.

2.2.6.4 Shell Canada Energy Ltd. – Jackpine Mine

Routine inspections for any noxious weeds at the site began in 2006 and will be continued in subsequent years (Shell 2007).

2.2.6.5 Canadian Natural Resources Ltd.

Routine inspections for weed infestations have been conducted as part of a weed management program. Assessments have been made on a case by case basis as to the best procedure to control weeds when they were found (mechanical, chemical, other means). To date, weeds that have been targeted have been manually removed, placed in plastic garbage bags and disposed in the on-site landfill (CNRL 2007).

2.2.6.6 Petro-Canada Oil Sands Inc.

A weed management strategy has not been implemented at the Fort Hills Project due to the early stage of development at the site.

2.2.7 Erosion Control

2.2.7.1 Suncor Energy Inc.

Erosion control in 1977 along bases of dykes was accomplished by digging trenches, then backfilling with 0.60 m of coke. A perforated drainage pipe (tied into the dyke collection system) was placed on top of the coke layer followed by another 0.60 m of coke, and finally a top dressing of sand and 0.10 m of peat-mineral mix. Drainage water from the coke filters was piped to tailings pond areas and the area was prepared for seeding. Riprap (pit-run) gravel was also used to control erosion and repair eroded areas on berms and in drainage ditches (Shopik and Klym 1978).

Erosion nets were used in 1978 and found to be effective to control erosion on overburden dykes, though it was observed that the effectiveness relied on a high level of ground contact with the nets (Klym and Shopik 1979). Instead of a D6 bulldozer, which was found to have traction problems when ascending tailings sand slopes, a wide-tracked front-end loader was found to be the most suitable for slope repair to reduce uprooting or covering over of vegetation with underlying sand or coke.

Water erosion problems on Dyke 2 and Tar Island Dyke (TID) were controlled through gully repair using conveyer belting material as a lining, followed by backfilling and seeding of the area. Erosion netting followed by seeding with grass was used to stabilize developing gullies and riprap material was used to construct drainage channels on some reclaimed overburden areas. Both of these methods were effective in providing protection from erosion caused by heavy runoff. Recontouring of berms was also used to redirect water flow and improve the mine drainage system.

Windblown areas were hydroseeded with a barley nurse crop to mitigate wind erosion on TID. Seeding of newly reclaimed areas with barley is the preferred method of erosion protection at Suncor although the application rate has doubled from 62 kg/ha in 1991 to 124 kg/ha by 2001 (Suncor 1992 and 2002).

In 2000 an environmentally friendly product referred to as "soil sement" was applied to the coke pile to control dust and erosion instead of a barley nurse crop. The objective of this product was to develop a thin "tarp like" cover over the coke product to reduce erosion potential (Suncor 2001).

2.2.7.2 Syncrude Canada Ltd.

There were various erosion control measures used by Syncrude in the early years of development. Initially, steep slopes and erodible surfaces were protected by the application of a dense cover of Silva-Fibre wood mulch which was sprayed with seed onto the ground surface. Sites more prone to erosion received a tackifier (asphalt emulsion Chevron SS-1 water miscible material) (Syncrude 1976). Steep slopes were terraced with stair-steps and covered with peat to eliminate the erosion hazard. Erosion gullies were filled with riprap (15-20 cm diameter) covered by a 0.20 m peat cap and followed by revegetation. Closely woven twisted-paper mesh was used to prevent wind erosion to ensure the integrity of slopes until a vegetative cover could establish. Cloth fabric with fleece facing was used to retain sands and silts where erosion had already occurred.

Soil stabilizers used in the hydroseeding/hydromulching program for protection of steep slopes and erodible surfaces continued to be used until 1982 and wood mulch fibres were used until 1986 (Syncrude 1983 and 1987). Mulch and stabilizers were applied at various rates over the years and were based on slope angle, surface preparation, soil type, and past performance.

- Mulches included: Weyerhaeuser Silva Fibre, Verdvol Mulch Extra, Peat moss (Greenhouse grade)
- Soil stabilizers included: Terra Tack III, Aquatain 'C', Huls 801

One of the objectives of early revegetation programs at Syncrude was to establish a viable, vigorous ground cover of grasses and legumes for control of surface erosion, therefore agronomic grass and legume species were used and seeding and fertilization rates were high. As early as 1982, Syncrude determined that even at lower rates of seeding, ground cover was adequate for surface erosion protection and seeding rates were reduced (Syncrude 1983).

A Rome Disk Bedder and Ridger was used in the late 1980s to treat reclamation sites in an attempt to create furrows large enough to allow sufficient erosion control on most slopes to eliminate the need for seeding of grasses and legumes. Furrowing across the slope followed by fertilization and seeding was used to repair erosion gullies and level drifting sand. It was determined that this method was not sufficient for erosion control and a nurse crop of barley and oats was drill seeded and then fertilized to provide erosion protection (Syncrude 1989 and 1990).

In 1991 it became common practice to use barley as a nurse crop to prevent soil erosion which reduced the need for seeding of grass and legumes, thus resulting in a less competitive environment for the seedling establishment (Syncrude 1992). Some sites identified to be disturbed in the future were still seeded with agronomic grass species such as creeping red fescue, Kentucky bluegrass, white clover, alsike clover and smooth brome. Muskeg stockpiles have been seeded for stabilization with birdsfoot trefoil, timothy and alfalfa.

Blowing sand at the crest of tailings sand dykes has been a problem at Syncrude since the early 1990's. In 1992 the crest of the Syncrude tailings sand dyke was capped with 15 cm of muskeg material to control blowing sand and aerial seeded with smooth brome at a rate of 30 kg/ha and barley at a rate of 50 kg/ha (Syncrude 1993). Two and a half meter berms were constructed on the tailings crest to prevent sand from blowing onto reclaimed slopes downwind. These berms proved to be ineffective and caused indirect problems with ponding water near the berms. A 2 to 3 cm coating of mature fine tails was sprayed onto the beach of the tailings crest to control blowing sand and to evaluate the potential to dewater manufactured fine tailings (MFT) by drying it in fine layers and then mixing for reclamation purposes. In addition, areas have been aerially seeded with seed coated with calcium carbonate, phosphate and micronutrients to determine if this method would reduce blowing sand by establishing a vegetative cover. Silt and snow fencing have been used to control wind blown sand. In areas where blowing sand formed a layer over previously reclaimed sites and degraded reclamation success, it was necessary for the sand to be removed (Syncrude 2000).

Swales have been developed on landforms where erosion has occurred and erosion matting, willow wattles, seed, fertilizer and erosion blankets have been used to protect the integrity of the swale. Gabion baskets and filter cloth have been used to channel water into ditches to prevent future washouts of tailing sand structures.

The common practices for repairing erosion gullies on slopes have been to reinforce drainage channels with erosion matting, followed by placement of reclamation material and revegetation. In 1998 notable erosion gullies on the Mildred Lake Settling Basin were observed on steep slope angles and areas which have tailings pipelines or roads and ditches (Syncrude 1999). Remediation of areas included the filling in of the erosion gully and addressing the root cause which usually involved eliminating the localized water source. Similarly at the Southwest Sand Storage facility erosion gullies were remediated with reclamation material and grass revegetation. In one of the larger gullies, six cross-channel berms of pitrun gravel were buried beneath the organic material at regular intervals along the channel to act as a source of material for self healing of erosion. The design included a buried six inch perforated pipe underdrain and a twelve inch solid pipe for management of runoff water until the vegetation on the surface of the swale established (Syncrude 1998).

2.2.7.3 Albian Sands Energy Inc. – Muskeg River Mine

Erosion control methods at Albian have consisted of broadcast seeding annual barley and biannual rye at a rate of 30 kg/ha, biodegradable coconut fiber mats, and silt fences (Albian 2004, 2006, and 2007a).

2.2.7.4 Shell Canada Energy Ltd. – Jackpine Mine

No major erosion control activities have occurred to date. There have been no built-up areas of soil on the site exposed for longer than one year. Minor erosion control activities such as installation of silt fences, georidges and use of rip rap or boulders to minimize the migration of surface soils are ongoing.

2.2.7.5 Canadian Natural Resources Ltd.

No major erosion control activities have occurred to date, however silt fences, contouring, and seeding to control erosion are in use at various locations at Horizon.

2.2.7.6 Petro-Canada Oil Sands Inc.

No major erosion control activities have occurred to date due to the stage of development.

2.3 TAILINGS RECLAMATION

Extraction and processing of bitumen from oil sands deposits results in several byproducts which must be managed to ensure environmental sustainability in the oil sands region. Two of the most important byproducts are tailings and process-affected water. Tailings change over time after they are created: initially they are a slurry of water, clay particles, sand, residual bitumen, and chemicals; these tailings are placed in tailings ponds, where the sand drops out of the suspension, leaving a stable mixture of fine clay particles and water. Eventually the fine clay particles settle out to form fine tailings, a mixture of approximately 85% water and 15% clay particles. These fine tailings (FT) will consolidate into a soil-like material over the course of hundreds of years; this process can be greatly accelerated by the addition of gypsum, resulting in the production of consolidated tailings (CT) in 10 to 20 years. Process-affected water, seepage from containment dykes, and runoff/drainage from reclaimed landscapes contains elevated levels of chemicals which naturally occur in the oil sands, including polycyclic aromatic hydrocarbons, naphthenic acids, and salts. It is necessary to remediate this water before releasing it into the environment.

The approval holders (Suncor, Syncrude and Albian) are required to submit a plan and schedule for a comprehensive tailings management research program to the Director. The purpose of the program shall be to obtain all necessary data required to formulate a tailings management plan that allows for the reclamation of the tailings storage areas to a forest ecosystem or a wetland ecosystem or a combination of forest and wetland ecosystems. The tailings management research program is required to investigate and evaluate both the forest and wetland ecosystems for the following:

- The forest ecosystem research program is required to include:
    - chemical and physical properties of CT
    - suitable capping depths
    - time required to consolidate to a trafficable surface
    - stability of the reclaimed surface over time
    - anticipated land capability of the reclaimed areas and
    - impact on terrestrial community development due to the uptake of organics and metals.
- The wetland ecosystem research is required to include:
    - chemical characterization (composition, concentration, toxicity) and rate of pore water release and surface runoff from consolidated tailings (CT) deposits
    - environmental fate, including degradation rates of toxic components in CT release waters
    - impact of CT release waters on aquatic communities and
    - if coke is slurried with CT, a comparison of the chemical characterization and rate of pore water release from CT with and without slurried coke.

2.3.1 SUNCOR ENERGY INC.

2.3.1.1 Non-Segregating Tailings (NST) Trials

Initial characterization and toxicity testing of tailings waste streams was started in 1975 by Great Canadian Oil Sands. A high organic carbon content and acute toxicity to rainbow trout was found in this first analysis, and research in later years focused on characterizing toxic fractions of the organic content (FTFC 1995).

The late 1980s and early 1990s saw an increase in co-operative research on land capability components between Suncor and Syncrude that started with wetlands (natural and constructed) investigation and progressed to the intensive work documented in the Fine Tailings Fundamentals Consortium *Advances in Oil Sands Tailings Research* (FTFC 1995). The collaboration had a particular focus on tailings management, and was documented in a series of stakeholder consultation documents.

In 1989, the Fine Tailings Fundamentals Consortium was formed by oil sands industry members (Suncor and Syncrude), and grew to include Alberta Energy, the Alberta Research Council, the Alberta Oil Sands Technology and Research Authority (AOSTRA), Environment Canada, Canada Center for Mineral and Energy Technology (CANMET), the National Research Council, and the Other Six Lease Owners (OSLO).

Suncor's participation in *Advances in Oil Sands Tailings Research* (FTFC 1995) was sustained and generated a series of experimental and test scale areas on their oil sands mine site, including;

- experimental water-capped fine tailings pits
- assessment of fine tailings as a reclamation soil amendment
- constructed wetlands
- laboratory tests on NST and
- freeze-thaw dewatering of fine tailings.

2.3.1.2 Water-Capped Fine Tailings Test Pits

The first wet landscape testing was completed by Suncor in the early 1980s when culverts were dug into the ground surface next to Pond 1A for CT treatment development, and limno-corrals were constructed within Pond 1A to measure biological activity and the effect of additives such as phosphate (Golder 2007).

Wet landscape options considered in *Advances in Oil Sands Tailings Research* (FTFC 1995) and then in the CEMA End Pit Lakes Working Group (2000 onwards) and closure and reclamation plans submitted as part of subsequent regulatory applications by Suncor, consider situations where fluid fine tailings are contained in geotechnically secure pit areas and capped with water. This is a non-trafficable option for tailings management, and provides an opportunity to direct, detain and treat process-affected water from other disturbed and/or reclaimed areas before it is released into surrounding waterbodies.

Suncor explored the concept of tailings disposal and pond reclamation where mature fine tailings were pumped out of tailings ponds and covered with tailings pond water. Water samples from these pits demonstrated bioremediation of chemicals in the pond top water over time, and experiments were constructed to assess possible acceleration of the remediation process (e.g. addition of phosphate) (Suncor 1992). Adding phosphate did increase the rate of biological activity, but eventually the test pits became eutrophic.

Studies were also conducted in 1991 for dewatering of tailings sludge for abandonment to a dry landscape. These included studies of sludge accumulation and dewatering behaviour, assessments of different methods for enhanced dewatering (e.g., freeze-thaw, uptake of water by vegetation) and for capturing fines (Suncor 1992).

Research on fine tailings reclamation continued in 1993 with assessments of alternative fine tailings accumulation and disposal techniques (Suncor 1994). Selective mining, modifications to the extraction process and engineered tailings were identified as the most viable options for reducing fine tailings accumulations. Continued assessments of dewatering techniques for fine tailings were also conducted in 1993 and focused on freeze-thaw, aggressive drainage, and vegetation evapotranspiration (Suncor 1994). A design for a system to transfer fine tailings into a single wet pond within the mine pit was also completed in 1994. This transfer process was to be initiated in 1995, however changes to Suncor's tailings management and closure plans were implemented at that time.

Several programs were also in operation (some in association with Syncrude) to study the accumulation and dewatering of fine tailings, as well as methods for treatment, disposal, reduction and removal of bitumen from fine tailings (Suncor 1993).

2.3.1.3 Fine Tailings used as Reclamation Soil Amendments

In the late 1970s and early 1980s, there was a debate between regulatory authorities and soil scientists over whether peat would completely decompose and leave nothing but sand in tailings sand/peat reclamation work at Suncor (Golder 2007). Suncor then undertook research to examine the stability of evolving soil with respect to mineral fines, and Norwest Consultants conducted research on TID in the mid-late 1970s on fines from mineral overburden and MFT. The MFT was laid on the surface of TID tailings sand dyke areas, but this proved very difficult to work with as Suncor had to build forms and pour in liquid MFT before waiting for it to dry out sufficiently to combine with the tailings sand and other reclamation soil amendments (i.e., peat and overburden).

In the short term (10 years), the addition of MFT to reclamation soils was found to have a negative effect on plant growth, however the magnitude of this effect was seen to diminish as time progressed (Golder 2007). Laboratory studies were completed in *Advances in Oil Sands Tailings Research* (FTFC 1995) to determine toxicology levels in various reference materials, sand, fine tailings and amended non-segregating tailings and to characterize the overall soil and leachate chemistry. Suncor mature fine tailings from Pond 1 and freeze/thaw tailings were found to have good potential as reclamation material.

Extensive laboratory tests were carried out from 1993 to 1995 to assess the rate of settlement at the surface, the rate of consolidation over time and the rate of water release of Non-segregated tailings (NST) options that could be used to fill Suncor's Pond 5. These included assessments of mixing MFT with new tailings, mixing cyclone underflow (a method of centrifuging tailings to remove water) with new tailings, and mixing fly ash, and later calcium sulphate, from a scrubber at the main power plant (Golder 2007).

In 1992 and 1993 Suncor undertook a large-scale field trial of thin-layered freeze-thaw dewatering of mature fine tailings in three test ponds constructed adjacent to Pond 2 on Lease 86/17. The processes of freezing, consolidating and drying reduced the height of the fine tailings layer by 50 to 70%.

The result of Suncor's exploration of NST technology showed that the processes detailed above did result in the consolidation of fine tailings, but that there was an initial cost to this option that was not sustainable for ongoing tailings production; the NST option initially results in an increase in the water inventory in the ponds. Treatment of the water would require remediation in a series of holding ponds, and then through treatment wetlands. Consideration of these high water volumes led to further work on the fly ash and later gypsum (calcium sulphate) treated MFT as a way to reduce the water used and to reduce tailings volumes in tailings ponds – the start of CT research.

2.3.1.4 Consolidated Tailings (CT) Reclamation

Beginning in 1994, Suncor began investigating a new tailings strategy for CT in response to approval requirements to investigate the feasibility of reclaiming fine tailings to a dry rather than wet landscape. This technology allows for rapid dewatering and "settling" of the tailings in relatively short consolidated times. For CT production, gypsum (a by-product of flue gas desulphurization) was used as a coagulant and mixed with MFT, fresh tailings and sand. A pilot test was initiated in 1993 and the 1994 results showed that this process produced tailings with a significantly more solid consistency than typical mature fine tailings in less than one year, and also released a large amount of water that would normally be held within the tailings (Suncor 1995). A major advantage of the CT process is that surfaces of CT deposits can eventually be stabilized to a landform capable of supporting both upland and wetland ecosystems (Suncor 1998).

The first commercial trial of CT technology was conducted between November 1995 and April 1996. Production of CT was incorporated and integrated with plant operations in phases to minimize impacts to ongoing plant operations and allow for monitoring of CT production and performance (Suncor 1997). It was determined in 1996 that the major indicators of CT performance were CT release water volume, chemistry and turbidity and the geotechnical properties of the deposit. The majority of critical CT facilities were commissioned in 1997. Early problems with the process included difficulties in achieving a consistent supply of gypsum and a steady ratio of sand to fines in the CT mixture, and these have been issues that Suncor has worked on consistently for the past 10 years (Golder 2007).

Problems encountered in 1998 with implementation of CT technology included excess gypsum in recycled CT release waters negatively impacting the bitumen extraction operations, although with improvements in water quality and stabilization of gypsum levels this was resolved by the following year (Suncor 1999).

Reclamation of CT landscapes presents certain challenges; CT material is high in salts from ions from the raw ore, sodium hydroxide from the extraction process and added gypsum ($CaSO_4 \cdot 2(H_2O)$). The two main salts found in CT are sodium chloride and sodium sulphate. Sodium can affect plants if the salt ions reach toxic concentrations or if a water deficit is created due to osmosis. In addition, the dispersal properties of sodium can cause the soil structure to collapse in fine textured soils.

Prior to 1999, CT reclamation research was at a conceptual or small-scale, pilot level. In 1999, construction began on a larger-scale CT reclamation landscape in Waste Area 11, hereinafter called the CT Demo site (Suncor 2001 and 2002). The objective of the CT Demo site was to develop and understand the nature, acceptability and sustainability of reclaimed ecosystems within a CT reclaimed landscape. Suncor retained Golder Associates to undertake the multi-year CT Demo project to study the water balance, water and sediment quality, wetlands vegetation and terrestrial vegetation. The construction was completed in the winter of 1999/2000 and the first plantings occurred in June 2000 (the first year of study at the site).

The CT Demo site is composed of two study areas: 1) Terrestrial Integrated Reclaimed Landscape Design (TIRLD); and 2) Wetlands Integrated Reclaimed Landscape Design (WIRLD). Both integrate terrestrial and wetlands habitat, however, one type of habitat predominates in each demonstration due to local site characteristics. Within the CT Demo Wetlands there were three main deposit zones:

- 1 m CT deposit (and peat cap in some areas) with CT release water, dyke drainage and local surface drainage water applied to the surface
- 4 m CT deposit which received all of the above water types from the upstream 1 m CT deposit area and
- no CT deposit in pre-existing wetlands downstream of both the 1 m and 4 m CT deposit areas, that receive all water from the CT Demo Wetlands area.

The CT Demo was created to research the reclamation options to "kick-start" the CT landscape with the goal of fast-tracking the development of a healthy ecosystem that is typical of regional ecosystems. Wetland habitat was to be the dominant environment at the CT demo site.

The focus of Phase I (2000 to 2004) in the WIRLD site was to assess wetlands and terrestrial vegetation that was planted or naturally colonizing the site. Phase I of the project was completed in 2004 and consisted of water balance determination, detailed vegetation monitoring, and analysis of water and sediment chemical in the aquatic and terrestrial landforms.

Phase II began in 2005 and consisted mainly of select vegetation monitoring, primarily in the aquatic and riparian areas and the establishment of a new willow transplant trial in a more suitable CT terrestrial site immediately upstream of the 4 m CT.

In addition there were terrestrial study areas in the CT Demo wetland areas that received either CT release water because of proximity to the adjacent 1 and 4 m CT deposit wetlands areas, or local surface drainage water. Objectives of plant survival growth studies in the CT Demo Wetlands have been to:

- determine the growth and survival of wetland vegetation (aquatic plants, emergent macrophytes and riparian vegetation) associated with various reclamation landforms, that vary by soil amendments (e.g., 0.2 m of peat depth over CT), and surface water type (e.g., CT release water, dyke drainage, local surface drainage).
- Evaluate the significance of these differences in growth and survival.

- Identify the effects of CT water on the growth and survival of wetland vegetation.

Annual monitoring and research in the CT Demo wetlands has taken place since 2000. Results over the monitoring period have shown that cattail, bulrush and sedge growth in all study areas was very successful even in areas that did not have a peat cap over the CT, and these species were colonizing the CT Demo wetlands from existing populations in some cases. Natural aquatic plant colonization is not happening as quickly in the CT Demo wetlands as it is in control areas and this may be due to the presence of uncapped overburden. A peat cap appears to support more successful plant growth and colonization (Golder 2007).

Saline-tolerant transplants have been successful in areas where increasing water levels have not destabilized the substrate. Most of the transplanted species are doing well in shallow water and are colonizing other shallow areas. Water level fluctuation has not been predictable over the years, and may be confounding some vegetation establishment results (particularly in riparian grass species and aquatic species that do not react well to change in water level). Changes to the timing of input of CT release water have made it difficult to reconcile the changes due to water level, and those due to salinity (Suncor 2006).

The CT process has become the basis for tailings management at Suncor, with research continuing to identify methods, materials and vegetation types best suited to reclaiming CT to terrestrial and wetlands environments. Issues have been identified with salinity levels in the CT Demo wetlands, however a number of (mainly wetlands and riparian) vegetation species have been identified as suitable candidates for establishing plant communities in areas of reclaimed CT, with studies continuing on these plants.

2.3.1.5 Phytoremediation and Dewatering of Consolidated Tailings

In addition to wet landscape reclamation of CT, research studies were completed to determine the potential for phytoremediation and dewatering of CT in a dry landscape scenario (Golder 2007).

Establishing permanent vegetation cover on fine tailings and tailings from oil sands mining operations requires that plant establishment and growth be monitored over several years to observe any cumulative effects. The growth of three plant species (reed canary grass, willow and poplar) in four types of CT (capped or uncapped with peat and fine tailings), freeze-thaw fine tailings, and weathered and unweathered fine tailings was monitored with the following objectives (Golder 2007):

- Measure the growth of these plant species in different oil sands tailings types.
- Measure the uptake of metals by these plant species to assess the likelihood of issues with herbivory of plant species in reclaimed areas.
- Identify the fine tailings and tailings regime that best result in the growth and survival of vegetation.

The most consistent growth of plants was seen in the freeze-thaw tailings (tailings subjected to five freeze and thaw cycles, increasing solid content to about 80%) and with poorer results in the weathered fine tailings (Golder 2007). This is likely due to the higher available moisture content of the freeze-thaw tailings, and the low moisture content and high metal content of the weathered tailings. Hydrocarbon content did not appear to negatively affect plant growth.

Plant growth on CT materials was best if the CT was capped with tailings sand and peat. Reed canary grass removed water from the CT by 75% more than from the control plots in the growing season. Willow and poplar removed 44% and 37% more water, respectively, from the CT than from the control treatment. Reed canary grass could potentially be used as a first step for dewatering of CT for dry landscape reclamation.

Plant growth rate was not correlated with metal concentration – metal uptake from tailings appeared to be related to overall biomass in the different study plots, and the metal uptake rates were low. This indicates that metal concentrations in the vegetation are unlikely to be a hazard for herbivorous species. Metal content of tailings or tailings sands type was not correlated with metal accumulation in the plant species – this is likely due to the small uptake rate of the species studied, and the lack of bioavailability of metals in the tailings. Peat or tailings sands amendment of tailings reduced the metal content of plant tissue.

In addition to continuing research on the CT Demo wetlands and dry landscape areas, ongoing research beginning in 1995 is being conducted on the physical and chemical properties of produced and ponded CT in preparation for creating a reclamation surface.

Current and future CT and tailings research programs include:

- MFT handling and reclamation
- CT production performance
- CT deposit performance
- residual bitumen characterization and
- use of alternative capping and dewatering technologies.

2.3.2 SYNCRUDE CANADA LTD.

2.3.2.1 Tailings History

Commencing in 1995, Syncrude was required to report on its research and development work related to the development of alternative technologies for the reclamation of fine tailings, and efforts to minimize the volume of accumulated fine tails requiring impoundment and reclamation.

Many topics have been explored in the laboratory and in the field with regards to tailings research and development. Prior to 1994, Syncrude's approach to fine tailings reclamation was to store the fine tailings in mined out areas and cover it with a water cap.

This approach is known as the live lake option. Subsequently, plans were made for partial conversion to composite tailings in 1998 to 1999.

Research into the viability of Mature Fine Tailings (MFT) capping, which has been ongoing since 1985, focused primarily on the assessment of seven 2,000 m^3 experimental pits. Monitoring of the experimental plots in 1992 indicated that clean water (2.5 to 3.0 m) overlying the MFT (4.0 m) remained uncontaminated for the third consecutive year (Syncrude 1993). Free ranging rainbow trout which were kept in the pits for several months showed few effects on survival, growth, tissue composition or taste and odour of the flesh. In the first three years of development the pits had developed into diverse, productive and self-sustaining aquatic ecosystems similar to nearby natural ponds.

In 1993 a wetland reclamation demonstration pit was established and filled with 70,000 m^3 of MFT (maximum depth 11 m) and covered with 65,000 m^3 of clean water (depth of 2.5 m). Monitoring of the physical and chemical properties of this demonstration began in October 1993 and assessments of the development of the biological components began in 1994. In the course of the construction of the wetland reclamation demonstration (large scale), several smaller pits were constructed. Each of these pits provided the ability to investigate several other aspects of the impact of wetlands with MFT substrate as permanent reclaimed structures in a final landscape. One of these pits contained 7,000 m^3 of tailings pond water, and was evaluated to determine the level of natural detoxification of undisturbed standing tailings pond water over time. A second pond was manipulated to encourage the development of a dense cover of emergent vegetation, primarily cattails, for evaluation of uptake of contaminants present in the pore water expressed from the fine tailings over time. A third pond was used as a source of MFT for research projects involving freeze-thaw densification of MFT (Syncrude 1994).

The freeze-thaw test used sulphuric acid to change the MFT properties and then used freeze-thaw to further consolidate the material beyond it's starting density of ~34% solids by weight. Results showed that it was very difficult to freeze large volumes of MFT by pouring it onto ice. To freeze large volumes required a very large generally flat terrestrial area for storage. MFT cannot be frozen from a continuous discharge location (large or small). MFT must be poured in thin lifts and allowed to freeze before continuing. Slopes 3:1 or greater are too steep because runoff carries the clay particles and recreates MFT. Based on the results from the program, Syncrude concluded that the freeze-thaw option was not viable for operational practices (Syncrude 1998).

Beginning in 1999 all tailings were treated as they were discharged from the plant to create composite tailings (CT) (Syncrude 2000). **CT are created by concentrating the sand stream of tailings by processing in a cyclone or primary separation vessel, blending the mature fine tailings with densified sand in a sand to fines ratio that yields a non-segregated mix, adding gypsum to stabilize the fines and pumping to a disposal site to deposit as a heavy non-segregated fluid.** Deposited CT material does not segregate and it releases water as it consolidates. The water released is relatively clear and contains less undesirable material than water released by conventional tailings.

The water also purifies easily under the action of sunlight and wind. The CT approach to tailings management yields a weak material that should solidify within a few years. Solid landscapes can then be developed on CT material.

The CT option releases large volumes of process water that must be managed. This contrasts with the very slow release of water from traditional fine tailings. Options explored for using the release water have included: re-use as process water, storage of surplus water (not a viable long term option), use of clean water in cooling facilities, and release of surplus water to the environment after appropriate cleansing (Syncrude 1998).

In order to provide field scale research areas for studying and demonstrating reclamation of CT based landscapes, Syncrude completed placement of CT and a sand cap in a 40 ha CT Prototype Deposit on the Mildred Lake Settling Basin in 1999 (Syncrude 2000).

Research programs to address the issues surrounding terrestrial reclamation of CT deposits have spanned a variety of study scales from bench and greenhouse scale to the CT pits and the CT prototype over the past 10 years. CT reclamation research encompasses both biophysical studies as well as geotechnical studies.

2.3.2.2 Tailings Management Plans

Syncrude has established tailings management plans that accommodate all tailings volumes produced at each of the three operating locations. The tailings management plans are based on the use of four tailings technologies. These are segregating tailings (coarse tailings disposal), composite tailings (CT), thickened tailings (TT) and water capping of mature fine tailings (MFT).

The current tailings systems for the Mildred lake operation are the Mildred Lake Settling Basin (MLSB) commissioned for storage of sand, mature fine tailings (MFT) and recycle water, the South West Sand Storage (SWSS) facility, the West In-Pit (WIP), and the East In-Pit (EIP).

The tailings management plan for Aurora North is based on producing segregated tailings for as many years as it takes to complete the out-of-pit containment structure, and to accumulate a sufficient volume of mature fine tailings to sustain CT production. The Aurora Settling Basin (ASB) was created in the early years to allow for sand disposal, process water clarification for recycle, and fine tailings accumulation and storage.

The current Aurora South waste and tailings disposal plans are based on the goal of maximizing the overburden placement in-pit while also containing all soft tailings materials in-pit at the end of the mine period. The overall tailings plan includes the implementation of a large external tailings pond. This external tailings facility will be constructed using the downstream construction method which allows for water and fine tailings to be stored within the impoundment.

CT will underlie some of the closure landscape at each of the Syncrude operating sites. Syncrude continues to carry out a comprehensive research and development program with goals related to producing and reclaiming CT deposits as summarized below:

- Determine optimum methods of CT production, discharge and deposition to create deposits that are fast to dewater and stable.
- Predict and mitigating any adverse effects of CT release water on all Upgrader water users and on reclamation material.
- Develop methods to enhance and expedite the bearing capacity of CT to permit efficient surface reclamation – in particular to enhance trafficability for mine reclamation equipment, including optimization of sand capping methods, crust management, and design of special equipment.

Research programs to date have provided very positive results which are being applied to the CT deposit in the Mildred Lake Base Mine.

Of particular importance to the reclamation of CT deposits is the rate of consolidation of the deposit and the design of the reclamation surface. The rate of consolidation affects the rate of pore-water release, subsidence, and the strength of the deposit – all major factors in the performance of the final CT landscape. Most consolidation occurs during active deposition. Consolidation nears completion within a few years of completing the deposition permitting sand capping and reclamation soon thereafter.

Present plans call for CT deposits to be capped with hydraulically deposited tailings sand. Research and development on sand capping and reclamation contine with the focus on:

- creating a high bearing-capacity layer to improve trafficability of reclamation equipment
- surcharging the deposit to enhance consolidation and strength
- creating a near-surface aquifer for control of CT release water and
- creating a proven substrate on which to place reclamation material.

Design of the surface topography is critical in managing salt effects from the CT release water. Other factors that can be influenced include CT recipe, sand capping thickness, surface water drainage and choice of reclamation species. Research is ongoing in these areas.

In the early and mid 1990s, a broad suite of greenhouse studies were undertaken with the University of Alberta to look at the effects of CT and CT release water on boreal forest plants (black spruce, white spruce, jack pine, hybrid poplar, willow, dogwood, raspberry, strawberry and bearberry).

The results of these programs indicate that CT water causes drought stress and toxic ion effects, with effects varying between and within species. Hybrid poplar and dogwood demonstrated the greatest resistance but all species exhibited some damage when salinity of solution exceeded 4 dS/m. The work demonstrated that these effects were made worse under low oxygen or hypoxic conditions, which are expected in CT deposits due to methane generation. Various projects also looked at the specific ion effects of possible

CT constituents and found that NaCl was more detrimental than Na_2SO_4, however there was no difference with respect to plant growth between CT made with alum or gypsum.

The research noted that in systems where CT is in the root zone, sodium, chloride, and boron accumulate in needles/leaves, resulting in their death through protein synthesis, energy metabolism and disruption of lipid metabolism. Naphthenic acids also significantly reduced plant processes. Finally, the U of A team demonstrated the negative synergistic effects of ions in CT mixtures: i.e. boron in presence of NaCl causes injury, alkaline pH of CT exacerbates manifestations of metabolic problems, in other words, the whole CT water mixture caused greater problems with upland plant growth than did the individual constituents. They also postulated that the adverse physical conditions of drained CT placed substantial constraints on plant growth.

The results from this extensive program clearly demonstrated that CT and CT water should not appear in the root zone in upland areas where productive forest is the target of post-closure vegetation.

At the same time that greenhouse work was being conducted at the U of A, Syncrude constructed a pilot scale CT deposit, the U-shaped cell in 1997. Field trials evaluating the potential of amending CT with sand and organic matter to create a soil-like material were evaluated in a study with the Alberta Research Council. This work demonstrated that the presence of CT in the root zone significantly impedes plant growth, although addition of peat ameliorates the effect somewhat. Over time when CT is underdrained, salts leach out of the "soil-like" profile, and plant growth improves. Hybrid poplar and aspen performed the best in these field trials, however in all cases plant growth is 50% or less than that observed under CT capped with regular reclamation soil. The conclusion from these field tests confirmed the greenhouse studies which demonstrated that CT should not appear in the root zone in upland areas expected to produce commercial forest.

With the knowledge that CT would have to be sand capped in order to protect the root zone of upland plant communities from CT materials and CT water, a research program was initiated with the University of Alberta to determine depth of sand cap required and to what extent CT salts would migrate into a sand cap. This research demonstrated that salt would migrate up into a sand cap at least 60 cm, indicating that any sand cap with a goal of protecting the root zone (top one meter) from CT water would need to be greater than 1.6 m in depth.

Two supplementary programs were undertaken in 1999 to evaluate if species other than upland boreal forest plants could germinate in a CT environment. The first program, another growth chamber experiment, showed that native and introduced grass species could germinate in CT. Concurrently, the University of Alberta, in partnership with Syncrude, commenced a study to evaluate natural saline systems in the region and to determine if there were ecosystems naturally adapted to higher salinity waters and soils. The results of this research indicate that diverse plant communities exist in naturally saline areas with salinity levels far greater than those anticipated for the CT areas, however in no case was a productive boreal forest supported where salinities in the root zone (upper 20 cm) exceeded 4 dS/m. Native salt tolerant plants obtained from the natural saline areas in the region and planted in the drainage ditches on the CT prototype flourished until they were inundated with sand, a problem which plagues all sand based reclamation areas. This work, coupled with the evidence from the CT wetlands at Suncor, which Syncrude partially supported, indicated that thriving wetland and riparian plant communities can develop on CT materials and in areas affected by CT water.

In 1998 Syncrude constructed the 40-hectare CT Prototype in order to develop the technology for a full scale CT plant. The CT prototype was partially sand capped in 1998. A one-hectare portion of the sand cap was reclaimed and planted to jack pine, white spruce and aspen and salt flushing and plant growth were monitored for five years. In 2004 the one-hectare reclamation test area on the CT prototype was resampled and a geophysical survey conducted to track soil salinity changes over time. When these soils were placed, substantial salinization of the soils occurred due to upwelling of tailings water induced by equipment traffic. Preliminary analyses of the results of the two monitoring programs indicate that substantial flushing of salts has occurred from the soils over three years.

2.4 WETLAND RECLAMATION

"Wetlands" are areas where the land is saturated with water for long enough periods to support wet-adapted processes and plants" (Harris 2007). They are shallow (≤ 2 m) with stagnant or slowly moving water. Wetland classes encountered in the oils sands region are bogs, fens, marshes, shallow open water wetlands and swamps. **Wetland reclamation is defined as the creation of wetlands on disturbed land where they did not formerly exist or where their previous form has been entirely lost (Harris 2007).**

The use of wetlands as a wet landscape option for reclaimed mine areas has been a major focus in the oil sands region (Golder 2007). Recognition that process-affected water, seepage from dyke areas and runoff/drainage from reclaimed landforms would need to be remediated before release, has led to a series of research initiatives involving constructed and natural wetlands areas. Much of the recent research has focused on understanding how reconstructed and natural watersheds (upland-wetland complexes) in the boreal forest function.

Most of the information pertinent to "wetlands reclamation" is associated with research rather than operational practices. In 2003 the Wetlands and Aquatics Subgroup (WASG) of the Reclamation Working Group (RWG) of CEMA commissioned a report entitled "Creating Wetlands in the Oil Sands Reclamation Workshop" (RWG 2006a). The workshop was intended to solicit expert views from leading authorities in a number of disciplines related to the creation and study of wetlands; investigate the challenges of creating a range of wetlands in a reclaimed oil sands landscape; and to develop recommendations for methods to create a range of wetlands.

The same group commissioned preparation of a report entitled "Predicted Water Quality of Oil Sands Reclamation Wetlands: Impacts of Physical Design and Hydrology" (RWG

2006b). This project developed a model to aid in the understanding or influences of key physical factors (e.g. area, depth, shape, surrounding landscape material), and contributing water quantity in conjunction with climatological factors (e.g. seasonal cycles of precipitation, ice cover and potentially climate change) on water quality in reclaimed wetlands. The project was completed by Golder Associates (RWG 2006b).

The group also supported the preparation of the "Guideline for Wetland Establishment on Reclaimed Oil Sands Leases Revised (2007) Edition" (Harris 2007). The second edition of the wetlands guideline is an update of the state of knowledge regarding reclamation of wetlands in the oil sands region. It describes an integrated approach to the planning design, construction, monitoring and adaptive management of reclaimed wetlands.

The following describes wetlands reclamation at Suncor Energy Inc. and Syncrude Canada Ltd., which have undertaken the majority of the research on reclaiming wetlands in the region. The discussion is based largely on research and demonstration results and overlaps to some extent with the discussion of "tailings" reclamation.

2.4.1 SUNCOR ENERGY INC.

2.4.1.1 "Natural Wetlands"

Suncor started research on wetlands in 1991. Initial research used water from dyke drainage and seepage in experimental wetlands; these wetlands were called the "Natural Wetlands". Dyke drainage and seepage water was considered to adequately represent process-affected water for experimental purposes. The "Natural Wetlands" were modified to increase water level and residence time by constructing a weir and internal berms; a boardwalk was also constructed to allow access for sampling the wetlands (Suncor 1992). In 1991, research was conducted on the "Natural Wetlands" to determine quality of input and wetland water, groundwater, wetland water toxicology, and to assess the flora and fauna of the wetland (Suncor 1992).

Tests in 1991 indicated that waters in the "Natural Wetlands" did not contain detectable levels of any Environmental Protection Agency Priority Pollutants, with the exception of a single result for polyaromatic hydrocarbons. Contaminants usually found in tailings pond recycle water were at much lower levels in the "Natural Wetlands". Contaminants such as oil, grease, and total extractable hydrocarbons in the "Natural Wetlands" exhibited a concentration gradient from inflow to outflow, suggesting these contaminants were being removed by the wetlands (Suncor 1992).

The toxicology of water from the "Natural Wetlands" was tested using the Microtox system and exposure of *Daphnia* (an invertebrate) and rainbow trout alevins (newly hatched fish). Microtox is a system using bioluminescent bacteria; the intensity of the light produced by the bacteria is related to the health of the bacteria, therefore, the light produced will be lower in water carrying toxins. As a result, higher EC50 values (a measure of light intensity) indicate healthier waters. For the "Natural Wetland" waters, EC50 values were greater than 100%. However, sublethal effects were noted during tests using *Daphnia* and trout alevins, though there was a trend for decreased toxicity in the water as it flowed through the wetlands (Suncor 1992).

Data on microbial respiration in the "Natural Wetlands" indicated that natural communities of bacteria in the wetlands were able to biodegrade contaminants such as phenol and cresol (Suncor 1992).

2.4.1.2 Constructed Wetlands

In 1991, Suncor built a series of nine parallel trenches for research purposes. These trenches were lined with impermeable polyethylene and clay to isolate them from groundwater influences, and water level and flow in the trenches was controlled by an impermeable dam, outlet weir, and controlled inlet piping. Each trench was planted with 300 cattail, (*Typhus latifolia*) and 60 bulrush (*Scirpus validus*) culms (6-15 shoots) collected from other wetlands on the Suncor lease. In 1991, research on the constructed wetlands focused on a baseline assessment of the soils, plant survival and growth in the wetlands, as well as an assessment of the areas groundwater quality (Suncor 1992).

The availability of nutrients in soils of the constructed wetlands was considered adequate for plant growth; soils were sandy loams with neutral pH and organic matter content of approximately 5.5%. Plant survival and growth in the constructed wetlands ranged from 60% to 208%.

In 1992, tests showed that the constructed wetlands detoxified dyke seepage and other contaminated water; known toxicants, such as naphthenic acids, were biodegraded with no loss of microbial activity. In fact, although the contaminated water entering the wetlands was found to have some influence on the wetlands, it was calculated that they could sustain more contaminant loading if enhancements to the system, such as increased surface area of microbial activity and addition of nutrients, were initiated (Suncor 1993).

Research in 1993 and 1994 found that the length to width ratio of the constructed wetlands (14:1) was adequate, with water at the downstream end of the wetlands meeting water quality guidelines in most cases. Because flow rate during this period was three times that used in 1992, however, water quality was lower than expected compared to that of natural wetlands (Suncor 1994 and 1995).

Microbial mineralization of contaminants was higher in the constructed wetlands than in controls, a process which could be enhanced by the addition of nitrogen and phosphorus to the wetland. Mineralization rates increased in 1994 as the wetlands matured. Higher salinities in dyke drainage water did not affect plankton communities in the constructed wetlands, but might impact those in natural wetlands. Phytoplankton communities in control and test wetlands were different, though the cause of this difference was not understood (Suncor 1995).

In 1995 tests indicated that the addition of phosphate to a pond-wetland system provided better treatment of CT release waters than a pond-wetland system alone, but that a wetlands trench system provided even better results. In addition, biological filters using gravel as a substrate were able to remove ammonia from contaminated wastewater. It was determined that total extractable hydrocarbons could be completely removed from dyke drainage waters with a wetland under certain conditions (Suncor 1996). To enhance water treatment effectiveness, subsurface gravel beds or initial biological filtration needed to be incorporated into the wetland design. Waterfowl were able to use the treatment wetlands, at least in the short term, without toxicological effects.

In 1998, studies indicated that viable wetland habitats would develop on reclaimed CT, but that the plant community in these wetlands was different than that in control wetlands (Suncor 1999). This was not, however, considered a long-term problem for local wildlife species. In addition, CT used in wetland construction should be capped with a layer of peat, and cattail and bulrush species should be planted in constructed wetlands to hasten development of a macrophyte community. A similar approach should be taken with invertebrate and plankton communities (Suncor 1999).

In 2006 the constructed wetlands were rehabilitated to support research into carbon dynamics and toxicology, a collaborative program called "Carbon Dynamics, Foodweb Structure and Reclamation Strategies in Athabasca Oil Sands Wetlands" (CFRAW) (Suncor 2007). Projects underway under the auspices of CFRAW included:

- growth and photosynthesis of cattail in process-affected water;
- aquatic macrophyte community composition and density
- net primary productivity
- rates of detrital decomposition and peal layer growth
- carbon dynamics and food web structure
- investigation of bioindicators such as wood frogs and invetratebrate communities
- toxicological studies including metal releases from coke, and aquatic toxicity of process-affected water and
- bathymetry of all wetlands used in the CFRAW study.

In terms of micro-organism, invertebrate, amphibian, fish and bird health, a series of studies evaluated the effects of exposure to CT water treatment in the CT constructed wetlands (Golder 2007; Research completed by Bendell-Young et al.). In summary, the following results were noted:

- Tailings pond water contains microorganisms that mineralize chemical constituents, including naphthenic acids.
- CT water is not ecologically viable for some species; fish died within 14 days, plants increased their photosynthetic rates but still had lower growth rates, and the benthic community was different than that of reference sites and the phosphate-treated wetlands. CT water which was treated with phosphate and gypsum also compromised the health of fish species, though fish were less stressed in this water than in other water treatment types.
- Addition of phosphate and gypsum to CT water in constructed wetlands produced conditions that supported benthic species similar to those found in reference wetlands.

- Plants in CT water amended with phosphate and gypsum had increased photosynthetic rates and biomass compared to reference wetlands. Benthic invertebrate communities in CT constructed wetlands differ from those of natural wetlands; they are dominated by chironomids. Amphibians are adversely affected by CT water.
- The effect of CT water on juvenile trout and fathead minnows varied with the concentration of CT water, but they generally exhibited immunological responses and reduced growth at high concentrations; results at low concentrations were inconclusive. Studies on adult trout were inconclusive as well; there did not appear to be any adverse effects on large trout introduced into CT wetlands, though there may be chronic effects that were not observed because of the short timeline of the study.
- Release water from CT production may have elevated sulphate levels. Initial studies indicate that wetlands with high sulphate levels will support a viable ecosystem, but further studies are recommended to determine if plant community composition shifts to sulphate-tolerant species.

A large-scale CT reclamation landscape was constructed from 1999 to 2000. The constructed landscape contains two CT Demo Sites – the TIRLD and the CT Demo Wetlands (WIRLD). Initial studies starting in 2000 concentrated on the CT Demo Wetlands. Ongoing studies of water and sediment chemistry have shown the following results (Golder 2007):

- In all CT Demo wetland areas, salinity and relatively anaerobic conditions are deleterious to most invertebrate and vertebrate aquatic life, but plant species have higher tolerances.
- Dissolved organic carbon levels tend to be higher than those of reference natural wetlands, however naphthenic acid and polycyclic aromatic hydrocarbon levels have been within Canadian Council of Ministers of the Environment guidelines. Water quality tests have shown that there is a significant improvement between CT input water and the quality of the same water downstream in the wetlands system.
- Sediment SAR doubled in the CT Demo wetlands between 2004 and 2006, likely due to changes in the source of CT input water or change in oil sands ore source. Sodium (800 mg/L), chloride and some metal concentrations were high, with the SAR levels detrimental to plant growth.
- Consolidation of CT between 2004 and 2006 resulted in 30% decrease in volume in the 1 m CT wetlands and a 10% decrease in the 4 m CT wetlands areas.
- Input water from the CT pond occasionally contains visible amounts of oil, and a straw-bale filter was set up in 2006 as a removal method. This will be replaced with an absorbent boon in 2007. In addition, sediment in the CT wetlands areas have become contaminated with oil, and it is suspected that this comes from a basal bitumen layer deposited underneath the peat-mineral cap during construction of the CT Demo wetlands.

2.4.2 SYNCRUDE CANADA LTD.

Research into capping of MFT in ponds started in 1985 and was focused on work at seven experimental pits, each with a volume of 2,000 m^3. These pits were constructed in 1989. Monitoring indicated that by 1992, the clean water cap (2.5 to 3.0 m thick) over the MFT layer (4 m thick) remained uncontaminated. Free-ranging rainbow trout (*Onchorhynchus mykiss*) kept in the pits in 1991, 1992, and 1993 exhibited few effects on survival, growth, tissue composition, morphology of internal organs, or taste and odour of the flesh (Syncrude 1993, 1994). In the three years following construction of the pits they developed into self-sustaining ecosystems similar to natural ponds found nearby (Syncrude 1993). Overwintering of fish populations, however, was limited due to oxygen depletion thought to be related to poor autumnal aeration, possibly because of the shape and size of the pits (Syncrude 1994).

One of the pits was capped with tailings water, rather than natural water, and even this pond became non-toxic (based on trout survival, growth, etc.) within three years of construction. A second pit which was completely filled with MFT and no capping water, developed a 0.5 m deep layer of capping water due to consolidation of MFT with corresponding release of water. The toxicity of this naturally developed capping water was declining rapidly, and the pit was being colonized, by multiple invertebrate species three years after construction (Syncrude 1993).

Work on the influence of fine tails release water on the quality of cap water in the experimental ponds indicated that there was a small but measurable impact in terms of toxicity. Several acute (rainbow trout, fathead minnow, daphnia, and bacteria LC_{50}s and IC_{50}s) and chronic (fish larval tests, *Ceriodaphnia* life cycle and algal tests) bioassay battery tests were conducted in 1996 on capping water. In all cases there were no acute or chronic responses to the capping water tests, with the exception of a lowest observed effect concentration (LOEC) response for *Selanastrum* in water with higher salinity. Additional work using abiotic bioaccumulators suggested that there were no negative impacts where the water cap was in contact with the fine tails substrate (Syncrude 1997). These results suggest that there are no effects associated with water contact with the fine tails that would limit fish survival and growth in these ponds (Syncrude 1998).

A relatively large experimental pond (3.8 ha, volume of 140,000 m^3, maximum depth of 14 m), called the "Large Scale Demonstration Pond", was constructed late in 1992 and filled with 70,000 m^3 of MFT (maximum depth 11 m) in early 1993. The MFT was capped with 65,000 m^3 of clean water (depth 2.5 m). Monitoring of physical and chemical aspects of this pond began in October 1993 (Syncrude 1994). In 1995, water quality parameters monitored included ionic content, dissolved organics, trace metals, nutrients, chlorophyll a (as a measure of primary productivity), acute toxicity, dissolved oxygen, chemical and biological oxygen demand, and turbidity. These parameters were measured as least once a month during the open water period, and at least twice when the wetland was iced over (Syncrude 1996).

In addition to the Large Scale Demonstration Pond, a 14 ha wetland (0 to 5 m depth, volume of 200,000 m^3) was constructed to test the use of constructed wetlands by waterfowl. To encourage waterfowl use, a dozen nesting islands were constructed of brush piles covered with 20 to 30 cm of clay. Late in 1993 a cross-dyke was built through the wetland, resulting in two separate, but adjacent, wetlands (Syncrude 1994).

Information on the entire food web of test ponds was collected starting in 1995, to determine the sampling intensity needed to monitor biological communities in large reclamation projects (e.g. Syncrude's Base Mine Lake – a large, shallow lake planned as a reclamation endpoint for one of the large, open-pit mines). Taxa that were monitored in test ponds included phytoplankton, zooplankton, emergent insects, bacteria, and fish (Syncrude 1996).

In the same year as construction of the Large Scale Demonstration Pond (1993), an agreement was signed during the Syncrude EUB hearings that established the Base Mine Lake as a larger scale demonstration of the water capping approach to tailings management (Syncrude 1997). The Base Mine Lake represents the large scale reclamation of an open-pit mine to an end pit lake ecosystem. It is designed to hold a total of 260 Mm^3 – 170 Mm^3 of MFT, 60 Mm^3 of sand, and 30 Mm^3 of water (representing a water cap 5 m deep) (Syncrude 1998). Tests done at smaller scale ponds are aimed at determining the best way to manage a reclamation project such as the Base Mine Lake, including what can be expected in terms of the response of different ecosystem elements to the tailings and water used during reclamation, and how impacts of these materials on biota may be mitigated.

Fish studies at Syncrude's test ponds have evolved from short term acute bioassays to longer term studies examining survival and bioindicator chemicals. Early tests using rainbow trout suggested that there were no gross affecets on health and palatability of fish living in test ponds; however, because overwintering success was low in these ponds, it was not possible to examine long-term effects on health and reproduction. To address this concern, in 1995 a test of full life cycles of indigenous fish species (fathead minnows [*Pimephales promales*], brook sticklebacks [*Culaea inconstans*], and lake chub [*Couesius plumbeus*]) began with addition of these species to the Demo Pond, followed by subsequent monitoring of the populations. In the same year yellow perch (*Perca flavescens*) were added to the Demo Pond and a Reference Wetland within Syncrude's South Bison Pasture (Syncrude 1996).

In addition to work on specific taxa, monitoring of the littoral zone of the test ponds was done to determine the rate and degree of colonization of these ponds. Littoral zones are important feeding and spawning areas for fish, and are important in the overall productivity of the pond. In addition, plants growing in this zone stabilize the shoreline, reducing erosion associated with wave action and overland water flow.

Surveys of the microbial communities in experimental ponds indicated that older ponds had better developed detrital layers, with active microbial and benthic invertebrate communities, than younger ponds. This suggests that as ponds age they will develop more diverse and active biological communities (Syncrude 1997). A visual survey of the MFT/water interface in 1997 using a remotely operated vehicle and video camera revealed a well established detrital zone which seals the MFT from uncontrolled mixing with the water column (Syncrude 1998).

Investigations of other components of pond ecosystems were starting or ongoing in 1996. This included work on benthic invertebrates and their use by fish, sublethal effects of water capped MFT on fathead minnow reproduction and larval fish, growth and maturity of adult fish, and effects on larval and adult yellow perch, including the production of biochemical indicators of environmental stress (Syncrude 1997).

In 1996 and 1997 evolution of gas from the MFT storage area of the In-Pit Pond (part of the Base Mine Lake) was noted. These gases were about 30% methane, and were thought to be of biological origin. Surveys of bacterial populations in the area revealed high levels of methanogenic bacteria (>10^5 cells/g), and sulphate-reducing bacteria in the MFT zone (Syncrude 1998 and 1999). Microbial activity in the MFT zone appeared to increase the rate of densification of the MFT layer, which would increase the storage efficiency of MFT ponds (Syncrude 2000). Microbial activity also seemed to decrease naphthenic acid (NAs) levels and acute toxicity levels of the MFT waters (Syncrude 2000 and 2002). Field studies confirmed that a reduction in total NAs was occurring in capping and pore waters, but that a portion of the NAs were resistant to microbial degradation. Further research confirmed that NAs were comprised of both labile and refractory fractions, and that the rate of biodegradation of NAs would vary with the source of oil sands process water (OSPW) added to reclamation lakes and wetlands. Fortunately, it is the labile fraction of the NAs that seems to be the most toxic, so microbial degradation of NAs should still reduce toxicity in reclamation lakes and wetlands (Syncrude 2006).

The activity of anaerobic sulphate-reducing and methanogenic bacteria results in production of biogenic gases (CH_4, CO_2). The methane bubbles up within the MFT, producing effective drainage pathways for water to escape into the water-capping layer. Increased dewatering rates associated with microbial activity have been linked to collapse of the clay structure within the MFT as well. Similar microbial activity is expected in all End-Pit Lakes (EPL) constructed during reclamation of oil sands mines (Syncrude 2006).

Changes in the origin of water added to the active tailings retention pond (WIP) increased the levels of salinity in the pond faster in 2001 than was seen in 1995-2000 (Syncrude, 2002). Modeling used to examine the salinity of the water capped layer of the BML under different starting and filling scenarios, however, suggested that as long as the BML is tied into the surface hydrology of the area and functions as a flow-through lake, salinity profiles under different scenarios will converge after 20-30 years (Syncrude 2001).

Observed reduction in the toxicity of MFT pore waters in the WIP suggest that inputs of toxic compounds (e.g. naphthenic acids) from pore water into the water cap will decrease over time. This should translate into reduced impediments on the biological colonization of the capping water. Ongoing tests of the response of various taxa (fish, plankton, benthic invertebrates, and bacteria) suggest that a water body underlain by MFT should become an ecologically productive lake, and therefore, an acceptable reclamation endpoint (Syncrude 2001). Given the long retention times expected in these constructed lakes, biodegradation will prevent accumulation of toxic compounds, such as polycyclic aromatic hydrocarbons (PAH's), in water capped fine tails systems (Syncrude 2004).

In 2004, Syncrude, Canadian Natural Resources Ltd., and Suncor Inc. sponsored research to determine if saline wetlands could be used to reclaim oil sands mined areas, and whether saline vegetation could grow and accumulate organic matter in natural and reclaimed wetlands. In addition, a paleobotany program to assess conditions present at the origin of wetlands was started to determine appropriate substrates and revegetation methods for a variety of types of wetlands (Syncrude 2006).

To determine if constructed wetlands are on a trajectory that is converging on natural systems, a project comparing constructed wetlands and a range of wetlands found naturally in analogous portions of the boreal forest (the "Hydrologic Requirements for Reconstructed Landscapes in Oil Sands Mining Areas using Case Studies and Natural Analogues" project) was started in 2004. This project was built on earlier work done during the "Hydrology, Ecology, and Disturbance of Boreal Wetlands" (HEAD) project. The main thrust of these projects was to understand the critical causal factors resulting in wetland formation and persistence in the undisturbed boreal forest (Syncrude 2006).

In addition to work examining wetland formation, another project was launched ("Carbon Dynamics, Food Web Structure and Reclamation Strategies in Albertan Oilsands-affected Wetlands" [CFRAW]) to examine and compare the ecology of undisturbed and constructed wetlands. This project began in 2005 (Syncrude 2006), and examines interactions between macrophytes, phytoplankton, zooplankton, benthic invertebrates, amphibians and waterfowl in wetland ecosystems. In addition, the project will examine how different types of biomass are incorporated into food webs as the constructed wetlands age, and the effectiveness of wetlands amendments (e.g. peat) on their productivity and their potential to become carbon-sequestering peat lands (Syncrude 2007).

Syncrude has also been developing revegetation techniques for some wetland species through its programs with Wildrose Consulting on "Propagation of Native Species of Concern". In 2003, a vegetative trial for wetland species was set up at Peat Pond (Smreciu et al. 2006). Rhizome division with leafy stems were taken for *Acorus calmus* (ratroot), *Aster puniceus* (purple-stemmed aster), *Carax aquatilis* (water sedge), *C. utriculata* (beaked sedge), *Eleocharis acicularis* (needle spike-rush), *E. palustris* (creeping spike-rush) and *Mentha arvensis* (wild mint). Rhizome pieces of *Acorus calamus* lacking aboveground parts were also planted as were *Salix* (willow) stem-cuttings and catkins. Plants were placed in rows within the plots from a wet area adjacent to the water to drier areas approximately 1.5 m upslope. Wetland propagule survival was determined and spread was evaluated.

Data from wetland plots is preliminary; long term survival and spread will only be determined after a full two to three years. Early survival of ratroot was good. So far, this species survived best if leafy rhizome pieces were planted rather than rhizome pieces with no aboveground shoots. To date, no spread has been recorded but plants appear to be healthy and vigorous.

Purple-stemmed aster, needle spike-rush, creeping spike-rush and wild mint cuttings are surviving well in the wetland plots. The latter three species are also spreading; wild mint throughout the plots and the spike-rush species' especially on the lower, moister slopes and wet areas. Seeding willow catkins has not resulted in large numbers of plants, whereas cuttings can be used to successfully propagate these species at wetland sites. Few cuttings of willow survived at the upland site (Smreciu et al. 2006).

2.5 BIODIVERSITY

"Biodiversity" or biological diversity is a broad concept and is a measure of the relative diversity among organisms present in different ecosystems. Early reclamation objectives defined by Suncor and Syncrude referred to the development of an erosion controlling cover of grasses and legumes. This reflected the emphasis on the establishment of a vegetation cover on the reclamation materials available at the time. The approach evolved into the development of a self-sustaining system in tune with the adjacent undisturbed area. More specifically, the intent was to establish a variety of self-supporting ecosystems suitable for forestry, wildlife habitat and recreation areas.

The change in emphasis to return to a vegetation cover comprised of a variety of species including herbaceous, shrub, and tree species resulted in enhanced habitat for a range of wildlife species. Current approvals include requirements to develop "Biodiversity Programs" which include plans to monitor and document the return of biodiversity in the reclaimed landscape.

Albian Sands (2006) states that "in the long-term successful revegetation efforts must provide the basis for efficient soil nutrient cycling establishment of a diversity of early and late successional native plant species, addition of organic matter and wildlife habitat use". They go on to state that "the complexity of ecosystem function demands that reclamation success be evaluated in an integrative way using indicators that reflect vegetation structure, species diversity and ecosystem processes".

The information pertinent to "biodiversity" in the documents reviewed for this project related primarily to wildlife monitoring and management activities. Information pertinent to revegetation in the context of biodiversity is included in the revegetation section.

2.5.1 SUNCOR ENERGY INC.

Reclamation of Suncor's lease site since the 1970s has involved the planting of a wide variety of native tree and shrub species in an effort to promote wildlife use and increase biodiversity (Golder 2007, Suncor 2007**). Wildlife use of reclamation habitat is assumed to be an indicator of the relative ecological function of designed habitat. As such, data has been used to relate wildlife use with habitat development. Assessment activities pertaining to biodiversity at Suncor's Oil Sands facility have focused on mammals (since 1975), bird communities (since 1976), and more recently amphibians (since 2003).**

Mammalian assessment objectives have included:

- an evaluation of regeneration seedling damage by small mammals (1975 to 1978)
- use of reclamation areas by mammals in an effort to relate use to habitat development (1976 to present), via snow-tracking, and more recently remote camera detection
- records of casual incidental sightings (1976 to present).

Avian assessment objectives have included:

- recording the use/colonization of reclamation areas by birds in an effort to relate use to habitat development (1976 to present)
- habitat enhancement activities including nest boxes and perches
- deterrent programs aimed at keeping waterbirds off tailings ponds (1978 to present).

Amphibian assessment objectives have included:

- recording use/colonization of reclamation areas by frogs and toads in an effort to relate use to habitat development (since 2003)
- ponds surveys to find evidence of breeding populations (since 2003)
- radio-telemetry of Canadian toads to identify behaviour and habitat requirements (since 2003).

2.5.2 SYNCRUDE CANADA LTD.

A Waterfowl Habitat Development Program was initiated in 1993 in an effort to understand factors that influence waterfowl abundance in manufactured wetlands (Syncrude 1993). This program includes recording bird mortality and injury observations at Syncrude's site (Syncrude 2004, 2006, 2007).

Habitat suitability index (HSI) modeling of three generic species (moose, black bear, and snowshoe hare) was used to evaluate wildlife habitat characteristics of post-closure landscapes. The HSI models generate an index of habitat quality based on a scale from 0 to 1 (low to high habitat suitability potential) for each ecosite phase within the study area. The objectives were to: 1) develop a habitat capability map for each of the three species at each of the three Syncrude mines, using the revegetation strategy provided for the closure plan; and, 2) identify habitat concerns for each of the target species, and develop potential modifications/improvements to the closure plan (Syncrude 2006).

The pre-development mix of habitat in the Syncrude lease area was considered to be valuable for black bears. Because most of the lease development occurs in muskeg dominated areas (habitat not preferred by black bears), the conversion of this habitat type to habitat more favoured by black bears, results in an overall increase in habitat suitability.

Pre-development habitat in the Syncrude lease area was considered to be poor habitat for moose, and moose density was low compared with other regions of boreal Alberta. The conversion of muskeg habitat to upland habitat providing forage and cover, results in dramatic increases in habitat suitability.

2.5.3 ALBIAN SANDS ENERGY INC. – MUSKEG RIVER MINE

Albian's Wildlife Management Program was created to monitor and mitigate the effects of the mining process on the surrounding environment and to promote the persistence of natural ecological processes in and around the mine area. **Four objectives were implemented as a part of this program: record casual wildlife observations to monitor species that continue to utilize the area, identify nuisance wildlife and apply controls, deter birds from entering the ETF (External Tailings Facility) and wastewater ponds, and monitor and report avian mortality.**

2.5.4 SHELL CANADA ENERGY LTD. – JACKPINE MINE

Shell currently has a wildlife monitoring program, a bird deterrent program, a wildlife enhancement plan and a fish and fish habitat monitoring program developed for the Jackpine mine. The wildlife program was initiated in November 2005, and the fish and fish habitat program was initiated in April 2006.

2.5.5 CANADIAN NATURAL RESOURCES LTD.

A number of monitoring studies are being conducted by Canadian Natural on the Horizon Project to fulfill conditions of the Horizon EPEA Approval. **Current monitoring programs include: wildlife habitat and corridor monitoring, remote camera monitoring, incidental observations of wildlife and a fisheries monitoring program.** The study design and methods employed for the programs are consistent with programs developed for other proponents in the region.

2.6 ANCILLARY MATERIALS

Coke, sulphur, and the Flue Gas Desulphurization (FGD) stream are used or "stored" on site.

2.6.1 FLUE GAS DESULPHURIZATION

Syncrude currently stores FGD waste in an industrial landfill. Suncor uses it for Consolidated Tailings (CT) production and a portion is stored in a pond onsite.

2.6.2 SULPHUR

Syncrude currently stores sulphur in blocks. Research and development work is underway to develop options for longer-term storage on site including the concept of storage below an earthen cover. Suncor currently ships all sulphur off site. There is only a very small sulphur storage area on site.

2.6.3 COKE

Coke is a by-product of the bitumen upgrading process and as a fuel source must be placed such that it could be recovered at a future date. Syncrude produces approximately two million m^3 of coke per year from its upgrader. Suncor and Syncrude cokes are produced by different processes that result in similar chemistry but different texture. Suncor coke is similar to a sandy gravel while Syncrude coke is like a fine sand. Reclamation efforts are focused on creating a landscape where petroleum coke is capped with mineral and organic soil strata and then reforested. Suncor, Syncrude and CNRL have entered into a collaborative research agreement to investigate coke reclamation issues (Suncor 2005). This research addresses the issues of coke combustion, long term releases and effects, physical aspects of coke reclamation, coke instrumented watersheds, long term releases and hydraulic reclamation. Specific objectives of this research are to:

- Pursue high-value opportunities in using coke as a reclamation material, such as a capping medium for soft tailings deposits. The definition of "high-value" is in terms of its value for superior reclamation relative to the value of storing coke for its potential future fuel value.
- Evaluate sub-aqueous storage of coke in end pit lakes or other tailings facilities. Evaluate potential roles for coke in the creation of underdrains and similar structures to accelerate soft tails consolidation.

Several collaborative research initiatives in 2004 included a coke ignition test of Suncor and Syncrude coke, hydraulic placement of coke on a soft deposit pond, and aerobic and anaerobic microbial effects on coke.

Syncrude deposits coke in the Mildred Lake Settling Basin. In 2003 a 6 ha coke instrumented watershed was initiated on the coke beach at Mildred Lake. Two 3 ha areas were capped with 1 m of reclamation soil and 0.35 m of reclamation soil to commence evaluation of the suitability of these two capping treatments and to establish study areas to evaluate the water and salt balances in a coke based landscape (Syncrude 2004).

A field study was conducted at Syncrude in 2004 to determine if petroleum coke would ignite and continue to smoulder under intense forest fire conditions. This experiment was conducted on coke cells with various reclamation caps and suggested that uncapped coke will ignite but will not continue to burn after woody debris has been consumed. They found that even a thin cover of mineral material prevents coke temperatures from rising to levels necessary for combustion (Syncrude 2005).

Suncor initiated a coke reclamation project in 2004 to study the hydraulic performance of caps on reclaimed coke. Two slopes (3:1 and 5:1) were capped with two thicknesses of tailings sand (0.35 and 0.80 m) followed by 0.20 m of peat-mineral mix. The overall objective of the project was to determine the optimal reclamation cover design for terrestrial coke reclamation (Suncor 2005). More specifically to:

- Establish a water balance for each of the instrumented covers with a focus on the key processes controlling the available water holding capacity.
- Establish the interaction between runoff, perculation and cover performance as it influences the dynamics and volume of water movement, particularly the influence that slope and textural break have on moisture storage and migration within the covers.
- Establish a salt balance for each cover which includes the initial weathering and leaching of both cover soils and underlying coke.
- Compare coke field weathering mechanisms and rates to laboratory measurements.
- Develop a preliminary characterization of any organic compounds observed in water collected from the coke.
- Evaluate the role that elevated thermal conditions within the coke may have on the available soil moisture holding capacity of the covers and vegetation development.
- Evaluate the influence of the textural contrast between tailings sand and coke on moisture holding capacity.

In 2004, Suncor completed a project to demonstrate the feasibility of using coke as a reclamation material on soft tailings (Suncor 2005). The general objective was to develop and demonstrate the techniques for placing coke caps over soft deposits. These caps must be able to support the placement of reclamation materials. Specific objectives included were to:

- Gain experience in loading, mixing and pumping Suncor coke that has been passed through a grizzly to reject oversize particles.
- Quantitatively evaluate the hydraulic characteristics of coke pumped at different slurry solids concentrations.
- Investigate the effects slurry solids concentration and flow velocity on the characteristics of the resulting beach slopes and graduation along the delta.
- Investigate the penetration of coke into the underlying CT deposit as a function of distance from the discharge point and thickness of the coke deposit.
- Investigate the trafficability of the coke cap for various thicknesses above the water level.

3.0 OPERATIONAL RECLAMATION PRACTICES AT THE MOUNTAIN COAL MINES

3.1. BACKGROUND

Information was obtained primarily from documents supplied by the mine operators in the mountain coal mine regions and Alberta Environment archives. The documents included “Annual Reclamation Reports”, approval documents and a variety of publications pertinent to the topic. A complete list of documents is provided in the reference section.

3.1.1 COMPANY OVERVIEWS

The following provides brief “historical” information for each company and their operations in terms of reclamation based on the extent of information available.

3.1.1.1 Coal Valley

The Coal Valley Mine is located approximately 100 km south of Edson, in the Coal Branch area of Alberta. The area has an extensive coal mining history dating back to the early 20th century. The mine was opened in 1978 to meet the growing power demand in Ontario. Later in the 1980s it began to supply bituminous thermal coal to export markets. The Coal Valley Mine has pioneered many of the technologies necessary to reclaim a mine site to forest end land use. It received the first reclamation certificate acknowledging the return of surface mined lands in the Eastern Slopes Region to a forest end use (Luscar Ltd. 1999).

3.1.1.2 Obed Mountain

Obed Mountain Mine is located 24 km northeast of Hinton, Alberta. It is an open-pit dragline mine producing high-volatile bituminous “C” coal for domestic and overseas markets. The mine commenced operations in 1984 and was acquired by Luscar in 1989. It has been idle since 2003. It is currently owned and maintained by Coal Valley Resources Inc.

The primary reclamation objective was for the reclaimed lands to support commercial forestry operations. This objective also supports wildlife habitat goals.

3.1.1.3 Cardinal River Coals Ltd. – Luscar and Cheviot Mines

The Luscar mine was opened north of Cadomin in 1921 by the same financial backers of the Mountain Park Mine. Luscar Collieries Limited acquired additional leases staked by John Gregg & R.W. Jones. The new company built a spur line from Leyland which was assumed by the Canadian National Railway upon completion. Peak production occurred in the late 1920s and again during WWII. Luscar survived the first mine closures in the early 1950s but when its briquette plant burned down in 1956, it was decided that the mine would not rebuild and operations ceased in October of that year. The mine saw rebirth in 1969 when Cardinal River Coals Ltd. reopened the Luscar mine located approximately 42 km south of Hinton in response to the growing Japanese market for coal. The Fording Coal Partnership has owned the Luscar mine since March 2003, but the previous owners, Luscar Ltd. and CONSOL Energy, have reclamation obligations for mining that took place before March 2003.

Cardinal River Coals Ltd. operates within the boundaries of Mineral Surface Lease 5972 located in Townships 47 and 48, Range 24, West of the Fifth Meridian. The area occurs within the Rocky Mountains physiographic subregion which has topography that consists of alternating ridges and valleys. The area ranges in altitude from 1650 m to 1860 m a.s.l. The surficial materials within the general area typically consist of shallow moraine over residuum and bedrock with moraine deposits becoming shallower and more discontinuous with increasing elevation.

The mine occurs in the Subalpine Ecoregion which is a climatic zone characterized by the occurrence of extensive areas of evergreen coniferous forests. Land uses in the general area consist of extensive forest harvesting to the east and north of the mine, the adjacent Gregg River Mine, the townsite of Cadomin, and an Inland Cement rock quarry to the southeast of the mine.

3.1.1.4 Gregg River Mine

Manalta Coal Ltd. began operations at the Gregg River Mine which is located 40 km south of Hinton, Alberta in 1983 to supply metallurgical coal for steel making in Japan. The mine consisted of multiple open pits which were mined simultaneously using the truck and shovel mining method. The primary end land use objective for reclaimed lands was wildlife habitat. In 1998 Luscar Ltd. acquired Manalta Coal Ltd. which included the Gregg River operation.

3.1.1.5 Grande Cache Area Operations

The information reported for "Grande Cache Area Operations" includes information pertinent to the current operator Grande Cache Coal Corporation Inc. (GCC) and previous operators Smoky River Coal Ltd. (SRCL), McIntyre Mines Ltd., and McIntyre Porcupine Mines Ltd. Total reserves in the Smoky River Coal reserve were estimated at 400 million tons. The first major exploration work of the deposit began in 1959 by the Columbia Iron Mining Co., progressed through the 1960s and culminated in the development of the coal reserves by McIntyre Porcupine Mines Limited in 1969.

Development at this time was made possible by the increasing world demand for metallurgical coal and the construction of the Alberta Resources Railway. Initially the coal was mined by underground methods which were subsequently augmented by surface mining beginning with the No. 8 Mine in 1971. Initial underground operations included the No. 2, No. 5 and Reiff Terrace Mines. Production from the No. 7 Underground Mine was initiated by GCC in 2004. The No. 9 Mine area was explored and evaluated in detail during 1969 to 1973 and production commenced in 1974.

In 1985, Dome Mines purchased McIntyre and established Smoky River Coal Limited as an operating company. In March 1987, a private Canadian - controlled corporation owned by Kaieteur Investments Inc., an Alberta corporation, and Dong Jin Commercial Inc., a commodity trading company based in Korea, purchased SRCL from Dome. SRCL continued the No. 9 Mine surface operation along with the underground operations and initiated production from the No. 12 Mine in 1988. SRCL mined from 1987 to March 31, 2000 when it was placed into receivership. In September 2000 GCC acquired some of the coal leases previously held by SRCL and began production in 2004.

The information presented in the various sections of the document are attributed to the company responsible for the respective chronological periods.

3.1.2 APPROVALS

3.1.2.1 Coal Valley

Luscar Sterco (1977) Ltd.'s initial D&R Approval for the Coal Valley mine stated that the approval holder shall reclaim disturbed land through appropriate conservation and replacement of soil materials, spoil placement, backfilling and recontouring, revegetation, and reclamation research. The land surface shall have characteristics and properties (topography, drainage, soils, vegetation) that will result in the return of land capabilities that are equivalent to those which existed prior to disturbance.

- On land to be disturbed, the Operator was to salvage sufficient suitable coversoil materials for reclamation purposes. Soil designated suitable for reclamation purposes was not to be buried or used for any other purpose unless approved by the Reclamation Officers.
- Whenever it was necessary to store soil and other surficial material suitable for reclamation of disturbed land, each storage site was required to have approval by the Reclamation officers prior to construction of the stockpile. The operator was to ensure that storage sites had stable foundations and were protected from wind and water erosion and that materials were accessible and retrievable.

With respect to soil replacement, the operator was to replace coversoil on the vegetation/land use types as follows,

- On sodic areas: 0.50 m on commercial timber areas, 0.30 m on general forest/wildlife areas, and 0.15 m on lowland areas.
- On non-sodic areas: 0.30 m on commercial timber and general forest/wildlife areas, and 0.15 m on lowland areas.

With respect to soil replacement in the pit (11) area, the operator shall replace coversoil at an average depth of 0.10 m on wetlands and general forest areas and 0.15 m on upland forest areas. Excavations were to be backfilled and graded to a slope not steeper than 2:1 (27°) and final slopes of discard dumps were to have no slope face angle steeper than 2:1

(27°) and suitably terraced or cross ditched to prevent soil erosion and to assist in stabilization and revegetation.

A 1985 amendment to the approval stated that the approval holder shall conduct direct placement of salvaged surface soil on contoured portions of the disturbed land whenever possible. When surface soil was stockpiled, the stockpiles were to be constructed as follows:

- Surface soil was to be stockpiled separately from other materials.
- Stockpile foundations were to be stable.
- Stockpiles were to be stabilized to control water and wind erosion.
- Stockpiles were to be accessible and retrievable.
- Stockpiles were to be revegetated.

The 1999 approval required that a minimum average depth of 0.30 m of surface soil be present in the reclaimed profile on 80% of the reclaimed area, based on a one hectare area; except in Lowland areas where a minimum average depth of 0.15 m of surface soil shall be present in the reclaimed profile on 80% of the reclaimed areas, based on a 1 hectare area. The approval holder was required to use seed that was free of prohibited and primary noxious weeds for native species and equivalent to Canada #1 seed for agronomic species. The approval holder in consultation with a Conservation and Reclamation Inspector, was required to consider the following:

- incorporation of undisturbed native vegetation islands in the landscape
- maximum direct placement of salvaged surface soil
- elimination of all agronomic species from the seed mix that have proven to be invasive and persistent under the climatic conditions existing at the mine
- maximum incorporation of native seed in the seed mix.

The approval holder was required to contour disturbed land such that the reclaimed landforms approximated the natural landforms in the areas adjacent to the mine. In areas disturbed prior to September 1, 1999 and excepting pit 11, the old plant tailings pond, and the cell #1 plant wastewater disposal area, the approval holder was required to replace salvaged surface soil as follows:

- On sodic areas
  - a minimum of 0.5 m of surface soil in areas of commercial timber
  - a minimum of 0.3 m of surface soil in areas of general forest/wildlife
  - a minimum of 0.15 m of surface soil in lowand areas.
- On non-sodic areas,
  - a minimum of 0.3 m of surface soil in commercial timber and general forest/wildlife areas, and
  - a minimum of 0.15 m of surface soil in lowland areas.

In areas disturbed after August 31, 1999, the approval holder was required to replace all salvaged surface soil as follows,

- The approval holder shall replace surface soil over 1.0 m of material (such as spoil, regolith and surface soil) having a good, fair or poor rating in the *Soil Quality Criteria Relative to Disturbance and Reclamation* (ASAC 1987).

3.1.2.2 Obed Mountain

Luscar Ltd.'s 1981 Approval for the operation and reclamation of the Obed Mountain Coal Mine stated that within the area of the plant site, tailings pond, access corridor, mining area, and clean coal storage and loadout facilities, the operator was required to:

- Salvage and stockpile a sufficient quantity of suitable root zone material, from all areas to be disturbed, for replacement on and stabilization of disturbed land within these areas. Soil designated suitable for reclamation purposes by this approval was not to be buried or used for any other purpose unless approved by Reclamation Officers.
- Obtain approval from a Reclamation Officer to store soil and other surficial material suitable for reclamation of disturbed land prior to construction of the stockpile.
- Replace a minimum of 0.3 m of suitable root zone material over all recontoured overburden and spoil areas and a minimum of 1.0 m of suitable material overall all recontoured overburden and spoil areas which consist of sodic materials.
- In terms of revegetation, the operator was required to maintain a soils and vegetation program to monitor the long term adequacy of the materials handling and reclamation procedures utilized by the Operator, to provide a suitable data base for considering any possible revisions to the Operator's materials handing and reclamation procedures and for determining when land reclamation was complete.

Luscar Ltd.'s 1999 Approval stated that the approval holder shall reclaim land through appropriate conservation and reclamation methods to construct land having characteristics (soils, topography and drainage) that result in a return of land capability equivalent to that existing prior to disturbance. Approval requirements stated that:

- The approval holder shall salvage all surface soil from land to be disturbed on slopes less than 22°.
- The approval holder shall conduct direct placement of salvaged surface soil on contoured portions of the disturbed land whenever possible.
- The approval holder shall backfill and contour all excavations and dumps so that slopes shall be no steeper than 2.5:1 (22°).
- The approval holder shall contour disturbed land such that the reclaimed landforms approximate the natural landforms in the areas adjacent to the mine.
- The approval holder shall replace all salvaged surface soil such that a minimum depth of 0.18 m and a minimum average depth of 0.30 m of surface soil shall be present in the reclaimed profile.
- The approval holder shall replace surface soil over 1.0 m of material having a good, fair or poor rating in the *Soil Quality Relative to Disturbance and Reclamation* (ASAC 1987).
- The approval holder shall only use the following types of seed for revegetation:
    - for agronomic species, that is equivalent to Canada #1 seed and is free of prohibited and primary noxious weeds and

    - for native species seed that is free of prohibited and primary noxious weeds and has a count of 5 or less secondary noxious weed seeds per 25 g of seed and has a count of 50 or less of other weed seeds per 25 g of seed.
- The approval holder shall in consultation with a Conservation and Reclamation Inspector, continue to evaluate the opportunities for incorporating native species into the final landscape and shall consider the following:
    - incorporation of undisturbed native vegetation islands in the landscape
    - maximum direct placement of salvaged surface soil
    - elimination of all agronomic species from the seed mix that have proven to be invasive and persistent under the climatic conditions existing at the mine and
    - Maximum incorporation of native seed in the seed mix.
- The tailings material shall be capped with 1.0 meters of material having a good, fair or poor rating in the *Soil Quality Relative to Disturbance and Reclamation* (ASAC 1987).
- The capped area shall be contoured such that a free-draining surface results.

3.1.2.3 Cardinal River Coals Ltd. – Luscar and Cheviot Mines

3.1.2.3.1 Luscar Mine

Cardinal River Coals Ltd.'s 1977 to 1996 Approvals and amendments for the Luscar Coal Mine stated that through appropriate conservation of soil materials, spoil placement, backfilling and recontouring, soil replacement, revegetation and reclamation research the reclaimed land surface shall have characteristics and properties (topography, drainage, soils, vegetation) that will result in the return of a land capability that is equivalent to that which existed prior to disturbance. Specific requirements included:

- The operator shall salvage soil materials designated as suitable for reclamation, which occur on slopes less than 22°, in sufficient quantity for reclamation of the disturbed land. The soil salvage activities and the respecting quantity and quality of salvaged soil materials shall be carried out in a manner approved by the Reclamation Officers.
- Whenever it is necessary to store soil and other surficial material suitable for reclamation of disturbed land, each storage site shall require approval by the Reclamation Officers prior to construction of the stockpile. The operator shall ensure that storage sites have stable foundations and are protected from wind and water erosion, and that materials are accessible and retrievable. Soil materials designated as suitable for reclamation shall not be buried or used for other purposes.
- To ensure the success of each soil salvage operation the Operator shall provide a training program and on-site supervision for equipment operators.
- All excavations shall be backfilled and graded and all dump sites shall be graded, such that individual slopes shall not be steeper than 2:1 (27°), except for areas of wildlife escape terrain.
- A reclamation research program shall be maintained by the Operator to determine satisfactory methods and techniques for reclamation of the disturbed land. In

regard to research on topsoil island construction, the Operator shall consider factors such as depth of topsoil and regolith replacement and their effects on attaining reclamation objectives.

- A minimum of 0.10 m of suitable subsoil materials (regolith) shall be placed on all recontoured areas, prior to replacement of topsoil materials.
- A minimum of 0.30 m of suitable topsoil materials shall be placed on all areas designated as topsoil island areas, to be applied after regolith placement.
- The operator shall reforest areas designated as topsoil island areas. Inter-island areas shall be revegetated with a grass/legume cover.

A 1996 amendment to the approval stated that the operator shall replace all available topsoil to an average depth of 0.28 m, for a total combined minimum regolith/topsoil replacement depth of 0.30 m, on all recontoured areas which are designated as forest revegetation requirements.

The 2000 Approval for the Luscar Mine incorporated the following additions:

- The approval holder shall conduct direct placement of salvaged regolith and surface soil on contoured portions of the disturbed land whenever possible. When regolith and surface soil is stockpiled, the stockpiles shall be separate.
- In certain areas the approval holder is required to establish reclaimed soil profiles consisting of a minimum of 0.30 m of salvaged surface soil on top of a minimum of 0.10 m of salvaged regolith.
- The approval holder may substitute recontoured material in place of the salvaged regolith following provision of written notice to a Conservation and Reclamation Inspector and provided that it meets the root zone suitability criteria for the Eastern Slopes Region defined in *Soil Quality Criteria Relative to Disturbance and Reclamation* (ASAC 1987).
- The tailings material shall be capped with 1.0 meters of material having a good, fair or poor rating in the *Soil Quality Criteria Relative to Disturbance and Reclamation* (ASAC 1987).
- The approval holder shall only use the following types of seed for revegetation:
    - for agronomic species, that is equivalent to Canada #1 seed and is free of prohibited and primary noxious weeds; and
    - for native species seed that is free of prohibited and primary noxious weeds and has a count of 5 or less secondary noxious weed seeds per 25 g of seed and has a count of 50 or less of other weed seeds per 25 g of seed.
- The approval holder shall maintain a soil and plant growth monitoring program to monitor the long term adequacy of the materials handling or reclamation procedures utilized at the mine and should include the following: soil replacement techniques, native species, topography, land capability, and sampling and analyses to provide a suitable database for considering any revisions to the material handling or reclamation procedures at the mine.

3.1.2.3.2 Cheviot Coal Mine

Cardinal River Coals Ltd.'s 1998 Approval No. 46972-00-00 for the opening up, operation and reclamation of the Cheviot Coal Mine stated that the approval holder shall reclaim the land through appropriate conservation and reclamation methods, to provide land having characteristics (soils, topography, vegetation and drainage) that result in a return of land capability at least equivalent to that existing prior to disturbance. Specific requirements included:

- The approval holder shall salvage all surface soil on slopes less than 22°.
- The approval holder shall stockpile all surface soil as follows: stockpile foundations shall be stable; stockpiles shall be stabilized to control water erosion; stockpiles shall be accessible and retrievable; and stockpiles shall be revegetated.
- The approval holder shall immediately suspend surface soil salvage when: wet or frozen field conditions will result in the degradation of surface soil; or high wind velocities, any other field conditions or mine operations will result in the degradation, of surface soil.
- The approval holder shall minimize vegetation clearing from May 1 to July 31 to reduce the impact on breeding bird populations. When proposing to clear vegetation within this period, the approval holder shall obtain authorization in writing from a Conservation and Reclamation Inspector prior to vegetation clearing.

A 2004 amendment stated:

- The approval holder shall salvage sufficient surface soil and regolith from disturbed land to meet the reclamation objectives, such that the highest quality surface soil is given salvage priority.
- The approval holder shall conduct direct placement of salvaged surface soil on contoured portions of the disturbed land.
- The approval holder shall backfill and contour all excavations and dumps in the mine, as per the Cheviot Creek Pit application, so that at a minimum all slopes, except highwalls, do not exceed 27°.
- The approval holder shall establish reclaimed soil profiles in the recontoured areas of mine disturbance consisting of a minimum of 0.3 m of salvaged surface soil on top of a minimum of 0.10 m of salvaged regolith, excluding the bed of waterbodies.
- The approval holder shall, in consultation with an Inspector, continue to evaluate the opportunities for incorporating native species into the final landscape and shall consider the following:
    - maintaining undisturbed native vegetation islands in the landscape
    - maximum direct placement of salvaged surface soils
    - elimination of all agronomic species from the seed mix that have proven to be invasive and persistent under the climatic conditions existing at the mine and
    - maximum incorporation of native seed in the seed mix.
- The approval holder shall revegetate disturbed lands on which surface soil has been replaced, as follows, unless otherwise specified within the approval:

- On the Grassland/Shrub areas, shrub and grass-legume cover shall be established.
- On the open forest areas, trees and shrubs shall be established so as to achieve a density of greater than 1,000 stems/ha. This density will be comprised of a diverse range of woody species. In the open forest areas, shrubs would be the dominant woody vegetation and trees would form a smaller component.
- On the closed forest areas, trees and shrubs shall be established so as to achieve a density of greater than 1,000 stems/ha. This density would be comprised of a diverse range of woody species. In the closed forest unit, trees would be the dominant woody vegetation and shrubs would form a smaller component.

3.1.2.2 Gregg River

Gregg River Resources Ltd.'s 1997 Approval for the operation or reclamation of the Gregg River Coal Mine stated that the approval holder shall reclaim land through appropriate conservation and reclamation methods to construct land having characteristics (soils, topography and drainage) that result in a return of land capability equivalent to that existing prior to disturbance. Specific requirements indicated that the approval holder shall:

- Backfill and contour all excavations so that slopes shall be no steeper than 2:1 (27°).
- Salvage surface soil on slopes of less than 22°, greater than 0.30 m in depth and not limited by coarse fragment content of greater than 25%.
- Salvage sufficient regolith for resurfacing recontoured areas.
- Direct place salvaged regolith and surface soil on contoured portions of the disturbed land whenever possible.
- Surface soil and regolith shall be stockpiled separately. Stockpiles shall be stabilized to control water erosion. They must be accessible and retrievable and be revegetated after one growing season.
- Replace salvaged regolith so that a minimum of 0.20 m of regolith will be present in the reclaimed profile on recontoured areas.
- Replace all salvaged surface soil so that a minimum of 0.15 m of surface soil will be present over regolith in the reclaimed profile on recontoured areas.
- Conduct fisheries studies to monitor and document fish populations upstream and downstream of the Energy and Utilities Board permit area on Sphinx Creek.

The Approval Holder for the 2000 Approval for the operation and reclamation of the Gregg River Coal Mine was Luscar Ltd. Additional requirements in the Approval stated that:

- The approval holder shall only use the following types of seed for revegetation:
    - for agronomic species seed, that is equivalent to Canada #1 seed and is free of prohibited and primary noxious weeds and

    - for native species seed, that is free of prohibited and primary noxious weeds and has a count of 5 or less secondary noxious weed seeds per 25 g of seed and has a count of 50 or less of other weed seeds per 25 g of seed.
- In the 15 Year Mine area and the Sphinx East area the approval holder shall
    - Establish reclaimed soil profiles on recontoured areas consisting of a minimum 0.15 m of salvaged surface soil on top of a minimum of 0.20 m of salvaged regolith.
    - Only substitute in place recontoured material for the salvaged regolith provided that it meets the following root zone suitability criteria for the Eastern Slopes Region defined in *Soil Quality Criteria Relative to Disturbance and Reclamation*, (ASAC 1987).
- In the Sphinx West area the approval holder shall establish reclaimed soil profiles using salvaged material such that:
    - A minimum of 0.40 m and a mean of 0.60 m of surface soil is present in the reclaimed profile on the coniferous moist cold, coniferous cold, or riparian ecological reclamation units.
    - A minimum of 0.25 m and a mean of 0.40 m of surface soil is present in the reclaimed profile of the coniferous dry or coniferous open dry ecological reclamation units.
    - A minimum of 0.10 m and a mean of 0.15 m of surface soil is present in the reclaimed profile of the grassland/shrubs ecological reclamation unit.

The Approval Holder for the 2006 Approval for the operation and reclamation of the Gregg River Coal Mine was Coal Valley Resources Inc. No new amendments pertinent to reclamation were made in this approval.

3.1.2.4 Grande Cache Area Operations

McIntyre Mines Ltd.'s Development and Reclamation Approval No. C-1-76 dated March 4, 1976 was amended several times by 1979. The 1979 Approval stated that:

- The approval holder was to carry out all surface disturbance activities in such a manner as to ultimately permit the reclamation of the land surface to ensure that the mined or disturbed land would be returned to self-supporting and productive forest land.
- Plant reject material from processing,\ was to be disposed of by the Operator by burial no less than 1.0 m below the root zone prescribed for the post-disturbance land use (except within an area measuring not more than 1.0 ha where research into its effectiveness as a soil amendment to improve revegetation success and maintenance was being evaluated).
- Unless otherwise prescribed in the post-disturbance land use plan, highwalls, footwalls, and embankments were to be reduced by backfilling and grading the fill material to a slope no greater than 2:1 (27º) or to the same contours that existed before the disturbance, or as closely as possible to those same conditions.
- Final slopes of discard dumps were to have no slope face angle greater than 2:1 (27º) and were to be suitably terraced to prevent soil erosion and to assist in stabilization and revegetation.

- Where soil profiles on land to be disturbed, having slopes of less than 2:1 (27º), were sufficiently well developed to support plant growth, the Operator was to salvage soil material for reclamation of the land to the approved post-disturbance land use. Soil salvage, respecting quantity and quality of salvaged soil material, was to be carried out in a manner approved by the Council. Wastage of material suitable for reclamation required approval of the Council.
- Whenever it was necessary to store soil and other surficial material suitable for reclamation, each storage site required approval of the Council prior to construction of that stockpile. The Operator was to ensure that foundations of the sites used by the Operator for storage were stable, storage sites were protected from wind and water erosion and were accessible, and the material retrievable for future use in reclamation of the lands.
- A reclamation research program was to be maintained by the Operator to determine satisfactory methods and techniques for reclamation of the disturbed lands under such terms and conditions and for such period of time as was approved by the Council.
- An average minimum of 0.27 m of organic and mineral soil material which was salvaged for revegetation purposes was to be placed back on the recontoured surface.

Development and Reclamation Approval No. C-1-77 (1976) stated the following pertinent to reclamation:

- All available organic and mineral material suitable and necessary for revegetation purposes shall be stripped, stockpiled and protected for ultimate reclamation purposes to attain a minimum six inch cover on the recontoured pad and the widened portion of the Reiff Terrace haul road.
- Reclamation at the Mine site shall include backfilling with suitable material to the natural contour, the recontouring of the disturbed land, the replacement of the organic or mineral material suitable for revegetation purposes, preparation of the surface for plant growth, the revegetation of the surface for soil stabilization, and the subsequent management of initial plant cover and implanting with commercial timber species to establish self-supporting and productive forest land.
- The approval holder shall carry on a program of observations and experimentation and employ the best applicable technology to determine the most satisfactory methods and techniques of reclamation and report them periodically to the Chairman of the Land Conservation and Reclamation Council.

Approval No. C-1-77 was amalgamated with Conservation and Reclamation Approval No. C-1-76 in 1992.

A 1981 amendment to Approval No. C-1-76 stated the following pertinent to reclamation and the plant reject material:

- All cuts and fills were to be backsloped to a slope ratio of not less than 3:1.
- All precautions and safeguards necessary to avoid the inception of soil erosion or siltation of any waterbody or watercourse were to be exercised.

- A buffer zone of undisturbed vegetation of a minimum width of 20 m between ash and reject material and the edge of the plateau paralleling the Muskeg River was to be left in place.
- All available topsoil and regolith material was to be stripped and piled in a manner that it could be distributed evenly over the excavated area when operations were completed.
- A minimum depth of 0.9 m of regolith and topsoil was to be replaced to cover the plant reject and ash on final reclamation areas.
- Reclamation was to be done progressively in sections or on a yearly basis.
- A vegetation cover of grasses was to be established yearly for quick erosion control.
- The second year after reclamation, seedling trees were to be progressively established at 600 stems or more per acre. It was suggested that lodgepole pine and white spruce be used, size (2-1) root pruned.
- Fertilizer was to be applied until such time as it became self sustaining.

A 1993 amendment to Approval No. C-1-76 for Smoky River Coal Ltd. stated the following pertinent to reclamation:

- Soil material, on the surface of land to be disturbed, designated as suitable for reclamation, was to be salvaged in a sufficient quantity for reclamation of disturbed land as was outlined in the Approval. Soil salvage, respecting quantity, and quality of salvaged soil material, was to be carried out in a manner approved by the Reclamation Officers.
- Plant reject material from processing was to be disposed of by the Operator by burial no less than 1.2 m below the reconstructed soil surface, unless otherwise approved by the Chairman.
- Unless otherwise specified in the Approval, soil replacement was to be as follows:
    - On all recontoured slopes up to and including 18º (3:1), a minimum depth of 0.30 m (12 inches) of salvaged soil material was to be placed.
    - On all recontoured slopes from 18º and up to and including 27º, a minimum depth of 0.10 m to 0.15 m (4 to 6 inches) of salvaged soil material was to be placed.
    - On all slopes greater than 27º, no salvaged soil was to be placed.
- Unless otherwise specified in the Approval, areas on which soil material had been replaced were to be revegetated as follows:
    - For the areas where recontoured slopes were up to and including 18º (3:1), revegetation was to consist of tree, shrub and grass legume establishment with the trees and shrubs established at a density of 1,000 stems per hectare at a ratio of 60% coniferous trees to 40% shrubs.
    - For the areas where recontoured slopes ranged from 18º up to and including 27º, a grass legume cover was to be established.
- The Barrett Mine Reclamation Plan specified:
    - Topsoil material was to be replaced on all recontoured surfaces less than 27º up to the 1,250 m (4,100 foot) elevation.
    - Coniferous tree seed from indigenous species was to be included in the seed mixes used on areas not designated for tree planting.

    - Surface water was to be diverted away from areas backfilled with ash. No ponding of water was permitted on these areas.
    - The flat surfaces of dumps not receiving topsoil were to be recontoured with undulating surfaces created.
- The No. 8 Mine Reiff Terrace Reclamation Plan stated that on all recontoured slopes up to and including 18º (3:1), a minimum depth of 0.15 m (6 inches) of salvaged soil material was to be placed.
- Soil materials rated as good and fair for suitability for revegetative purposes on the surface of the land to be disturbed and on slopes up to and including 22º, were to be salvaged in a sufficient quantity to reclaim the disturbed lands as outlined in the Approval. If a shortage of good and fair soil materials was documented, soil materials rated as poor for suitability for revegetative purposes, but not limited due to rock fragment content, were to be salvaged to obtain a sufficient quantity of material to reclaim the disturbed land as outlined in the Approval.
- At the No. 12 Mine soil replacement was to be as follows:
    - On all recontoured slopes up to and including 18º (3:1), a minimum depth of 0.46 m (18 inches) of salvaged soil material was to be placed.
    - On all recontoured slopes from 18º and up to and including 27º, a minimum depth of 0.30 m (12 inches) of salvaged soil material was to be replaced.
- At the No. 12 Mine revegetation was to be as follows:
    - A minimum of 80% of the disturbed land was to consist of acceptable tree establishment at a minimum density of 1,000 stems/ha. Reforestation was to meet the regeneration standards of the Alberta Forest Service.
    - The remaining disturbed land was to be revegetated with a shrub and grass legume cover suitable for wildlife habitat, as determined by the Reclamation Officer.

The following amendments were stated in Smoky River Coal Ltd.'s 1999 Approval:

- The approval holder shall reclaim the plant reject material disposal areas as follows:
    - The plant reject material shall be capped with 1.0 meters of material having a good, fair, or poor rating in the *Soil Quality Criteria Relative to Disturbance and Reclamation* (ASAC 1987).
    - The capped area shall be contoured such that a free draining surface results.
    - Surface soil shall be replaced and the reclaimed surface shall be vegetated.
- In areas disturbed prior to September 1, 1999 and unless otherwise specified in this Approval, the approval holder shall replace all salvaged surface soil as follows:
    - On all recontoured slopes up to and including 18° (3:1), a minimum depth of 0.30 m of surface soil shall be present in the reclaimed profile.
    - On all recontoured slopes from 18° and up to and including 27°, a minimum depth of 0.10 m of surface soil shall be present in the reclaimed profile.
    - On slopes greater than 27°, no surface soil shall be replaced.

- At the No. 11 and 12 Mines the approval holder shall replace salvaged surface soil as follows:
    - On all recontoured slopes up to and including 18° (3:1), a minimum depth of 0.46 m of surface soil shall be present in the reclaimed profile.
    - On all recontoured slopes from 18° and up to and including 27°, a minimum depth of 0.30 m of surface soil shall be present in the reclaimed profile.
    - At the No. 11 mine, on all recontoured slopes from 18° and up to and including 27° and for areas to be revegetated with a shrub and grass legume cover a minimum depth of 0.10 m to 0.15 m of surface salvaged soil material shall be replaced.
- In areas disturbed after August 31, 1999 and unless otherwise specified in this approval, the approval holder shall replace all salvaged surface soil as follows:
    - The approval holder shall replace surface soil over 1.0 m of material (such as spoil, regolith and surface soil) having a good, fair or poor rating in the *Soil Quality Criteria Relative to Disturbance and Reclamation* (ASAC 1987).
    - On all recontoured slopes up to and including 18° (3:1), a minimum average depth of 0.30 m of surface soil shall be present in the reclaimed profile on 80% of the reclaimed area, based on a one hectare area.
    - On all recontoured slopes from 18° and up to and including 27°, a minimum depth of 0.15 m of surface soil shall be present in the reclaimed profile on 80% of the reclaimed area, based on a one hectare area.
    - On slopes greater than 27°, no surface soil shall be replaced.

In addition to the soil and vegetation requirements, Grande Cache Coal Corporation's 2005 Approval for the operation and reclamation of the Grande Cache Coal Mine stated that:

- The approval holder shall submit a Soil and Plant Growth Monitoring Program Proposal to monitor the long term adequacy of the materials handling or reclamation procedures utilized at the mine and shall include soil replacement techniques, areas of contamination, remediation areas and techniques employed, native species, topography, land capability and sampling and analysis to provide a suitable database for considering any revisions to the material handling or reclamation procedures at the mine.
- The approval holder shall revegetate the areas of the Flood Creek Disposal Facility, the settling ponds and the tailings ponds on which no surface soil has been replaced, as follows:
    - On recontoured slopes up to and including 18°, grass-legume cover and shrubs, shall be established.
    - On recontoured slopes from 18° up to and including 27°, a grass-legume cover shall be established.

3.2 DRY LAND RECLAMATION

3.2.1 SOIL SALVAGE

3.2.1.1 Coal Valley

In 1986 soil was salvaged with motorized scrapers and dozers to a depth of 12 to 30 inches (0.31 to 0.76 m), depending on soil depth and availability in the area (Luscar Ltd. 1987). Problems were encountered salvaging soil on steep terrain, however the process was made easier by using dozers to push the soil down to an accessible location, and salvaging suitable soil to a slightly greater depth.

In most soil salvage sites, the areas were 'grubbed' first to remove large stumps and timber. **Soil salvage techniques remained fairly consistent over time with the salvage depth the only variable changing.** From 1988 to 1998 soil was salvaged to a depth of 0.15 to 0.60 m. In 1998 to 2004 soil was salvaged to a minimum depth of 0.30 m. Combinations of dozers, backhoes, haul trucks and the Page 752 dragline were used for the soil salvage activities.

3.2.1.2 Obed Mountain

The average depth of topsoil salvaged in 1986 was 0.71 m which was well above the average topsoil thickness in the overall mine area (Obed Mountain Coal Company Ltd 1986). The suitability of some of the salvaged material for use as topsoil may have been questionable. Topsoil and subsoil were salvaged at depths of 0.30 to 0.50 m at Obed North and South in 1987. At Obed North, topsoil and subsoil were salvaged in a single-lift operation.

A relatively mild winter hampered soil salvage and replacement activity in 1988. A review of the quantity and quality of the material in stockpiles was completed. The split between topsoil and subsoil was estimated at the time of removal and consequently the materials were mixed together, therefore stockpiles were referred to as a blend rather than as separate topsoil and subsoil stockpiles (Obed Mountain Coal Company Ltd. 1988). Stockpiles subsequently were measured by stockpile volume rather than salvage load count.

Soil salvage operations in 1989 were hampered by a tight production schedule and by highwall and spoil pile sloughing and salinity problems. In 1990, soil salvage and replacement activities operated more efficiently than in previous years due to the formation of distinct reclamation crews and the acquisition of additional equipment (Caterpillar D7 LGP) which was used for the majority of topsoil salvage operations.

Topsoil salvage in 1991 involved dozing into piles and then loading and hauling to prepared slopes or stockpiles. Any tree growth not considered salvageable was incorporated with the topsoil. In 1995 approximately one quarter of the topsoil salvaged was hauled to stockpiles because of the limited areas available for direct placement.

Topsoil salvage was generally done with a dozer by pushing the stripped soil into piles. In some instances in 1995 and 1996 it was impossible to operate trucks and loading equipment on the topsoil stripped sites due to poor ground conditions and excessive highwall instability. In these areas, topsoil was either pushed to a location beyond the final cut and left in a temporary stockpile or it was pushed to the highwall above the shovel face. At the shovel face, usually not more than 15 m high, topsoil was pushed over the highwall and loaded into haul trucks using the shovel.

There was no stockpiling of surface soil in 2001. No mining occurred at Obed Mountain Mine during 2004, 2005 or 2006, therefore there were no topsoil salvage or spreading operations.

3.2.1.3 Cardinal River Coals Ltd. – Luscar and Cheviot Mines

3.2.1.3.1 Luscar Mine

The majority of timber was unmerchantable and past experiences had shown that timber salvage operations from the types of timber found on the minesite were very costly and time-consuming therefore timber was handled in one of two ways. If the area contained a full 12 inches (0.31 m) of topsoil destined to be removed, the trees were bucked to a maximum length of 3 feet (0.91 m) and incorporated in the topsoil removal. If the area was on a ridgetop with 3 inches (7.6 cm) or less of available topsoil, the majority of the felled timber was piled by hand or with a brush rake to be burned. This practice remained the same throughout the life of the mine (Cardinal River Coal Ltd. 1980).

Topsoil at Cardinal River Coals Ltd. in 1979 (Cardinal River Coal Ltd. 1980) was defined as the upper layer of fine material (including surficial organics and slash) to a maximum depth of 12 inches (0.31 m). This, in most cases, included the LFH, A, B and possibly upper C horizons. The amount of slash incorporated depended on timber density and available topsoil depth such that the final salvaged material did not exceed approximately 20% organics.

Two methods of topsoil removal had been used before 1979. A scraper operation was employed where the terrain was relatively flat (under 18º) and length of haul was not extreme. This was the preferred method when the topsoil could be directly placed on a recontoured area. Where slopes were more extreme (18 to 27º) or haul length was considerable, the topsoil material was dozed downhill to a loading area where it could be hauled to a stockpiling site. Topsoil removal and all other reclamation activities with the exception of regolith stripping, were contracted to an outside company because mine equipment was not available.

Regolith was utilized by Cardinal River Coals Ltd. (1981) as a subsoil material. It was salvaged during the normal in-pit stripping operations through the selection of finer material from the upper bench by the shovel operator and stockpiled separately from topsoil material.

Topsoil salvaged between 1982 and 1984 from different areas ranged in thickness from 0.50 to 1.5 m. There was no topsoil salvaged in 1985. New development was confined to a very steep slope on which soil accumulation was minimal and the soil was classified by the pedological survey as "poor" by virtue of the limited depth, low pH and high coarse fragment content (Table 3.1).

Table 3.1. Criteria for evaluating the suitability of root zone material in the Eastern Slopes Region.

Rating/Property	Good	Fair	Poor	Unsuitable
Reaction (pH)[1]	5.0 to 6.5	4.0 to 5.0, 6.5 to 7.5	3.5 to 4.0, 7.5 to 9.0	<3.5 and >9.0
Salinity (EC) (dS/m)	<2	2 to 4	4 to 8	>8
Sodicity (SAR)	<4	4 to 8	8 to 12	>12
Saturation (%)	30 to 60	20 to 30, 60 to 80	15 to 20, 80 to 100	>15 and >100
Coarse Fragments (%/vol/vol)	<30 [2] <15 [3]	30 to 50 15 to 30	50 to 70 30 to 50	>70 >50
Texture	L,SiCl, SCL, SL, FSL	CL, SiL, VFSL, SC, SiC	LS, S, Si, C, HC	Consolidated Bedrock
Moist Consistence	VFr, Friable	Firm	Loose, VFirm	Ext. Firm
$CaCO_3$	<2	2 to 20	20 to 70	>70

[1] pH values presented are most appropriate for trees, primarily conifers.
[2] matrix texture finer than sandy loam.
[3] matrix texture sandy loam and coarser.
(Source: Soil Quality Criteria Relative to Disturbance and Reclamation (ASAC 1987))

Mine dozers were utilized in 1987 to strip topsoil from underlying subsoil into piles to be hauled to stockpiles. A program was implemented in 1989 to directly place regolith material anywhere possible providing additional haul distances were not prohibitive and sufficient equipment was available. Several areas received regolith material as a result. Regolith was stockpiled in 1990.

Topsoil salvage was conducted after 1990 to recover all practically salvageable soil materials. The material included a mix of organic and mineral surface soil horizons. **Salvage depth generally varied from 0.30 to 0.60 m, but was occasionally as much as 1 to 2 m in areas of accumulated organic materials. Steep slopes, thin soils, wet conditions and coarse fragment content made soil salvage impractical on some lands**. Topsoil was either stockpiled for future use or directly placed on reclamation sites.

3.2.1.3.2 Cheviot Mine

Topsoil salvage operations were carried out following timber clearing activities (Elk Valley Coal Corp. 2004). Where timber salvage was not required, trees were cut and incorporated into the topsoil during the salvage operation. Timber was also buried under dump construction where steep slopes prohibited timber and topsoil salvage operations.

Topsoil salvage was undertaken to recover all salvageable soil. The salvaged material included a mix of organic and the upper mineral surface soil horizons. Salvage depth generally varied from 0.30 to 0.60 m, but was carried out to a depth of 2 m in areas of accumulated organic materials. Field reconnaissance was carried out to determine the suitability of the material before topsoil salvage was undertaken. Soil salvage was not undertaken in areas that had one or more of the following deficiencies: steep slopes, thin soils, wet conditions, and high coarse fragment content.

Topsoil salvage since 2004 has been carried out by full-time contractors using small (30 and 40 ton) trucks. The topsoil was pushed into windrows with bulldozers, loaded into trucks by a backhoe and hauled to areas requiring direct placement or to stockpile sites for future use.

3.2.1.4 Gregg River

During 1981, considerable topsoil was salvaged from the plant site area. All material salvaged was either stockpiled or returned directly to constructed slopes (Gregg River Resources Ltd. 1981).

There was relatively little topsoil encountered during construction in 1982. Erosion and reclamation work performed in 1982 was based on recommendations from an engineering company following detailed soil surveys performed on all construction phase slopes (Gregg River Resources Ltd. 1982). These investigations showed that the material exposed as a result of construction phase disturbances had a relatively low to moderate erosion potential and, with the exception of areas high in course fragment content, presented no major obstacles to revegetation. Most areas high in course fragment content were correspondingly low in fines, and thus did not present a significant erosion hazard.

Equipment used for reclamation in 2000 and 2001 included:

- front end loader
- D10 dozers
- 177 tonne trucks
- 4.0 m^3/10.0 m^3 backhoe/shovel

During 2000, no regolith was salvaged or utilized. In 2001, no regolith was salvaged, however some was utilized in areas where the recontoured waste did not meet the criteria defined in Soil Quality Criteria Relative to Disturbance and Reclamation (ASAC 1987).

After 2001, no additional clearing took place as mining was completed and reclamation commenced. All surface soil utilized for reclamation came from existing surface soil stockpiles.

3.2.1.5 Grande Cache Area Operations

Soil salvage became an integral part of the materials handling program associated with the overall mining operations in 1971 prior to the requirements of the 1973 Land Surface Conservation and Reclamation Act. Soil surveys and soil suitability evaluations were conducted to determine the depth of salvageable material available and the physical and chemical properties of the material available for salvage. Surveys were conducted at the No. 9 Mine (Macyk 1973), No. 8 Mine (Macyk and Widtman 1985), No. 11 Mine (Macyk and Widtman 1988), No. 12 Mine (Macyk and Widtman 1986), No. 7 Mine (Macyk and Faught 1999), and No. 8 Mine East Extension (Macyk 2007). The soils were described, mapped and classified according to the most recent version of the Canadian System of Soil Classification at the time of the survey. The soils were dominantly Brunisolic and Regosolic with lesser amounts of Luvisolic, Gleysolic and Organic soils. The depth of salvageable material overlying bedrock at the various mine properties ranged from 0 cm to 1 m. Depth of salvageable soil maps were also prepared to accompany the soil classification maps.

The depth of salvageable soil was generally the depth to bedrock and in a few limited areas depth to the mineral C horizon (Plates 3.1 to 3.4). Depth of salvageable material varied considerably over short distances making salvage operations that attempted to minimize the amount of coarse fragments incorporated difficult (Macyk 1985) (Plates 3.5 and 3.6). Because the surface or organo-mineral horizons were minimal or nonexistent and the sola were quite variable in thickness, segregation or selective handling of soil material was not considered. **The soil material was removed as a single lift and stockpiled for reclamation purposes (Plates 3.7 and 3.8).** Practical soil salvage guidelines were developed along with a description of the procedures that should be followed to ensure that the limited soil resource available was managed effectively. The guiding principles were:

- Soil quality is more important that soil quantity.
- The salvage process involves the removal of suitable soil material from as large an area as possible rather than removal of suitable and less suitable material from a smaller area to achieve the required volume needed for replacement.
- Coarse fragment or rock content in the salvaged soil should be minimized. It is recognized that it is impossible to eliminate them completely due to the nature of the soils in the area.
- The maximum slope that allows for the efficient use of equipment for soil salvage is about 27°. A substantial portion or the sub-alpine and alpine areas mined have slopes greater than 27° making soil salvage difficult and in many cases impossible (Plates 3.9 and 3.10).

Plate 3.1. Depth of salvageable soil was generally depth to bedrock.

Plate 3.2. Organic litter layer over bedrock.

Plate 3.3. Shallow organic layer over weathered bedrock.

Plate 3.4. Relatively thick (0.5 to 0.70 m)
layer of salvageable soil.

Plate 3.5. Soil thickness variable over short distances (0.50 to 0.70 m on left, bedrock to surface on right).

Plate 3.6. Variable soil thickness over short distances makes salvage difficult.

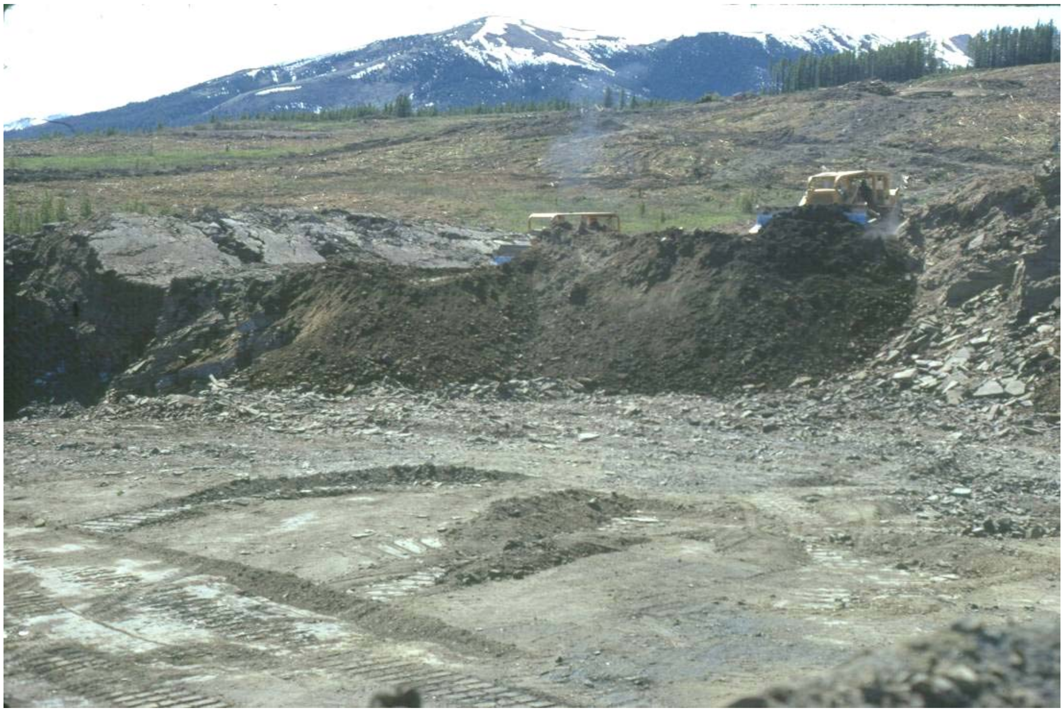

Plate 3.7. Soil salvage in one lift.

Plate 3.8. Soil stockpile.

Plate 3.9. Steep slope precludes soil salvage.

Plate 3.10. Steep slopes are typical of the landscape in the Grande Cache area operations.

A soil salvage manual was developed for use by equipment operators and supervisory staff (Macyk 2000). In addition, soil salvage training sessions including field components to identify the salvageable soil horizons and the non salvageable materials have been conducted (Plate 3.11).

Plate 3.11. Soil salvage training session in the Alpine with Grande Cache Coal Corporation staff.

3.2.2 SOIL PLACEMENT

3.2.2.1 Coal Valley

Direct placement was practiced wherever possible. In 1986, depths of soil replacement were 6 to 18 inches (0.15 to 0.46 m) (average of 12 inches (0.31 m)) depending on overburden sodicity, saturation percent and designated end land use (Luscar Ltd. 1987). In all cases, topsoil was hauled using motor scrapers and in most areas, the soil was replaced with this equipment. Dozers were used on some sites to spread the soil over the area.

The Coal Valley Mine was required to recontour to final slope angles of 27º (2:1) or less. Steep slopes were cross-ditched after soil placement to reduce erosion and promote micro-site diversity (Luscar Ltd. 1987). Dozers were used to complete most of the cross-ditching needed in 1986. Gently sloping areas were not cross-ditched, as the uneven surface left after soil placement provided the desired effect. In 1987, a dozer and a ‘V’ plow previously used by a forestry company for scarification in muskeg, were used for cross-ditching on steep slopes.

Direct placement of salvaged topsoil was still the preferred reclamation technique used when possible in 1998 to 2004. Soil replacement depths varied between 0.15 m and 0.50 m with an average of 0.30 m targeted for most areas. Soil replacement activities were conducted using the scraper/dozer fleet and a truck/shovel/dozer combination, particularly where peat/muskeg soils of sufficient depth and quality were salvaged. In order to be prepared for revegetation, many areas required further surface preparation after levelling and topsoil activities were complete to be prepared for revegetation. Dozers were used in 1998 to 2003 for back-blading and to pull harrows to prepare the area prior to seeding.

3.2.2.2 Obed Mountain

Salvaged material was replaced directly on recontoured spoil piles at an average depth of 0.30 meters in 1986 (Obed Mountain Coal Company Ltd. 1986).

Results from the physical and chemical analysis of spoil material done in 1986 indicated that the material was acceptable as subsoil for the support of tree growth (Obed Mountain Coal Company Ltd. 1986). It was noted however, that although the pH levels were acceptable, they were somewhat higher than optimum. It was expected that the carbonates associated with the relatively high pH would be relatively soluble and therefore leach through the spoil.

As a result of an amendment to soil salvage and replacement approvals, revised procedures were implemented in 1988 to evaluate recontoured spoil prior to soil replacement. Soil samples from recontoured spoil piles were collected and analyzed for sodicity. **All areas having sodic materials with an SAR > 10 and a saturation percentage greater than 100 had soil replaced to a minimum depth of 0.50 m. Non-sodic areas received suitable root zone material to a minimum depth of 0.30 m (Obed Mountain Coal Company Ltd. 1988).**

Between 1991 and 2003 topsoil was either stockpiled or directly placed on slopes at an average depth of 0.30 m. There were no topsoil spreading operations between 2004 and 2006.

3.2.2.3 Cardinal River Coals Ltd. – Luscar and Cheviot Mines

3.2.2.3.1 Luscar Mine

Previous to 1979, regolith was spread directly down the face of the slope causing runoff problems during the spring. In an attempt to solve this problem dozers worked diagonal to the face and although it was marginally successful on slopes up to about 22º, it became too dangerous to operate on steeper grades (Cardinal River Coals Ltd. 1980). This practice was used subsequently where the opportunity presented itself. **Regolith was placed over the entire reclamation surface in a 0.15 m layer as a growth material.**

Under terms of the 1979 Development and Reclamation Approval, all dump slopes were to be recontoured to 27º or less from the angle of repose (38º) (Cardinal River Coals Ltd. 1980). Regolith replacement was accomplished by one of two methods in 1979. A scraper operation was used to haul regolith to the reclamation sites however, steep slopes caused difficulties and dozers were used to spread the material. For longer distances, a truck/loader operation was faster and was substituted for the scrapers.

Direct placement was the preferred method of handling topsoil in 1979 because the stockpiling area was at a premium. Topsoil was replaced by either scrapers/dozers or truck/loader operations. **Due to limitations in topsoil volumes over much of the mine, reclamation plans developed "topsoil islands" for the establishment of forest cover related to wildlife use, as components of the reclaimed land use (Cardinal River Coals Ltd. 1980). Topsoil was placed in strategically located islands at substantial depths as opposed to laying a thin veneer of topsoil over the entire surface.** In some locations topsoil was spread as a consistent cover over the complete area requirements.

No topsoil islands were established in 1980 because topsoil salvage operations were generally restricted to areas where soil materials had to be stockpiled for future. Furthermore approval from Alberta Environment had not been granted for the 'topsoil island' reclamation practice (Cardinal River Coals Ltd. 1981).

During 1981, one topsoil island was established on the Gregg Dump. Topsoil was spread to create an island 0.9 ha in area with an average topsoil depth of 0.55 m (Cardinal River Coals Ltd. 1982). The island was situated at the north end of the Dump adjacent to a residual stand of trees.

During 1982, five topsoil islands were established. Topsoil was hauled and spread in a single-handle direct placement operation in August and December. The islands created a total area of 11.3 ha with an average topsoil depth of 0.25 m (Cardinal River Coals Ltd. 1983). Topsoil islands created in 1984 were spread to a depth of 45.7 cm and created a total area of 1.25 hectares (Cardinal River Coals Ltd. 1985). Topsoil island construction outlined for 1985 was not undertaken largely due to poor weather through the latter part of the summer.

A substantial volume of topsoil was hauled and placed in 1987 to form islands. Final spreading was completed with a small wide pad dozer. A small amount of topsoil was replaced in 1988, 1989 and 1990. No topsoil placement was undertaken in 1991.

General criteria used in developing the topsoil islands included (Cardinal River Coals Ltd. 1994):

- In accordance with the minesite's D&R Approval, a minimum topsoil depth of 0.30 m was replaced over a minimum of 0.10 m of regolith.
- Island locations were finalized based on microsite characteristics, specifically considering wind protection, aspect and moisture/snow retention capabilities.

- The size and dimensions for the islands were based on site characteristics, considering past literature reviews related to wildlife cover needs and balancing the requirements of various species.

Topsoil replacement during 1995 was a combination of placement from both stockpiles and direct placement from soil salvage operations. Topsoil replacement depths ranged from 0.30 to 0.40 m. The topsoil was placed by a small cat in a retreating manner to reduce compaction and leave the area as rough as possible.

In 2000, topsoil was replaced using the "rough/mounded" method (Plate 3.12) where soil was pushed with a dozer to the place of final deposit and left as a rough, mounded surface (Cardinal River Coals Ltd. 2001). The next bladeful of soil would be pushed up to, but not over, the last bladeful, again leaving it as a rough mound. The final surface had a rough, mounded surface that provided important microsite diversity and inherent erosion control and minimized compaction (Plate 3.13). A small dozer was used primarily for the topsoil spreading process.

Plate 3.12. Rough/mounded method for soil placement. Photo courtesy of M. Symbaluk, Elk River Coal.

Plate 3.13. Final rough/mounded surface. Photo courtesy of M. Symbaluk, Elk River Coal.

3.2.2.3.2 Cheviot Mine

The mine site EPEA approval required Cardinal River Coals Ltd. to replace topsoil to a minimum depth of 0.30 m. **Topsoil was replaced using the "rough/mounded" method that minimized compaction and provided additional microsites for enhanced reclamation.** Both small dozers and large dozers were used for the topsoil spreading process.

During 2004 topsoil was spread along the Cheviot haul road at an average depth of 40 cm. The topsoil was direct-hauled from topsoil salvage operations along the haul road. A small amount of topsoil was spread in 2005 and no soil placement activities occurred in 2006 (Elk Valley Coal Corp. 2005 and 2006).

3.2.2.4 Gregg River

In the early 1980s salvaged topsoil was generally dumped at the top of the slope and spread down the slope with a backhoe. The average thickness of topsoil material replaced was approximately 0.25 to 0.30 m. Since topsoiling was generally not required to ensure erosion control, the only areas topsoiled in 1982 were areas that had potential for permanent reclamation sites. In 1984 salvaged topsoil was replaced to a depth of 0.20 m on 0.50 ha (Gregg River Resources Ltd 1985). The topsoil was placed over regolith, which was resloped over spoil.

In 1993, regolith material was salvaged and placed to a depth of no less than 20 cm as per the required depth in the D&R Approval (Gregg River Resources Ltd. 1994). Field checks were undertaken on a continuous basis to ensure regolith depths were over the minimum depth required.

Field measurements were taken on an ongoing basis to ensure that topsoil depths were spread to a minimum depth of 15 cm as was required in the EPEA Approval from 1995 to 1998 (Gregg River Resources Ltd. 1999).

3.2.2.5 Grande Cache Area Operations

In 1973 and 1974 soil material was replaced on the graded spoil surface by scrapers in more gently sloping areas (Plate 3.14) or truck/caterpillar operations on steeper slopes (Plate 3.15) (McIntyre Mines Ltd. 1976). **During large scale operations in 1975, virtually all areas had topsoil applied prior to seeding. It was determined that a smooth graded surface did not necessarily provide the most suitable condition for revegetation. A partially "roughed-up" surface was advantageous for grasses, legumes and tree seedlings.**

In 1975, a new type of drag was designed to scarify the soil surface prior to and following seeding. This drag was proven to be more suitable than the drag chain (Plate 3.16) used previously. It was comprised of several independently mounted sections which had pointed teeth to make small ridges in the soil surface (Plate 3.17). These ridges provided excellent sites for seed germination and subsequent growth (McIntyre Mines Inc. 1976).

From 1984 to 1986, 12 inches (0.30 m) of topsoil was placed on areas of 0 to 18º slopes and six inches (0.15 m) of topsoil was replaced on areas of 18 to 27º slopes.

In 1988 topsoil was replaced to an average of 5 inches thick (0.13 m) (Smoky River Coal Ltd. 1989). All topsoil came from stockpiles. In 1990 to 1991 soil was replaced at a depth of 0.46 m on 0 to 18 º slopes and 30 cm on 27 º slopes. The soil in 1990 was hauled directly from salvage operations and not from stockpiles (Smoky River Coal Ltd. 1991) which was the practice used previously and again in subsequent years.

There was no topsoil placement on any of the reclamation areas during 1994 or 1995. In 1995 the intent was that soil replacement at the No. 12 Mine would be 0.40 m on 0 to 18° slopes and 0.30 m on 19 to 27° slopes. At the No. 2 Mine Barrett soil replacement was required to be 10 inches (0.25 m) on 0 to 18° slopes and 6 inches (0.15 m) on 19 to 27° slopes.


Plate 3.14. Scrapers were used to spread soil in more gently sloping areas.


Plate 3.15. Bulldozers spreading soil downslope.

Plate 3.16. Chain drag used for surface scarification.

Plate 3.17. Drag comprised of independent sections.

3.2.3 SOIL MONITORING

Coal mine operators have been performing soil monitoring and research activities since the early 1970s. The activities and research presented in this section has been obtained primarily from annual conservation and reclamation reports which did not always provide the results for the projects completed therefore results are not available for each project.

3.2.3.1 Coal Valley

Soil depth and material suitability plots were established and vegetated in 1980 (Luscar Ltd. 1981). The objective of the plots was to determine the required depth of coversoil material needed to be capped over spoil. Composite soil samples were taken to a depth of 0.45 m for the purpose of soil monitoring (Luscar Ltd. 1981). To examine the effects of materials on different revegetation programs, half of each plot was planted to trees and the remaining half was seeded to a grass/legume mixture. Three year old bare root lodgepole pine seedlings were planted in May and June, 1980. Twenty five seedlings were planted 1.8 m apart on each plot. Along the edge of each plot a 3 m strip was seeded with the standard seed mix used in 1980 (Table 3.2). Planting was done by digging a hole with a dibble approximately 20 cm deep and placing the bare root seedling in the hole. Establishment rates were poor, therefore replanting occurred in 1981 (Luscar Ltd. 1982).

Coal Valley began evaluating the use of muskeg/till mix as a coversoil material in 1988. Three sites capped with this material established a grass cover and one was planted with pine and spruce in 1989 (Luscar Ltd. 1990).

A soil reclamation assessment of the Coal Valley Mine was completed by Paragon Soil and Environmental Consulting Inc. in 2007 (Arregoces and Leskiw 2007). Coversoil and spoil evaluation were based on the interaction of soil physical and chemical properties and final ratings were based on the degree of suitability of material. The Soil Quality Criteria (ASAC 1987) was used to evaluate the soil horizons and profiles (Table 3.1). The convention used in the Soil Quality Criteria (ASAC 1987) was to rate soil according to its most limiting property, and this approach was used in the evaluation. Results indicated that overall reclamation in the reclaimed areas was well done, with little evidence of erosion and no evidence of compaction. Most of the cover soils and spoil materials were rated as good quality; a few sites (6%) had fair cover soil due to one or more limitations including pH, coarse fragments, texture, and $CaCO_3$. Spoil materials were rated as good to fair in terms of their chemical properties, however were inferior due to increased coarse fragment contents. Reclaimed landforms blended well with the natural surrounding landscape and reclaimed soils have allowed establishment of vegetation with 80 to 90% cover in the majority of the areas.

3.2.3.2 Obed Mountain

Twelve probes installed in 1987 on a south facing slope of Obed North allowed for soil moisture and temperature measurements in the summer months of 1988. Initial readings indicated that subsurface temperature and moisture were well within the range advantageous to tree growth (Obed Mountain Coal Company Ltd. 1988).

A long term soil and vegetation monitoring program was initiated in 2002 which involved the establishment and baseline assessments of seven research plots that were monitored over several years (Leskiw et al. 2007). The investigation of representative reclaimed plots indicated that land reclamation at the Obed Mine was resulting in soils of comparable characteristics and quality to natural soils in the locality (Leskiw et al. 2007). Soil physical properties, nutrient levels and salinity are all within the range found in natural soils (based on limited sample size). While the soil materials did not appear to be limiting the achievement of land use objectives, a number of suggestions were made to reduce limitations resulting from reclamation practices:

- Implement proper erosion control practices at sites affected with rill and gully erosion in the reclaimed landscape.
- Direct placement of soil has provided superior rooting conditions and encouraged the re-establishment of native plant species, and should be continued. Consideration should be given to the placement of soil using techniques that produce a rougher, more mounded soil surface.

3.2.3.3 Cardinal River Coals Ltd. – Luscar Mine

Beginning in 1987 research plots were established to determine the effectiveness of topsoil depth for reforestation. The project took several years to develop due to mining activities. Three topsoil islands were constructed, each in three sections of 8, 12 and 16 inch depths (approximately 20, 30, and 40 cm). Each section was planted with Engelmann spruce, lodgepole pine, hybrid poplar, dwarf birch, dogwood, wild rose, black elderberry, willow, silverberry, elderberry and shrubby cinquefoil. Not all species were planted on each topsoil island. Additional planting was conducted in 1988, 1989 and 1990 with the same species to complete the planting (Cardinal River Coals Ltd. 1991).

Knapik and Macyk (1996) carried out an evaluation of soil development on reclaimed areas at Cardinal River Coals Luscar Mine. They reported that the rough, mounded micro-relief of the mine soil surface provided numerous good planting sites and diversity for trees, shrubs, herbs and grasses. There was also a large amount of woody material, lumps and rocks on the surface, all of which added to surface roughness and diversity. The combination of landscape location and surface roughness reduced wind exposure which reduced moisture loss and helped to retain snow cover during winter Chinook events. Maintaining an adequate snow cover is a key factor for the survival of tree seedlings in this area. The surface layer of the minesoil (the salvaged and replaced "topsoil island") had low bulk density due to the "dump and push" construction method, which is ideal for tree planting and for unrestricted root growth.

In 2001, a soil monitoring program based on the criteria for evaluating the suitability of root zone material in the Eastern Slopes Region as outlined in *Soil Quality Criteria Relative to Disturbance and Reclamation* (ASAC 1987) was initiated by Can Ag Enterprises (Cardinal River Coals Ltd. 2003). The program was carried out on a biannual basis to chart the progress of soil re-establishment on areas reclaimed with topsoil. Two reclaimed plots and one natural plot were established to monitor soil quality, vegetation growth and the development of forest ecosystems.

The results from 2001 indicated that the soil quality ratings within the natural and reclaimed profiles were similar with the exception of pH as a limitation for the reclaimed soils (Leskiw and Pollard 2001). There were higher pH values in the reclaimed soils, while salinity (EC) and sodicity (SAR) values were very low and similar to those of natural soils. Soil nutrient status suggested that equivalent nutrient status was being attained. Cation exchange capacity and organic carbon values were similar on reclaimed and natural soils. Soil structure, consistence and color were also similar on reclaimed and natural soils.

A soil survey of portions of the reclaimed lands within the Luscar Mine was conducted by Paragon in 2005 to provide an assessment of the reclamation completed between 1985 and 2000 (Arregoces et al. 2006). The mapping in the reclaimed areas indicated that the reclamation was well done, and the reclaimed landforms blend well with the natural surrounding landscape. Reclaimed soils have allowed establishment of vegetation with 90 percent cover in the majority of the three areas mapped, with only a few small (<10 m^2) bare areas. Most of the cover soils and regolith materials were rated as good quality; a few (22%) were fair due to one or more limitations including pH, SAR, texture, and $CaCO_3$. There was no evidence of compaction and there was little erosion in vegetated areas. Spoil materials were also good to fair in terms of chemical properties but they were inferior due to higher coarse fragment content. The conclusion of the study was that soil mounding is considered to be a very effective reclamation practice that contributes to favourable soil conditions, micro-site diversity and reduced erosion.

3.2.3.4 Gregg River

No information was available.

3.2.3.5 Grande Cache Area Operations

In 1971, McIntyre Porcupine Mines Ltd., the original mine operator in the Grande Cache area commissioned the Alberta Research Council (ARC) to establish a reclamation research study in the No. 8 Mine area. A similar study was initiated at the No. 9 Mine in 1976. A project to evaluate the potential for revegetation of mined land in the alpine region at the No. 12 Mine was initiated in 1992. The projects which have focused on soil management, revegetation, and climate monitoring, have continued for the duration to the present. Annual reports and conference papers provide the details of the various projects and the results obtained.

Soil monitoring data obtained in the early 1970s indicated that reconstructed soils were generally coarser textured, higher in pH and lower in available nutrients than unmined soils. The silt loam texture combined with very low levels of organic matter resulted in a crusting problem which had a direct bearing on infiltration capacity and processes such as runoff and erosion. Infiltration tests indicated that the undisturbed soils had considerably higher infiltration rates than the reconstructed soils (Macyk 1975). Plate 3.18 provides a cross-section of a reconstructed soil in 1975, two years after coversoil placement on the rock spoil. Plate 3.19 provides a cross section from the same area in 2001 or 28 years after initial placement. Plate 3.20 provides a cross section of another site in 2005. The coversoil was replaced in this area in 1972 and initial revegetation occurred in 1973.

A field experiment to study the effect of soil depth on revegetation success was established at the No. 9 Mine in 1979. The plot area represented south and southeast facing aspects and the overall soil thickness ranged from 0 to 0.42 m (Plate 3.21). Agronomic and native grass seed and fertilizer were part of the treatment. By 1983 the vegetation was well established and not grazed heavily by sheep therefore yield samples could be obtained (Macyk and Widtman 1983). A substantial difference in growth between fertilized and unfertilized plots was observed. The 1983 data indicated that yield was not a function of soil depth. Four of the eight treatments showed higher yields on the 0.15 to 0.30 m soil depths and the remaining four showed higher yields on the 0.30 to 0.40 m depths. It was apparent that 0.15 m of soil was adequate for revegetation utilizing grasses and legumes, provided that nutrient levels are maintained and moisture levels adequate. In 1985 treatments with 0.15 to 0.30 m of topsoil produced higher yields than plots with 0 to 0.15 m of topsoil under moisture stress conditions due to an increased water holding capacity associated with the thicker soil layers.

Additional studies indicated that raw spoil would support a vegetation cover of grasses and legumes (Plate 3.22) (Macyk 1982a). The quality and quantity of the growth was dependent on the amount of fines present, the plant species utilized, and the amount and frequency of fertilizer application. The application of topsoil over spoil areas was not necessary for establishment of a vegetation cover of grasses and legumes, however, the extent of the cover was proportional to the characteristics of the spoil.

Two different surface or growth medium materials including the surface soil material (Plate 3.23) and the "rock spoil" material (Plate 3.24) were utilized for plot establishment at the No. 12 Mine alpine site in 1992 (Macyk 1994). Four species were tested on the plots, alpine bluegrass, slender wheatgrass, broadglumed wheatgrass and sheep fescue. Results in 1996 indicated that the four grass species utilized in the experiment were suitable for revegetation in the area (Macyk and Pojasok 1998). Although the coversoil and rock spoil materials both offered attributes that enhanced the potential for reclamation success, the grass cover was denser at the coversoil than the rock spoil plots. The coversoil material offered more potential germination sites, had higher natural soil fertility, and provided a better medium for nutrient retention and availability to plants.

Plate 3.18. Cross-section of a reconstructed soil in 1975.

Plate 3.19. Cross-section of a reconstructed soil similar to Plate 3.18 in 2001.

Plate 3.20. Cross-section of a reconstructed soil in 2005 (coversoil replaced in 1972).

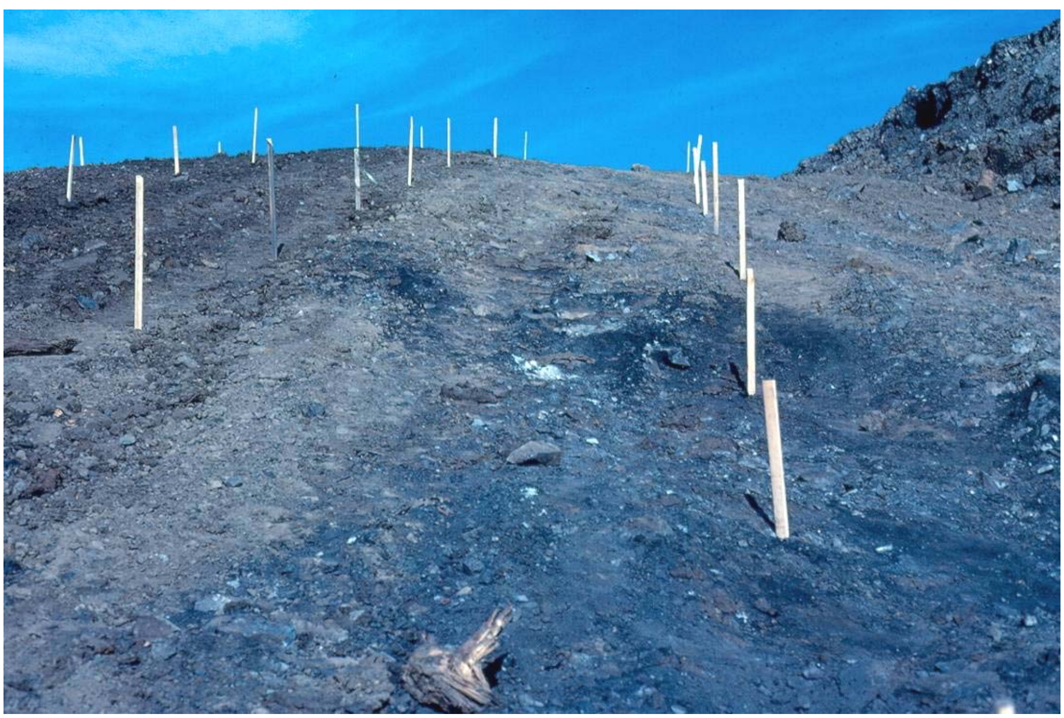

Plate 3.21. Soil depth study at No. 9 Mine.


Plate 3.22. Vegetation on rock spoil at Barrett area.


Plate 3.23. Coversoil or surface soil material at No. 12 Mine.


Plate 3.24. Rock spoil material as surface "soil" at No. 12 Mine.

A comprehensive climate monitoring program was implemented in 1973. During the course of this program, climate was recognized as the most limiting factor to reclamation success in the region (Macyk et al. 1989). The types of equipment used changed with time as the technology improved and monitoring locations were added as mining advanced to include stations at the 800 m, 1,500 m, 1,800 m and 2,100 m elevations (Plate 3.25). The parameters measured included air temperature, soil temperature, rainfall, wind speed and direction, relative humidity, solar radiation and soil moisture.

Rainfall distribution data has allowed for the development of recommendations regarding the optimum time for seeding and planting and the periods when less than optimum precipitation and ultimately soil moisture conditions are likely to prevail. Rainfall intensity data has provided insight into the ability of reconstructed soils to absorb water or allow infiltration to occur and the potential for runoff and erosion to occur.

Soil temperature data has provided the basis for recommendations regarding locations where planting of tree seedlings should not be undertaken due to high surface soil temperature. Wind speed and direction data has resulted in revegetation strategies that take into account the dynamics of native seed dispersion and the effects of snow cover removal in some areas, and the need for adequate ground cover to protect susceptible species such as newly planted tree seedlings.


Plate 3.25. Weather station at the alpine site.

3.2.4 REVEGETATION

3.2.4.1 Herbaceous Revegetation

3.2.4.1.1 Coal Valley

In 1980 the equipment used for revegetation included an ATV-mounted electric seeder, hand held seeders a John Deere 350 crawler tractor and harrows. **Three seed mixes were developed for different site conditions at the Coal Valley Mine site.** A "wet mix" was used in ditches, a "thin mix" was used in areas of low fertility or thin soil sites and a "standard mix" was used on slopes and normal sites (Table 3.2) (Luscar Ltd. 1981). A hydroseeder was added to the equipment used for revegetation in 1981 and the "thin mix" was eliminated from the program.

Table 3.2. Seed mixes used at Coal Valley Mine from 1978 to 1980.

Wet Mix	Thin Mix	Standard Mix
35% Reed canarygrass	10% Lemtal Italian ryegrass	10% White clover
35% Meadow foxtail	15% Creeping red fescue	20% Timothy
20% Alsike clover	5% Alsike clover	30% Violet wheatgrass or Crested wheatgrass
10% Lemtal Italian ryegrass	10% Violet wheatgrass	30% Russian wild ryegrass
	15% Streambank wheatgrass	10% Lemtal Italian ryegrass
	15% Hard fescue	
	10% Timothy	
	10% Beardless wheatgrass	
	10% Cicer milkvetch	

Note: All seed was mixed with fertilizer (11-48-0 and 34-0-0) and applied at a rate of 45 kg/ha.

In 1982 a D 3 Caterpillar crawler tractor with a seed-drag set was used in the revegetation program and a "fast growing mix" was added for sites requiring immediate revegetation (e.g. steep slopes, impoundment berms and soil stockpiles) (Table 3.3).

Table 3.3. Seed mixes used at Coal Valley Mine in 1982.

Wet Mix	Standard Mix	Fast Growing Mix
30% Reed canarygrass	20% Timothy	30% Crested wheatgrass
35% Meadow foxtail	10% Sheep fescue	35% Creeping red fescue
20% Alsike clover	10% Dutch white clover	15% Italian ryegrass
10% Winter wheat	15% Russian wild ryegrass	10% Alsike clover
5% Common red top	5% Creeping red fescue	5% Alfalfa
	15% Crested wheatgrass	
	10% Streambank wheatgrass	

In 1983 three varieties of the standard seed mix were used on slopes and upland sites (Table 3.4) (Luscar Ltd. 1984). These different mixes were chosen to examine the suitability of some different grass or legume species, in slightly different combinations, for reclamation purposes. Initial fertilizing was generally done at the same time as seeding. Prior to seeding, the seed was mixed with an equal amount by weight of 11-48-0 fertilizer. If possible, seeding was done in spring to take advantage of better soil moisture conditions. However, coversoiling of reclaimed areas was an ongoing process and seeding of these areas was sometimes done at less than optimum conditions. **Techniques which improved establishment included harrowing, early seeding (April/May) and the inclusion of annual ryegrass and sweet clover in the mix (Luscar Ltd. 1986). The ryegrass established quickly and died off in one or two years and the sweet clover provided good cover and improved soil nitrogen levels while still allowing space for establishing tree and shrub seedlings.**

Table 3.4. Seed mixes used at Coal Valley Mine in 1983 and 1984.

Wet Mix	Fast Growing Mix	
30% Reed canarygrass	20% Crested wheatgrass	
35% Meadow foxtail	20% Creeping red fescue	
20% Alsike clover	10% Timothy	
10% Winter wheat	10% Alsike clover	
5% Common red top	15% Sweet clover	
	25% Fall rye	
Standard Mix ‘A’	**Standard Mix ‘B’**	**Standard Mix ‘C’**
20% Timothy	10% Dutch white clover	5% Dutch white clover
10% Sheep fescue	10% Timothy	5% Timothy
10% Dutch white clover	10% Creeping red fescue	10% Creeping red fescue
15% Russian wild ryegrass	20% Winter wheat	20% Fall rye
5% Creeping red fescue	20% Sheeps fescue	20% Crested wheatgrass
15% Crested wheatgrass	20% Crested wheatgrass	10% Red top
10% Streambank wheatgrass	5% Red top	5% Sweet clover
10% White clover	5% Sweet clover	15% Meadow foxtail
10% Winter wheat		10% Sainfoin
5% Red top		

Grass seeding on mined, reclaimed areas in 1986 followed procedures similar to those used in 1985:

- Seed was broadcast at a rate of 25 to 50 lb/ac (28 to 56 kg/ha) depending on erosion potential and site aspect.
- Electric seeders (ATV mounted) and hand-held seeders were used.
- Seeding was done in April to June, to take advantage of moist soil conditions.
- Most seeded areas were harrowed shortly afterwards.
- No fertilizer was directly applied with the seed in 1986.

Grass seeding on reclaimed areas in 1988 followed procedures used previously. Smooth brome was included in the mix on a test basis in 1988 to further improve ground cover establishment. From 1998 to 2002 areas were broadcast seeded using three methods:

- Cyclone seeders mounted on a D8 or D7 dozer were used to seed larger areas. Seed was applied at a rate of 60 kg/ha along with fertilizer at a rate of 180 kg/ha. All areas were harrowed immediately after the seeding was complete.
- Hand seeding using small cyclone seeders was completed in smaller areas and those areas which were inaccessible by heavy equipment.
- A cyclone seeder mounted on the rear of an ATV was used for areas of moderate terrain.

In 2002 larger areas were broadcast seeded by helicopter. Seed mixes consisted of the species in Table 3.5.

Table 3.5. Seed mixes used at Coal Valley in 2001 to 2005.

Seed Mix 1 and 2 – Standard Upland

2001 Seed Mix	%	2002 to 2005 Seed Mix	%
Common red top	10	Northern wheatgrass	10
Boreal red fescue	15	Boreal red fescue	15
Smooth brome grass	10	Mountain Brome	10
Climax timothy	10	Slender wheatgrass	10
Annual rye grass	20	Annual rye grass	20
Durar hard fescue	5	Durar hard fescue	5
Common sweet clover	5	Common sweet Clover	5
Dutch white clover	15	Dutch white clover	15
Sainfoin	10	Sainfoin	10

Seed Mix 3 – Tailings Pond Mix

2001 Seed Mix	%	2002 to 2005 Seed Mix	%
Common red top	10	Common red top	10
Alsike clover	15	Alsike clover	15
Climax timothy	20	Reed canary grass	40
Reed canary grass	40	Red clover	15
Red clover	15	Northern Wheatgrass	20

Seed Mix 4 – Wetland Mix

2001 Seed Mix	%	2002 to 2005 Seed Mix	%
Reed canary grass	30	Reed canary grass	30
Meadow foxtail	10	Meadow foxtail	10
Common red top	10	Common red top	10
Climax timothy	10	Northern wheatgrass	10
Annual rye grass	15	Annual rye grass	15
Alsike clover	12.5	Alsike clover	12.5
Cicer milk vetch	12.5	Cicer milk vetch	12.5

3.2.4.1.2 Obed Mountain

The 1985 revegetation and erosion control programs consisted primarily of remedial hydroseeding and planting of willow cuttings along the ditches and slopes of the access corridor for bank stabilization. The seed mix was applied at a rate of 50 kg/ha and was comprised of Climax timothy, Durar hard fescue, Manhattan perennial ryegrass, Fairway crested wheatgrass, Rambler alfalfa, Sodar streambank wheatgrass, Aurora alsike clover, and Boreal creeping red fescue. Fertilizer (27-27-0) was broadcast at a rate of 150 kg/ha.

The 1986 revegetation program consisted primarily of remedial hydroseeding and handseeding. The seed mixture used in the program contained the species listed in Table 3.6.

Table 3.6. Species mix used in 1986 at Obed Mountain Mine.

Species	%
Climax timothy	7
Crested wheatgrass	13
Durar hard fescue	14
Creeping red fescue	14
Rambler alfalfa	20
Alsike clover	14
Cicer milkvetch	10
White sweetclover	8

This seed mixture was noted for its durability, adaptability, tolerance to weather extremes and creation of fibrous root systems necessary for soil stabilization on slopes of granular material (Obed Mountain Coal Company Ltd. 1986). The mixture was applied at an average rate of 80 kg/ha. Fertilizer was applied at a rate of 125 kg/ha with the seed.

The 1987 revegetation program consisted of combined hydroseeding and handseeding methods with the same seed mixture used in 1986. The seed mixture was applied at an average rate of 75 kg/ha.

The 1988 and 1989 revegetation programs consisted of remedial hydroseeding on existing reclaimed sites. The species mix for both years was altered to include perennial ryegrass and meadow foxtail, and timothy and hard fescue were removed.

The majority of seeding in 1990 was carried out with a specially designed broadcast seeder attached to a D7 dozer. Seed was applied at a rate of 75 kg/ha and fertilized with 12-51-0 at 150 kg/ha. The seed mixture used in 1990 differed only slightly from that used in the past, as meadow foxtail was replaced with orchard grass (Table 3.7). Erosion areas were seeded using hand Cyclone seeders at similar application rates. A Finn hydroseeder was utilized for the remedial seeding program along slopes to aid in erosion control and slope stability. Due to the woody nature of the topsoil used on site, conventional draw harrows were inadequate. A drag that operated efficiently and required little maintenance was therefore constructed (Obed Mountain Coal Company Ltd. 1990).

All of the seeding in 1991 was done with a broadcast seeder attached to a D7 dozer. Seed was applied at a rate of 75 kg/ha and fertilized with a 12-51-0 mixture at 150 kg/ha. Both the seed and fertilizer were applied at the same time. The seed mixture differed from 1990 in the percentages of the species in the mix (Table 3.7). The manual of *Plant Species Suitability for Reclamation in Alberta* – 2nd Ed (Hardy BBT Ltd. 1989) provided the information and suggestions necessary for the re-evaluation of the seed mix.

Table 3.7. Species mix used in 1990 and 1991 at Obed Mountain Mine.

Species	1990 %	1991 %
Rambler alfalfa	20	20
Cicer milkvetch	15	10
Creeping red fescue	15	20
Crested wheatgrass	15	15
Orchard grass	15	15
Sweet clover	10	15
Perennial ryegrass	10	5

Areas that were seeded in 1990 were visually assessed in 1991 to determine if the harrowing regime affected revegetation. **It appeared that harrowing prior to seeding and not during seeding was the most effective practice for the soil type at the mine (Obed Mountain Coal Company Ltd. 1991). It was also determined that spring sowing needed to be carried out while the frost was still in the ground to allow for superficial levelling with harrows to minimize the disturbance caused by the seeding equipment and to give the seed the greatest growing season length.**

In 1992 broadcast seeding took place in late winter/early spring and in the fall. Seed was applied at a rate of 75 kg/ha and fertilized with a mixture of 12-51-0 at 150 kg/ha. The seed mixture used in 1992 was the same as that used in 1991 (Table 3.8).

The seed mixture used in 1993 was modified based on recommendations from a reforestation consultant (Table 3.8). **The mixture was changed so that the percentage of "leggy" grasses and legumes were reduced making the grass cover more compatible with reforestation.**

Table 3.8. Seed mixes used at Obed Mountain Mine in 1992 and 1993.

1992 Seed Mix	%	1993 Seed Mix	%
Rambler alfalfa	20	White clover	20
Cicer milkvetch	10	Sainfoin	10
Creeping red fescue	20	Creeping red fescue	15
Crest wheatgrass	15	Crest wheatgrass	7
Orchard grass	15	Climax timothy	10
Sweet clover	15	Sweet clover	10
Perennial rye	5	Annual ryegrass	10
		Red top	10
		Slender wheatgrass	8

Seeding and fertilization methods and rates used in 1994 and 1995 were the same as those used in 1993. A drag bar, constructed of old railway rail was used as a harrowing unit pulled directly behind the dozer applying the seed and fertilizer with a broadcast seeder.

In 1997 all of the broadcast seeding was completed during the fall prior to snowfall. Seed was sown at a rate of 75 kg/ha and fertilized with a 12-51-0 mixture at 150 kg/ha. Where necessary, a harrowing device was pulled directly behind the dozer. The seed mixture used in 1997 was slightly different from that used previously as the percentage of sweet clover was dropped from 10% to 5% and Sainfoin was increased by 5%.

Seed and fertilizer were applied in 1998 at the same time and rate as previously, however, the fertilizer was changed to 11-51-0. The seed mixture used in 1998 was slightly different from that used in 1997 because sweet clover was removed from the reclamation mix and birdsfoot trefoil was added at 5% to replace it (Obed Mountain Coal Company Ltd. 1998).

Seeding rate was reduced to 60 kg/ha and fertilizer rate was reduced to 115 kg/ha (11-51-0) in 1999. Seeding methods and seed mixture remained identical to those used in 1998.

There was no revegetation completed at the mine site during 2000 because areas planned for seeding had not yet reached the appropriate stage of reclamation for seeding.

Both seed and fertilizer were applied before the ground froze in 2001 using a D7 dozer and a broadcast seeder. Seed was sown at a rate of 75 kg/ha and fertilized with17-20-0 at 200 kg/ha. A new seed mixture was formulated to incorporate native species and enhance ungulate browse capabilities (Table 3.9) (Luscar Ltd. 2001).

Table 3.9. Species mix used at Obed Mountain Mine in 2001.

Species	%
White clover	19
Creeping red fescue	7
Sainfoin	9
Canada bluegrass	7
Annual ryegrass	22
Red top	8
Slender wheatgrass	11
Fowl bluegrass	6
Hard fescue	4
Tufted hairgrass	3
Rocky Mountain bluegrass	4

Seed was sown in 2002 at a rate of 75 kg/ha and fertilized with a 17-20-0 mixture at 200 kg/ha.

3.2.4.1.3 Cardinal River Coals Ltd. – Luscar and Cheviot Mines

The terrain at Cardinal River Coals Ltd. is highly variable and seeding techniques were site specific. Hydroseeding was used until 1979, however, it was expensive and thereafter used in a more discriminating fashion.

Areas completed in 1979 were seeded either by the hydroseeder in early October or in August with an electrically operated cyclone seeder mounted on a D3 dozer pulling a set of chain-following harrows to incorporate the mixture into the replaced soil layer. The seeding was completed in August using the following mixtures (Table 3.10) (Cardinal River Coals Ltd. 1980).

Table 3.10. Seed mix and application rates used at Cardinal River Coal Ltd.'s Luscar mine in 1979.

Components	%	Hydroseeding Application Rate	Cyclone Seeding Application Rate
Seed – Alfalfa	12	55 lb/ac	30 lb/ac
Timothy	2	(62 kg/ha)	(34 kg/ha)
White sweetclover	10		
White Dutch clover	4		
Smooth brome	20		
Creeping red fescue	5		
Crested wheatgrass	14		
Pubescent wheatgrass	33		
Fertilizer - 11-21-0		150 lb/ac (169 kg/ha)	100 lb/ac (112 kg/ha)
Fertilizer - 34-0-0			25 lb/ac (28 kg/ha)
Mulch		500 lb/ac (562 kg/ha)	

On steep embankments where erosion and exposure posed potential problems, mulching rate was increased to 1000 lb/ac (1124 kg/ha) and an organic binder called "Hydro Seal" was applied at 50 lb/ac (56 kg/ha).

Seeding in 1980 consisted mainly of small projects around the minesite. The seed mix applied during 1980 contained orchard grass, alsike clover, sainfoin and cicer milkvetch in addition to the species used previously. The mixture was developed to achieve a 50-50 blend of legume and grass seeds. The application rate for seed, fertilizer and other soil amendments was as follows: seed mixture – 62 kg/ha, fertilizer (34-0-0) - 56 kg/ha, (11-51-0) - 112 kg/ha, fibre mulch – 1120 kg/ha, and J Tac binder – 45 kg/ha.

There was no seeding of pit reclamation areas in 1981. Seeding in 1982 consisted mainly of several small projects around the minesite and the underground portal site. **The seed mix applied in 1982 consisted of creeping red fescue, Canada bluegrass, Durar hard fescue, streambank wheatgrass, crested wheatgrass, tall fescue, alfalfa, alsike clover, sanfoin, cicer milkvetch and sweet clover.** A hydroseeder was utilized for all seeding except where restricted access required the use of a hand carried or dozer mounted cyclone seeder.

The restriction of the sloping and regolith spreading programs during 1984 limited the volume of revegetation conducted. Only two small areas were seeded. Both areas were seeded utilizing an electrically powered cyclone seeder mounted on the rear of a 850 dozer. A set of chain following harrows was dragged behind the dozer to incorporate the seed-fertilizer mixture into the soil. In a steep area, the hydroseeder sprayed a similar seed-fertilizer mixture in combination with cellulose fibre mulch at a rate of 1000 lb/ac (1124 kg/ha). In addition to the species used in 1982, new species added to the seed mix included Arctared fescue, Kentucky bluegrass, orchard grass, timothy and smooth bromegrass. Application rate was based on 250 bare seeds/ft^2 (0.093 m^2) of coverage. Fertilizer applied with the seed included 55 lb (25 kg) of 34-0-0 and 110 lb (50 kg) of 11-51-0.

Delays in regolith replacement operations caused by inclement weather during the summer of 1985 limited the amount of revegetation completed. Large areas were seeded aerially by helicopter in 1985. Either a hydroseeder, dozer mounted cyclone seeder or hand carried cyclone seeder were utilized for seeding. Species within the seed mixes remained the same, only the percentage of each species in the mix changed. Seed was applied at a rate of 42 lb/ac (47 kg/ha). Fertilizer was applied with all seed mixtures at a rate of 55 (62 kg/ha) and 110 lb/ac (124 kg/ha) of 34-0-0 and 11-51-0, respectively. In hydroseeder applications the seed-fertilizer mixture was sprayed in combination with a cellulose fibre mulch at a rate of 500 lb/ac (562 kg/ha). A set of chain following harrows was used during the dozer mounted cyclone seeding to incorporate the seed-fertilizer mixture into the soil.

Seed was applied by hydroseeder and broadcast seeders carried by dozers, helicopters or manually in 1986. Fertilizer rates, seeding methods and seed mixes in 1986 remained the same as 1985.

The 1987 and 1988 revegetation programs utilized several different application methods dependent upon the size and topography of the different sites (Cardinal River Coals Ltd. 1988). Broadcast application from a small helicopter or dozer was used at the majority of the sites. Manual broadcast seeding and hydroseeding were the preferred methods at the smaller sites and those with steeper topography. Seed and fertilizer were applied in combination with cellulose mulch at a rate of 500 lb/ac (562 kg/ha) during the hydroseeding application. A set of chain following harrows was used when dozer broadcast seeding. Fertilizer was applied with the seed mix at a rate of 55 lb/ac (62 kg/ha) of 34-0-0 and 110 lb/ac (124 kg/ha) of 11-51-0 in most areas. The seed mixture components and application rates changed slightly. Pubescent wheatgrass and annual ryegrass were added to the seed mix in 1987 and three application rates were used depending on the area: 42 lb/ac (47 kg/ha), 2.5 lb/ac (2.8 kg/ha) and 54.3 lb/ac (61 kg/ha). Sweet clover was applied with fertilizer on topsoil island areas.

No aerial seeding was conducted in 1989, 1990 or 1991. Seeding methods utilized depended on the size and topography of the individual sites. A small dozer was used to simultaneously broadcast seed and harrow at the majority of the sites and manual broadcast seeding and hydroseeding were the preferred methods at the smaller sites with steeper topography. Topsoil island seeding was supplemented with 115 lb/ac (129 kg/ha) of 11-51-0. The difference between “normal” and “topsoil island” seed mixes was the percent of each species (by weight) in the mix and the application rates. The “normal” seed mix was applied at 53.8 kg/ha and the "topsoil island" mix was applied at 25.2 kg/ha.

Although the seeding program remained similar in 1992 and 1993, aerial seeding was conducted on the larger areas.

For 1994, the seed mix was modified by the inclusion of two native species: northern wheatgrass and alpine bluegrass. These two species were noted as invader species on reclaimed rock dumps. Several of the tall growing species including orchard grass and Canada/Kentucky bluegrass were eliminated due to lodging problems with tree seedlings (Cardinal River Coals Ltd. 1995). Smooth bromegrass was also removed from the mix as it was felt that it was too competitive for the native species. Commencing in 1994, one seed mix was used for all areas of the mine to save cost.

The seed mix was revised in 1998 due to poor performance on regolith replaced sites (Cardinal River Coals Ltd. 1999). Different seed mixes were used for topsoil and regolith areas. The new regolith mix was based on a seed mix used previously that had good success on regolith. The seed mixes are provided in Table 3.11 and were applied at a rate of 53.8 kg/ha.

Table 3.11. Topsoil and regolith seed mixtures used in 1998 at the Luscar Mine.

Topsoil Seed Mixture		**Regolith Seed Mixture**	
Seed Variety	**%**	**Seed Variety**	**%**
Boreal red fescue	5	Arctared fescue	4.2
Hard fescue	9	Hard fescue	3.9
Mountain bromegrass	10	Kentucky bluegrass	1
Alpine bluegrass	5	Canada bluegrass	1.5
Kentucky bluegrass	5	Smooth bromegrass	16.7
Canada bluegrass	5	Pubescent wheatgrass	13.9
Northern wheatgrass	15	Slender wheatgrass	7.4
Wild ryegrass	15	Rangelander alfalfa	11.3
Rangelander alfalfa	7	Kay orchardgrass	3.5
Alsike clover	4	Alsike clover	4.2
Cicer Milkvetch	10	Cicer Milkvetch	8.3
Sweet clover	5	Sweet clover	6.6
Annual ryegrass	5	Annual ryegrass	5
		Sanfoin	12.5

The seed mix application rate was increased to 55.9 lb/ac (62.8 kg/ha) in 2000. In 2001, a mix utilizing native species was used for topsoil areas and another mix was used on areas requiring re-seeding of regolith areas. The mixture used for re-seeding consisted of Canada bluegrass, hard fescue, slender wheatgrass, pubescent wheatgrass, Duhurian wild rye and Nordica alfalfa. In the topsoil seed mix Boreal red fescue was replaced with Creeping red fescue; slender wheatgrass and white clover were added to the mix and Kentucky bluegrass, alsike clover and cicer milkvetech were eliminated. The application rate was reduced to 53.8 kg/ha in 2002. Seeding in 2002 was done by hand because areas were small. In 2003, all seeding was undertaken by helicopter. Seed was applied at an average rate of 31 kg/ha.

In 2004, a seed mix utilizing a combination of agronomic and native species was used for topsoiled areas and a regolith seed mixture was used on areas designated as grasslands (Table 3.12). In 2004, all seeding was done by hand as locations were relatively small. The application rate for both seed mixes was 31 kg/ha.

Table 3.12. Seed mixtures used in 2004 at the Luscar Mine.

Topsoil/Agronomic Seed Mixture		**Regolith Seed Mixture**	
Seed Variety	**%**	**Seed Variety**	**%**
Rangelander alfalfa noducoat	11.3	Rangelander alfalfa noducoat	6.0
Alsike noducoat	9.2	Alsike noducoat	4.0
Oxley cicer milkvetch	8.3	Oxley cicer milkvetch	10.0
Sainfoin noducoat	12.5	Sweet clover noducoat	5.0
Sweet clover noducoat	8.8	Alpine bluegrass	8.0
Canada bluegrass	1.5	Canada bluegrass	5.0
Kentucky bluegrass	1.0	Kentucky bluegrass	5.0
Carlton brome	10.7	Mountain bromegrass	10.0
Creeping red fescue	4.2	Boreal creeping red fescue	5.0
Hard fescue	3.4	Hard fescue	9.0
Orchardgrass	3.5	Annual ryegrass	5.0
Annual ryegrass	5.0	Northern wheatgrass	13.0
Pubescent wheatgrass	13.9	Dahurian rye	15.0
Slender wheatgrass	7.7		

No seeding operations were conducted in 2005. **In 2006, two seed mixes were used on the minesite. A seed mix utilizing a combination of agronomic and native species was used for topsoiled areas and a regolith seed mixture was used on areas designated as grasslands (Table 3.13). The topsoil mix changed from previous years to encourage natural recovery (Elk Valley Coal Corp. 2007). Much of the mix was comprised of short-lived annual ryegrass, and most of the remaining species were either native or slow-growing, non-competitive grasses.** The application rate for both seed mixes was 50 kg/ha.

Table 3.13. Seed mixes used in 2005 at the Luscar Mine.

Species	Topsoil Mix %	Regolith Mix %
White clover	-	14
White/yellow sweet clover	5	-
Slender wheatgrass	10	7
Annual ryegrass	70	50
Rocky mountain fescue	5	3
Alpine bluegrass	4	3
Hard fescue	6	3
Northern wheatgrass	-	5
Tufted hairgrass	-	5
Fringed bromegrass	-	5
Canada bluegrass	-	5

The two primary goals for the revegetation program at the Cheviot mine are to minimize erosion and to provide high quality forage for wildlife (Elk Valley Coal Corp. 2006). Two seeding strategies were used on the Cardinal River Coals Cheviot mine between 2004 and 2006. A seed mix utilizing a combination of agronomic and native species was used on areas that were prone to erosion and a nurse crop of annual ryegrass was used on areas that were not prone. The area seeded was located along the haul road. Seeding methods utilized were based on the size and/or topography of the sites requiring treatment. In 2004, all seeding was undertaken by hydroseeder and hand broadcast. Seed was applied at an average of 28 lb/ac (31.5 kg/ha) and fertilized with a blend of 13-16-25.

In 2005, an annual agronomic cover crop was planted on recently disturbed areas along the haul road. The cover crop was planted to protect the soil from desiccation as well as from erosion by wind and water.

3.2.4.1.4 Gregg River

Revegetation in 1981 was consistent with the stated objective of erosion control as opposed to an objective of permanent reclamation (Gregg River Resources Ltd. 1982). Revegetation was performed using agronomic seed mixtures with a proven ability for rapid establishment. Various seed mixtures and application rates were tested and the following species were used: creeping red fescue, Kentucky blue grass, streambank wheat grass, intermediate wheat grass, timothy, orchard grass, crested wheat grass, alsike clover, Rambler alfalfa, and brome grass. Grass was broadcast seeded in May and August at a rate of 30 to 40 kg/ha and fertilized with 10-30-10 at a rate of 100 to 120 kg/ha.

Slopes along the Gregg River that were topsoiled and qualified as final reclamation slopes were seeded on the assumption that they may eventually be reforested as part of the comprehensive mine reclamation program aimed at achieving the desired end land uses of wildlife habitat and watershed protection.

Revegetation work performed in 1982 consisted of ripping/disking the surface where necessary (e.g. tailings dam face), cyclone seeding slopes at 35 to 50 kg/ha, fertilizing at 135 to 400 kg/ha with 11-48-0 and harrowing where slopes permitted (Gregg River Resources Ltd. 1983). Seeding was done in late October and early November with Canada #1 reclamation super mix which included Boreal creeping red fescue, Basho timothy, Kentucky bluegrass, white clover, and alsike clover.

In June 1983, Gregg River Resources began a hydroseeding program on areas disturbed during the construction period. Materials for hydroseeding consisted of pubescent wheatgrass, Nordan wheat grass, red or hard fescue, orchard grass, climax timothy, alsike clover, fertilizer (6-24-24 and 34-0-0) and fibra mulch. The majority of hydroseeding was for erosion control while a lesser portion of the area revegetated was part of the final mine reclamation. The hydroseeding program was successful, however, the actual application rate per hectare was greater than originally anticipated (Table 3.14).

Table 3.14. Seed and fertilizer application rates in 1983 at Gregg River Mine.

Materials	Original Guidelines (kg/ha)	Actual Application (kg/ha)
Seed	50	73
Fertilizer (6-24-24)	500	866
Fertilizer (34-0-0)	50	107
Mulch	125	191

Species in the hydroseeding program in 1984 were altered to include crested wheatgrass and Rambler alfalfa. Application rates were comparable with the guidelines recommended. The amount of mulch was reduced to 75 kg/ha from the 125 kg/ha recommended in 1983 (Gregg River Resources Ltd. 1985).

Areas previously seeded in 1982 and 1983 were reseeded in 1984 to increase the amount of vegetation cover in these areas. Reseeding was done with the same mixtures as used in the initial seeding program however the application rates differed (Table 3.15). Areas were reseeded according to the amount of seed required for each specific location rather than following a set rate.

Table 3.15. Seed and fertilizer application rates in 1984 at Gregg River Mine.

Materials	Actual Application (kg/ha)
Seed	37
Fertilizer (6-24-24)	325
Fertilizer (34-0-0)	63
Mulch	64

Areas not requiring reseeding were fertilized as part of the overall revegetation program. Fertilizer rates were as follows: (6-24-24) - 367 kg/ha, (34-0-0) - 73 kg/ha, and mulch - 68 kg/ha.

Revegetation in 1985 consisted of a hydroseeding program as well as initiation of the first seedling transplanting program. In 1986 the revegetation program consisted of seeding, reseeding, fertilizing and tree and shrub planting. Three different seed mixtures were used in the hydroseeding program which contained different combinations and percentages of the following species: crested wheatgrass, hard fescue, orchard grass, climax timothy, alsike clover, Rambler alfalfa, creeping red fescue, streambank wheatgrass, and pubescent wheatgrass. Fertilizer (6-24-24 and 21-0-0) and fibra mulch were also part of the mixture. Seed and fertilizer rates, 205 and 1,005 kg/ha (6-24-24), 160 kg/ha (21-0-0) respectively, were higher in 1986 than in 1985.

The majority of seeding in 1993 was accomplished by hydroseeding a mixture of seed at 154 kg/ha, fertilizer (6-24-24 at 1645 kg/ha and 34-0-0 at 98 kg/ha) and mulch at 113 kg/ha. A small area was seeded with a seed mix that consisted primarily of native species with a cyclone seeder which was being evaluated for future uses on the minesite (Gregg River Resources Ltd. 1994). The native seed mixture contained slender wheatgrass, sheep fescue, Canada bluegrass, cicer milkvetch, alsike clover, fowl bluegrass, orchard grass and alpine bluegrass. The species in the agronomic mixture remained the same.

In 1994 and 1995 both an agronomic and native seeding program were employed. Areas seeded with agronomic seed mixtures were designated as grazing land for the wildlife component. The only change in the seeding methods was the fertilizer used in the hydroseeding mixture (Table 3.16). The new fertilizer used was 8-24-24. Mixed forest and riparian zone developments were seeded with the native seed mixture to minimize competition on any future tree and shrub plantings (Table 3.17). The species in the native species mixture remained the same with the exception of orchard grass being removed.

Table 3.16. Hydroseeding treatment rates at Gregg River Mine in 1994 and 1995.

Materials	Actual Application (kg/ha)
Seed	84
Fertilizer (8-24-24)	1117
Fertilizer (34-0-0)	74
Mulch	68

Table 3.17. Seed mixtures used at Gregg River Mine in 1994 and 1995.

Agronomic Mixture	Native Mixture
Intermediate wheatgrass	Slender wheatgrass
Crested wheatgrass	Sheep fescue
Hard fescue	Canada bluegrass
Orchard grass	Cicer milkvetch
Climax timothy	Alsike clover
Alsike clover	Fowl bluegrass
Rambler alfalfa	Alpine bluegrass

Seeding in 1996 was carried out on permanently reclaimed areas and reseeding was undertaken on bare locations that had previously been seeded and topsoil piles requiring additional vegetative cover for wind erosion problems. Seeding rates, fertilizer rates and seeding mixtures did not change much from 1995.

In 1997, 1998 and 1999 all areas were seeded with a mixture comprised of both agronomic and native seed (combined agronomic mixture and native mixture).

The grass and legume (agronomic and native seed) mixture was used in the reclamation program in 2000. During June 2001, reclaimed minesite areas were seeded by helicopter with a wildlife forage mix and a reforestation mix. The only species included in the wildlife forage mix that is not included in the reforestation mix is cicer milkvetch (Table 3.18).

Table 3.18. Seed mixtures used in 2001 at Gregg River Mine.

Wildlife forage mix	Reforestation Mix
Slender wheatgrass	Slender wheatgrass
Broadglumed wheatgrass	Broadglumed wheatgrass
Bearded wheatgrass	Bearded wheatgrass
Creeping red fescue	Creeping red fescue
Nakiska hard fescue	Nakiska hard fescue
Canada bluegrass	Canada bluegrass
Alpine blueridge bluegrass	Alpine blueridge bluegrass
Alpine glacier bluegrass	Alpine glacier bluegrass
Annual ryegrass	Annual ryegrass
Alsike clover	White clover
Alfalfa	Alfalfa
Sainfoin	Sainfoin
Cicer milkvetch	Yellow sweetclover
Yellow sweetclover	

There were no changes to the revegetation mix from 2001 to 2002. In 2003 Nakiska hard fescue was removed from the mixtures and Sheep fescue, fringed bromegrass and Troy Kentucky bluegrass were added. Mountaineer wheatgrass and Northern wheatgrass were added to the mixtures in 2004 and tufted hairgrass was added in 2005. All the reclaimed areas at Gregg River Mine had been seeded as of 2005, therefore no further seeding was conducted in 2006 with the exception of a small amount of remedial seeding.

3.2.4.1.5 <u>Grande Cache Area Operations</u>

In 1971 all disturbed land was seeded according to Alberta Forest Service specifications. These included application of 40 lb/ac (45 kg/ha) to 80 lb/ac (90 kg/ha) of a seed mix including:

- 50% creeping red fescue
- 20% Kentucky bluegrass
- 15% perennial ryegrass
- 15% alsike clover

The fertilizer was 16-20-0 applied at a rate of 200 lb/ac (225 kg/ha) (McIntyre Mines Ltd. 1976).

In 1972 seeding and fertilizing were completed with hand operated broadcast seeders. The seed mixture, rate and fertilizer remained the same as the previous year. A system of small contour terraces was used on steep side hills.

In 1972, 1973, and 1974 experimental plots were established at several locations in the No. 8 Mine area by the ARC (Plates 3.26 and 3.27) (Macyk 1973, Macyk 1974, and Macyk 1975). These plots were established to test various grasses, legumes, tree seedlings, fertilizer types, and application rates as well as soil stabilizer amendments.

In 1973 the first "operational" revegetation took place at the No. 8 Mine. The area was hand broadcast seeded in two directions to ensure a uniform application. The area was fertilized with 27-14-0 and 0-0-60. Following spreading of seed and fertilizer the area was dragged with a heavy chain attached to a caterpillar dozer. The following seed mixture was spread in the area at a rate of 60 lb/ac (67 kg/ha):

- 20% Crested wheatgrass
- 20% Sawki Russian wild rye
- 40% Carleton brome grass
- 20% Boreal creeping red fescue
- 10% Rambler alfalfa

Slow release fertilizers were first tested in 1975 to determine their effectiveness for revegetation purposes (Macyk 1976). Seed which had been collected from native species in August 1974 was planted in 1975. In the following year hairy wildrye produced some ground cover but little or no growth occurred where seed of alpine hedysarum, loco-weed and lupine were planted. However, in the summer of 1977 the remaining three species produced excellent ground cover.

Grass and legume growth on sloped surfaces was significantly increased with the use of burlap (Plate 3.28) and leno-mesh (Plate 3.29) (Macyk 1976). Burlap was more effective than leno-mesh under drier conditions as it retained more moisture and maintained a cooler ground surface. Leno-mesh was more useful under moister conditions and the coarser weave allowed for easier penetration by germinants.

In 1975, a 50 acre area was seeded and fertilized. The seed mixture, applied at 80 lb/ac (90 kg/ha), was comprised of:

- 20% Crested wheatgrass
- 20% Magna bromegrass
- 20% Creeping red fescue
- 20% Climax timothy
- 20% Rambler alfalfa

Variations of this seed mix were used in other areas where alfalfa was removed and the amount of crested wheatgrass was increased in the mix. Where possible the seeded areas were dragged prior to and following seeding. All seeding and fertilization at No. 8 Mine was done by hand broadcast (Plate 3.30).

Plate 3.26. Plots at No. 8 Mine.


Plate 3.27. Plots at No. 8 Mine.


Plate 3.28. Burlap.


Plate 3.29. Leno-mesh (right side of photo).


Plate 3.30. Hand broadcasting seed and fertilizer.

In the 1970s, after an area was initially seeded and fertilized (Year 1), it was reseeded and re-fertilized in Year 2 at a rate of 50% of the initial application. This was generally found to be sufficient for seeding. The area was then re-fertilized in Years 3, 5 and 7, again at rates of 50% of the initial application (McIntyre Mines Ltd. 1981). No herbicides, pesticides or soil sterilants were used.

In 1980, two seed mixes were used (Table 3.19). Seed mix No. 1 was used on relatively moist and cool north and east facing exposures and seed mix No. 2 was used on relatively dry, crown, south and west facing exposures (McIntyre Mines Ltd. 1980). The seed mixes were seeded at a rate of 80 lb/ac (90 kg/ha) using broadcast seeders. Flatter areas were seeded using a powered seeder mounted on a pickup truck while steeper areas were seeded by using hand broadcast seeders.

Table 3.19. Seed mixes used at McIntyre Mines Ltd. in 1980.

Seed Mix No. 1		**Seed Mix No. 2**	
Species	**% of Mix**	**Species**	**% of Mix**
Carlton bromegrass	30	Boreal creeping red fescue	30
Climax timothy	20	Fairway crested wheatgrass	15
Boreal creeping red fescue	15	Carleton bromegrass	15
Fairway crested wheatgrass	15	Sawki Russian wildrye	15
Alsike clover	20	Rambler alfalfa	20

In 1985 only one seed mix was applied at a rate of 80 lb/ac (90 kg/ha) using broadcast seeders. The seed mix consisted of the same species as seed mix No. 2 although the composition changed. Hydroseeding became the major seeding technique at No. 9 Mine. Two types of seeding methods were used in 1986: broadcast seeding and hydroseeding.

Smoky River Coal Ltd's revegetation strategy was as follows (Smokey River Coal Ltd. 1987):

Year 1 – Seed and fertilize grass and legumes to provide an initial cover for site stabilization and erosion control.

Year 2 – Re-fertilize the area and reseed areas where the initial establishment was poor. Direct planting of willow cuttings may begin.

Year 3 – Leave the area alone. The erosion control should be well established and by not fertilizing in year 3, it should begin to "slow down" and reduce the competition with native species to be planted in year 4.

Year 4 – Plant native species such as loco-weed, lupine, willow and alder. This will provide a cover crop for conifers where planting is required.

Year 5 – Plant conifers where required.

For areas with slopes of 18 to 27º, the methodology remained the same except there were no conifers planted in Year 5.

In 1987 the seed mixture was changed as a result of research conducted by the Alberta Research Council. The change suggested that lesser amounts of species such as creeping red fescue be included in seed mixtures and that fertilizer applications be minimized when establishing and maintaining an effective grass/legume cover (Smoky River Coal Ltd. 1988). As a consequence of the observations and experience to date the proportion of alfalfa and bromegrass in the seed mix used for operational revegetation was increased and the proportion of creeping red fescue decreased for the 1987 seeding program:

- 10% Creeping red fescue
- 20% Crested wheatgrass
- 20% Brome grass
- 20% Russian wildrye
- 30% Alfalfa.

All seeding was done at a rate of 80 lb/ac (90 kg/ha) by broadcast seeding or hydroseeding.

The same seed mix was used from 1988 to 1997, however all large area seeding between 1988 and 1993 was done with a hydroseeder at a rate of 90 kg/ha. Broadcast seeding was also done on “fill-in” areas using hand seeders. During 1992 an additional 10 lbs (4.5 kg) of wildflower seed mix was also spread on select areas. It was anticipated that the wildflowers would spread to adjacent areas over time. **Revegetation “staging” was practiced at Smoky River Coal beginning in 1992. This meant the revegetation process included 1) an initial cover, 2) the addition of non woody native species and shrubs (by natural means or seeding/planting, and 3) addition of tree species by use of direct seeding or seedlings.**

All seeding in 1997 was done by broadcast seeding utilizing hand held seeders. Four native grasses including alpine bluegrass, Highlander slender wheatgrass, Mountaineer broadglumed wheatgrass and sheep fescue obtained from native plant researchers at the Alberta Environment Center and a commercial seed supplier were seeded at the alpine research site in 1992 (Plate 3.31) (Smoky River Coal Ltd. 1993). Germination and emergence were well underway by mid-June 1993 and by 1995 mature seed was being produced by all species (Plates 3.32 and 3.33). Excellent growth was maintained throughout the subsequent years to the present (Plates 3.34 and 3.35).


Plate 3.31. Aerial view of alpine research site.


Plate 3.32. Initial growth at Caw Ridge plots in 1994.

Plate 3.33. Seed set by broadglumed wheatgrass.

Plate 3.34. Growth at Caw Ridge Plots in 1999.

Plate 3.35. Growth at Caw Ridge Plots in 2005.

In 1998 a second seed mix was used that was more adaptive to particular elevations and aspects (Smoky River Coals Ltd. 1999). The seed mix included:

- 10% durar hard fescue
- 10% rough fescue
- 20% dahurian wild rye
- 20% russian wild rye
- 20% brome grass
- 10% PS120 alfalfa
- 10% cicer milk vetch.

Seeding activities were completed using both a hydroseeder and manual seeding. Fertilizer was placed within two weeks of the initial seeding to prevent the potential for seed burning.

In 1999 the seed mix was changed to:

- 10% alpine blue grass
- 15% rough fescue
- 30% highlander slender wheat grass
- 30% mountaineer broadglumed wheat grass
- 15% PS 120 alfalfa.

This seed mixture contained commercially available native varieties as they are more adaptive to the area (Smoky River Coal Ltd. 1999). Seeding during 1999 was completed using both a hydro-seeder and broadcast seeding methods.

In 2005 the seed mixes used for the purpose of establishing an erosion control plant cover and temporary reclamation consisted of the species in Table 3.20.

Table 3.20. Seed mixes used at Grande Cache Coal in 2005 and 2006.

Seed Mix 1	Seed Mix 2	Seed Mix 3
10% Alpine bluegrass	10% Alpine bluegrass	35% Slender wheatgrass
10% Alpine fescue	15% June grass	30% Sheep fescue
10% Sheep fescue	20% Rough fescue	5% Fowl bluegrass
25% Slender wheatgrass	20% Slender wheatgrass	5% Fringed Brome
25% Broad-glumed wheatgrass	20% Broad-glumed wheatgrass	10% Streambank wheatgrass
15% PS alflafa	15% Wild vetch	5% June grass
		10% Perennial Rye

3.2.4.2 Trees and Shrubs

3.2.4.2.1 Coal Valley

In 1981 approximately 3,950 lodgepole pine seedlings and 7,050 rooted cuttings of several species of shrubs and herbs mainly willow, bearberry, and lesser amounts of 16 other species were planted at a density of 1,428 stems/ha (Luscar Ltd. 1981).

In 1982 approximately 6,500 lodgepole pine seedlings and 3,200 rooted cuttings mainly willow, balsam poplar, alder, and lesser amounts of 12 other species were planted at a density of approximately 806 stems/ha.

In 1983 approximately 56,500 lodgepole pine seedlings reared in Spencer-Lemaire "Fives" and 7,500 other seedlings and rooted cuttings including mainly willow, green alder, white birch, dock species, pussytoe species, and lesser amounts of 10 other species were planted on 24.8 ha of land. Seedlings were planted using either tree planting mattocks or Swedish "Pottiputkis" (Luscar Ltd. 1984). On reclaimed areas, lodgepole pine seedlings were planted with a spacing of 2 to 2.8 m. Other seedlings or rooted cuttings were planted in small groups of 15 to 30 plants, with 10 to 25 groups/ha. Plant spacing within each group was 1 to 2 m.

Fifty seven hectares of reclaimed land were planted in 1984 with 115,400 lodgepole pine, 13,100 white and black spruce, 12,200 other tree or shrub species including willow, green alder, aspen poplar, balsam poplar, dwarf birch, red osier dogwood and shrubby cinquefoil and 3,600 of several species of herbs. Planting methods remained the same in 1984 as 1983.

In 1986, 120,000 trees and shrubs were planted. Species were the same as used previously. All of the pine seedlings were 1 year stock, grown in Styroblock 4s or equivalent. Seedlings were planted with shovels in May. Pine seedlings on the more extreme, southern exposures were individually fertilized immediately following planting. Twenty grams of 7-40-6 'Mag-Amp' was spread around the base of each seedling.

The tree and shrub planting program in 1987 was similar to previous years with the addition of rose and currant species. In 1988, 43,800 lodgepole pine, trembling aspen, balsam poplar, and willow were planted on reclaimed lands. Planting times and techniques remained consistent with previous years. The same species were planted in 1989 on Coal Valley's reclaimed lands.

In 1998 white spruce and lodgepole pine were planted at two different times; 2+0 stock were planted in May and 1+0 stock were planted in early July. All seedlings were individually fertilized with a fertilizer tablet (5 g) (20-10-5, Agriform). All planting stock was grown from seed collected in the vicinity of the Coal Valley minesite. The planting density in 1998 to 2005 averaged 2,000 stems/ha. In 2002, 34.6 ha of land was reforested with white spruce and lodgepole pine and willow cuttings were planted on an area of approximately 1 ha along the lakeshore (Table 3.21).

Table 3.21. Tree species and stock type used at Coal Valley Mine in 2002 and 2005.

Family	Species	Stock Type
Coniferous Tree Seedlings	Lodgepole Pine	Nursery Stock 2+0, 1+0 PSB 415b+415d containers
	White Spruce	Nursery Stock 2+0, 1+0 PSB 415b+415d containers
Deciduous Tree Seedlings	Willow	Bareroot stock 1+0 Grown on Mine Site
	Green Alder	Nursery Stock 1+0

3.2.4.2.2 <u>Obed Mountain</u>

In 1987, 2,640 spruce and pine seedlings were planted on reclaimed slopes in Obed North. A portion of the area was not hydroseeded in order to observe the rate of natural vegetation regeneration (Obed Mountain Coal Company Ltd. 1987).

The first major reforestation program since reclamation activities began at Obed North in 1986 was carried out in 1989. A mixture of spruce and pine seedlings were planted at a rate of 1,320 stems/ha. The seedlings were planted in an area that had been revegetated for two full growing seasons. Various seedling sizes were planted and evaluation of the growth and survival potential of the different seedlings was conducted.

Reforestation activities in 1990 were limited to picking cones for seed stock since no suitable planting sites were available, however the cones selected were generally of poor quality and no suitable seed stock was recovered. No planting or cone collection was undertaken in 1991.

During 1993 several Siberian larch test plots were established across the site to determine the effectiveness and potential for using alternative species for reforestation. As well, a total of 27,600 spruce seedlings were planted using 2+0 313 plug size white spruce stock grown by Pelton Reforestation.

Reforestation was not conducted at the minesite during 1994. In late June, 1995 tree planters planted 18,020 1+0 stock lodgepole pine and white spruce. A total of 97,250 tree seedlings were planted on reclaimed areas of the mine in 1996. Both lodgepole pine and white spruce were planted at a density of 2,000 to 2,200 stems/ha. The seedlings planted were a 2+0 aged 415B plug size tree. The pine seedlings were grown in copper treated cavities (cooperblock) to limit binding of the roots. Observations of the Siberian larch test plots indicated good growth for those trees that survived, but mortality was quite high.

A total of 20,790 tree seedlings were planted on reclaimed areas of the mine in 1997. Both lodgepole pine and white spruce were planted at a density of 2,000 to 2,200 stems/ha.

There was no reforestation completed at the minesite during 1998 and 1999 as a result of very few areas being reclaimed to the degree necessary for tree planting.

A total of 100,440 2+0 aged 415B plug size tree seedlings were planted by contract planters on reclaimed areas of the mine in June 2000. Both lodgepole pine and white spruce were planted at a density of 2,000 and 2,200 stems/ha.

A total of 21,240 tree seedlings were planted on reclaimed areas of the mine in 2001. Both lodgepole pine and white spruce were planted at a density of 2,300 stems/ha. No reforestation occurred during 2002.

Historically pine seedlings had suffered a high rate of mortality due to browsing by deer and competition from grasses (Luscar Ltd. 2003). The planting sites for the 54,000 1+0 pine seedlings planted in 2003 were chosen to minimize exposure to deer. Various methods of site preparation were also considered. Spruce cones were collected from a subalpine area by a contractor for future use.

In 2004, 65,000 2+0 spruce seedlings were planted at a stocking density of 2300 stems/ha. Of the 65,000 seedlings planted, 50,000 were planted using Reforestation Technologies International Silva Pak 26-12-6 (9 g) fertilizer packets.

In 2005 there were 119,340 2-0 spruce seedlings planted at a density of 2,200 stems/ha in an attempt to reach the target density of 1,800 stems/ha for mature trees.

3.2.4.2.3 Cardinal River Coals Ltd. – Luscar Mine

In June 1980, approximately 2,000 lodgepole pine bareroot seedlings were received from the Alberta Forest Service and planted at Cardinal River Coal Ltd.'s Luscar Mine in August. Simpson Timber Co. (Alberta) Ltd. were contracted during 1980 to plant 5,000 lodgepole pine and 5,000 engelmann spruce in Spencer-Lemaire containers (Cardinal River Coals Ltd. 1981). **Pine and spruce cones were collected from the area for future planting.**

In the summer of 1981, 9,700 lodgepole pine and 9,900 Englemann spruce seedlings, reared under contract by Simpson Timber Co. (Alberta) Ltd., were transferred to the on-site shadehouse for hardening off. Deciduous cuttings were collected and were propagated off site to be planted in 1982.

A planting program was conducted in five areas during September of 1982 (Cardinal River Coals Ltd. 1983). The areas included the Gregg dump topsoil island, Gregg dump prescribed burn plot, Gregg dump scarification plot, topsoil islands on the backfill dump and on a recontoured dump. Engelmann spruce and lodgepole pine propagated in Spencer Lemaire containers from seed collected on-site were planted. The two species were alternately planted at 9 ft. x 9 ft. (2.7 m x 2.7 m) spacing for a stocking rate of 1,330 stems/ha. The seedlings were treated on two occasions with the antidessicant "Wilt Pruf"; once in the shadehouse prior to planting and once in the field immediately after planting. A contract planting crew utilized both mattocks and planting bars with the former being most efficient, particularly in areas where scalping was required.

During 1984, attempts were made to remedy low survival. Extra care and attention was taken when replanting previous years' losses and windbreak structures (i.e. rocks and stumps) were placed adjacent to each seedling (Cardinal River Coals Ltd. 1985). Two small plots were enclosed to determine the survival rate when sheep were restricted from using the area.

In 1994 a total of 18,050 coniferous seedlings consisting of lodgepole pine (11,550) and englemann spruce (6,500) were planted. The planting was completed both on a dump site and on topsoil islands.

A total of 37,930 seedlings were planted in 1995: 8,775 willow, 8,600 cinquefoil, 7,675 black poplar, 2,685 white spruce and 10,245 lodgepole pine. The deciduous seedlings were planted on topsoil islands and the coniferous seedlings were planted on the dumps. A slow release fertilizer was applied to each seedling during planting.

The reforestation completed in 1997 and 1998 was done in two stages with frozen and hotlift stock. The frozen stock planted in May, 1997 included 51,441 lodgepole pine and 15,930 white spruce. The hotlift stock planted in June, 1997 included a total of 14,520 alder, birch, and buffaloberry and 19,710 white spruce. A total of 112,680 seedlings were planted in 1998 and consisted of buffaloberry, white spruce and lodgepole pine.

The reforestation program in 2000 consisted of planting 68,310 deciduous and coniferous seedlings in June. Species included white spruce, lodgepole pine and green alder. In 2001, 1,800 willow cuttings were planted in May and another 41,680 deciduous and coniferous (cinquefoil, bog birch, alder, buffaloberry, willow and white spruce) seedlings in June. All seedlings were planted with a slow release fertilizer tea bag. Biopak (16-6-8) tea bags were used with coniferous seedlings and alderpak (5-25-8) tea bags were used with deciduous seedlings.

The reforestation program in 2002 consisted of planting a total of 54,705 seedlings in early July. The seedlings consisted of 50,220 spruce, 2,595 buffaloberry and 1,890 seedlings from the *Rhododendron* genus.

No reforestation was undertaken in 2003 or 2004. In 2005, 57,000 coniferous seedlings were planted and in 2006, approximately 29,000 hybridized white and Engelmann spruce and 29,000 lodgepole pine seedlings were planted. These were two-year old greenhouse grown seedlings, produced in 412B styroblocks from seed collected at the mine site.

3.2.4.2.4 Gregg River

Tree and shrub planting was initiated at the Gregg River Mine in 1985. All cuttings and seed except for balsam poplar were collected from the Gregg River property and started in a commercial greenhouse. Tree species collected included lodgepole pine and balsam poplar. Shrub species included buffaloberry, shrubby cinquefoil, bearberry, wild rose, wolf willow, wild raspberry, and willow. Tree and shrub species were planted at a density of 1,100 stems/ha (Gregg River Resources Ltd. 1986).

The 1987 reforestation program consisted of a mixed forest shrub community with both trees and shrubs being planted at 1,100 stems/ha. Trees planted were white spruce, lodgepole pine and balsam poplar. Shrubs planted included wolf willow, willow, wild rose, cinquefoil, dogwood, elderberry and honeysuckle.

Revegetation practices remained the same until 1991 when northwest poplar was added to the reforestation plan and planting densities changed (Gregg River Resources Ltd. 1992). Coniferous species were planted at a stocking rate of 900 stems/ha. Poplars were planted at a rate of 600 stems/ha, with the majority of the plants being balsam poplar. A stocking rate of 1,500 stems/ha was used for the remainder of the species planted. The planting density in 1992 changed to 2,000 stems/ha for coniferous species and 1,450 stems/ha for shrubs and deciduous trees.

Tree planting in 1993 was completed in May with three year old coniferous stock consisting of white spruce and lodgepole pine at a stocking density of approximately 1,470 stems/ha. All stock was transplanted from styroblock 20 containers.

Siberian larch was added to the list of coniferous species planted in 1994. A total of 49,275 spruce seedlings were planted in 1995 at a rate of 2,000 stems/ha. In 1996, 43,840 spruce seedlings and 11,990 deciduous seedlings were planted. Deciduous species included wolf willow, willow, cinquefoil, wild rose, balsam poplar, raspberry, and snowberry.

Seedlings were planted at an average density of 2,545 stems/ha in 1997 (Gregg River Resources Ltd. 1998). Species included white spruce, alder, willow and wild rose. In 1998, 41,930 trees and shrubs were planted at an average density of 3,080 stems/ha. Species included white spruce, alder, willow, wild rose, cinquefoil, wolf willow, and buffaloberry.

In 1999, white spruce and Douglas fir were planted at a stocking density of 2,500 stems/ha. No trees were planted in 2000. A total of 22,050 lodgepole pine, alder, bog birch, spruce, buffaloberry and cinquefoil seedlings were planted in 2001. A total of 7,020 spruce seedlings were planted in 2002. A total of 261,775 spruce, pine, cinquefoil, birch and alder seedlings were planted throughout the minesite in 2003. A total of 380,315 spruce, pine, cinquefoil, birch and alder seedlings were planted in 2004. A total of 383,670 spruce, pine, cinquefoil, birch and alder seedlings were planted in April and May 2005. The seedlings were "spring" stock which were pulled from their containers the previous fall and frozen until just before planting time. The pine and spruce were 2-0 and the balsam poplar and cinquefoil were 1+0, all grown in 412B styroblocks. Alder were 1+0, grown in 415D's. All seedlings were typically planted within 24 hours of being pulled from the refrigerated trailer. One quarter of the seedlings were planted with a fertilizer "teabag" (BioPak 16-6-8 plus minor elements) inserted into the planting hole without coming into contact with the seedling root plug. A total of 250,980 spruce and pine were planted throughout the minesite in April and May 2006.

3.2.4.2.5 Grande Cache Area Operations

A program to introduce trees and shrubs to the disturbed areas was undertaken concurrently with the grass and legume establishment program conducted by the ARC. In 1972 approximately 500 one year old seedlings and 300 three year old bare root seedlings were planted in two areas. The one year old seedlings were grown in a "peat sausage" container developed by ARC. This container was produced by extruding a peat-water mixture into a continuous casing which was sliced into cylinders or "sausages" which were 2.5 cm in diameter and 7.5 cm long (Mitchell et al. 1972). Before planting the polyethylene tube casing was either removed, not removed or perforated. It was determined that the skin off treatment had the highest survival rate.

Because conifer seedlings suitable for planting above an elevation of 1,100 m were unavailable at the time, a cone collection program (Plate 3.36) was undertaken and greenhouse space acquired to produce lodgepole pine, englemann spruce, and white spruce (Plate 3.37). Different types and sizes of containers were utilized to determine which ones were most effective for use in the reconstructed areas and to determine cost-effectiveness. The container type was the "Spencer Lemaire" with four difference sizes: Ferdinand – 39 cm^3, Five – 39 cm^3, Hillson – 164 cm^3 and, Tinus – 328 cm^3. The highest seedling survival rates occurred with the Tinus containers (Macyk 1985).

Willow (Plate 3.38) and balsam poplar (Plate 3.39) cuttings, as well as root cuttings of aspen, were rooted in the greenhouse for subsequent planting and caragana seedlings propagated from seed were planted (Plate 3.40). Willow cuttings were also direct planted (Plate 3.41). **These materials were planted in areas with an established grass and legume cover. This practice was questioned initially because of the anticipated competition for moisture. It became obvious that the negative aspects of competition for moisture were far outweighed by the protection afforded the seedlings by the grass and legume cover, especially in holding snow in the winter (Plates 3.42 and 3.43).**

Plate 3.36. Cone collection.


Plate 3.37. Seedlings in different sized containers in the greenhouse.

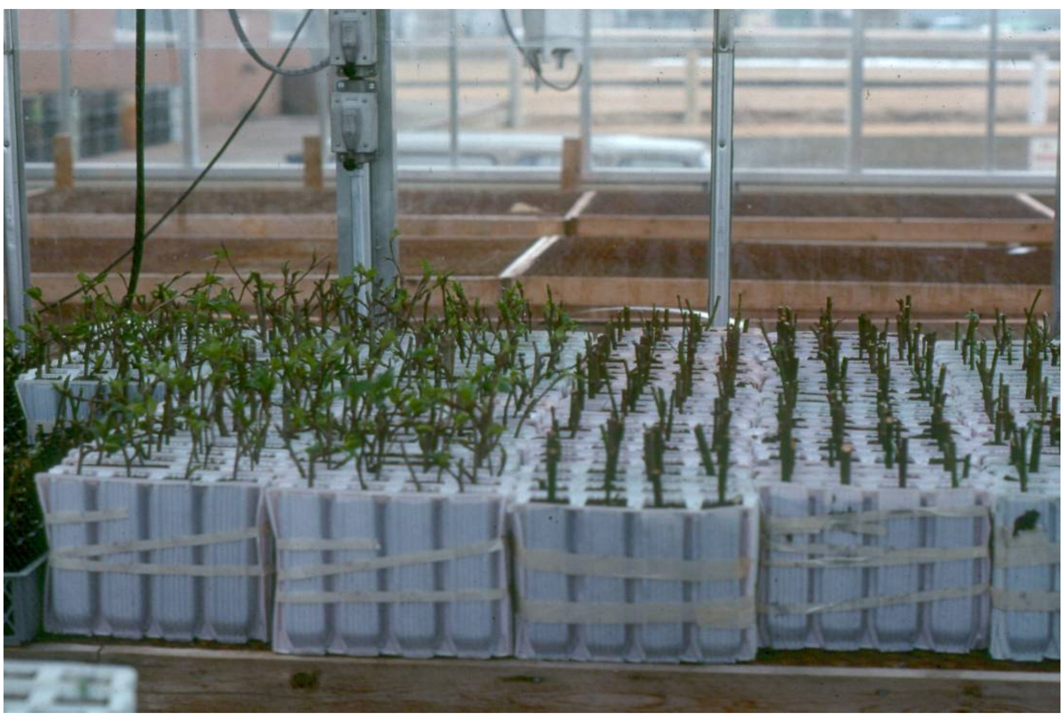
Plate 3.38. Willow cuttings rooted in greenhouse.


Plate 3.39. Balsam poplar cuttings rooted prior to planting.

Plate 3.40. Caragana.


Plate 3.41. Direct planted willow.


Plate 3.42. Grass cover protecting seedling in first winter following planting.


Plate 3.43. Grass cover continues to protect seedling several years after planting.

A total of 6,000 tree seedlings (3,000 two year old bare root white spruce and 3,000 two year old bare root lodgepole pine) were planted in various locations at the No. 8 Mine area in 1975. They were planted in areas where a grass and legume mixture had been planted the previous year. During 1981, 23,500 englemann spruce seedlings were planted at No. 8 Mine along with balsam poplar and willow rooted cuttings.

Direct seeding trials for conifer establishment were initiated in 1983 for two major reasons. First of all, investigations relative to seedling survival and growth indicated that some of the seedlings demonstrating poor growth had limited root egress (Plate 3.44). Furthermore, frost heaving of some of the container seedlings resulted in the exposure of the upper root mass above the soil surface resulting in the eventual death of the seedling (Plate 3.45). Spring and fall seeding programs including engelmann spruce and lodgepole pine were initiated in 1984. Following three years of trials the results indicated that pine had a better germination rate and that fall seeding resulted in substantially higher germination rates than spring seeding. Plates 3.46 to 3.48 illustrate the progression of pine germinants from 1984 to 1996. Alder was included in the program in 1985 (Plates 3.49 and 3.50) and the technique became an excellent one for alder establishment.


Plate 3.44. Poor root egress from containers.


Plate 3.45. Root crown exposed resulting in seedling mortality.

Plate 3.46. Pine after germination.

Plate 3.47. Pine 5 years after seeding.

Plate 3.48. Pine 13 years after seeding.


Plate 3.49. Alder germinants.


Plate 3.50. Alder several years later.

Five hundred willow cuttings were direct planted in spring 1985. The survival rate of these cuttings was approximately 10%. In the fall of 1985, seeds from lodgepole pine, englemann spruce, alder, lupine and fireweed were collected.

Operational scale planting tests were initiated in 1990. These tests included planting rooted and non rooted willow, alder and poplar cuttings for shrubs, direct seeding of pine and spruce seeds, transplanting of pine and spruce from areas being cleared and transplanting shrubs. Species included pine, spruce, willow, poplar, rose, wolf willow, alder and dogwood. The source for all the species were areas that were actively being cleared for mining.

A total of 2,987 seedlings were planted in 1991. Species included pine, spruce, poplar, willow, alder, rose, raspberry and buffaloberry. During 1992, a total of 12 tree and shrub test plots were established. A total of 912 trees and shrubs were planted in these plots. The species included pine, spruce, willow, poplar, rose, wolf willow, alder and dogwood. An additional 2,678 cuttings and seedlings were planted in different areas including seepage sites, light drainage areas and established grass sites. In 1993, 15,000 seedlings were planted in selected areas at the No. 9 Mine. Lodgepole pine made up the coniferous component and the remaining deciduous species consisted of alder, poplar, dogwood, rose and willow cuttings collected from the property. The planting program in 1994 consisted of two year old pine stock and willow, alder and poplar. The stock for the deciduous component was collected from cuttings around the minesite and planted in the onsite greenhouse.

The planting strategy of seedlings was diversified in 1995. The previous practice was to plant a mix of greenhouse grown coniferous and deciduous species which resulted in poor survival rates. In 1995 the approach changed to a "random debris placement" method. This involved the scattering of "live blocks and cuttings" of various sizes of deciduous species. Due to the limited placement of debris blocks, an accurate assessment of this approach could not be made in 1996.

During 1997, 30,000 tree seedlings, including lodgepole pine, were planted on reclaimed and partially disturbed areas. A total of 20,000 lodgepole pine seedlings were planted in 1998. Smoky River Coal Ltd was required to plant trees and shrubs to a density of 1000 stems/ha at a ratio of 60% coniferous and 40% deciduous stock. Seedling plantings in 1997 showed an 80% coniferous to 20% deciduous ratio. The difference from the required ratio of planting was attributed to climatic concerns, soil tilth and fertility, and wildlife. Due to limitations such as climate, moisture deficits and limited soil quality a "clump planting" strategy was adapted where applicable. This meant that along with planting the seedlings at a three meter spacing (1000 stems/ha) the seedlings were planted at between 1 and 1.5 m intervals resulting in the planting of over 4000 stems/ha in some areas. These were planted in locations conducive to good planting and growing conditions. Both deciduous and coniferous species were mixed into this type of planting.

In 1999, 5,000 willow and 10,000 balsam poplar cuttings collected from Smoky River Coal Ltd.'s property were planted.

3.2.4.3 Revegetation Monitoring

Coal mine operators have been performing revegetation monitoring and research activities since the early 1970s. The information presented in this section has been obtained from annual conservation and reclamation reports which did not always provide the results for the projects completed, therefore results are not available for each project.

3.2.4.3.1 Coal Valley

Trials were set up in 1978 to evaluate variables affecting the establishment and maintenance of a suitable vegetation cover on reclaimed lands (Luscar Ltd. 1984). The variables included various grass or legume species establishment and relative competitiveness, seeding densities, seeding techniques, and fertilizer application rates. It was found that:

- Some varieties of species were overly competitive with native vegetation and planting stock. Conversely, others did not become established.
- Fast growing, non-sod forming, very short-lived species were beneficial on many sites. They provided the planted stock with protection from exposure during the critical establishment period, and acted as a short term erosion control cover until the slower-growing, less competitive species became established.
- Hydroseeding was not an effective or cost efficient means of establishing vegetation cover at Coal Valley.

- Heavy fertilizer application resulted in heavy grass production and tended to inhibit legumes and native plant/seedling growth.

"Wedge" plots were established in 1979 to demonstrate the growth potential of vegetation on a wedge of either blend material or topsoil over bentonitic clay (Luscar Ltd. 1980). The wedge plots were seeded with a grass/legume mix in 1979.

Biomass yields were obtained in 1980 from research plots. To obtain yields, all above ground vegetative growth, within the designated area, was measured in the field. Sub-samples were taken to determine field moisture content and allow for calculations of dry weight yields.

A native species demonstration plot was established in 1980 (Luscar Ltd. 1981). The plot was established to test various native species revegetation techniques on reclaimed land. Techniques involved laying down slash, transplanting shrubs and spreading ripe seed pods of herbs. There was no fertilizer treatment or seeding of agronomic species. Research continued in 1984 on different methods of native species establishment. Included in this research was direct seeding, the use of 'Shelter Cones', plant production techniques, and a field study of native species established on disturbed lands (Luscar Ltd. 1985).

Research was initiated in 1983 on the use of mycorrhizae to inoculate lodgepole pine seedlings to be planted on reclaimed areas (Luscar Ltd. 1984). Small quantities of two species of ecto-mycorrhizae were purchased and experiments were set up to determine appropriate methods of inoculating container-grown pine seedlings. A total of 6,500 seedlings were inoculated. At the end of the growing season, when the seedlings had become root-stable, samples of the seedlings from each of the treatments were analysed. These seedlings were planted on reclaimed sites in 1984.

In 1984, a seedling nutrient supply project was initiated involving fertilizing tree seedlings while they were being planted. Data collected supported the contention that initial pine seedling establishment and early growth on exposed sites could be significantly improved by fertilizing individual trees (Luscar Ltd. 1988).

Planting success was assessed annually on several temporary plots in previously reclaimed areas. Preliminary results in 1985 indicated that pine seedling survival rates were low, likely due to site exposure (south aspect and no grass cover) and seedling stock quality (poor hardiness at time of planting) (Luscar Ltd. 1986). Visual observations of other species indicated that alder, dwarf birch and rose were re-establishing well and the willows and hybrid and balsam poplar were establishing, but not as well. Other woody plants that appeared to be establishing well included shrubby cinquefoil, trembling aspen and bearberry.

In 1986 standard Alberta Forest Service Surveys (as per the Alberta Forest Regeneration Survey Manual, April 1979) were conducted on six areas at Coal Valley (Luscar Ltd. 1987). Additional information was collected on seedling growth and vigor and other growth-affecting factors (e.g. slope, aspect, exposure, ground cover, drainage, frost heaving, etc.). Stocking results were greater than 80% for all sites except one which had a stocking rate of 54.3%. Results indicated that spring planting of dormant stock provided better initial establishment than summer or fall planting or using non-dormant stock.

A study was conducted by Strong (2000) on revegetated lands within the Coal Valley mine to measure species composition, woody plant frequency and tree heights. Results indicated that the vegetation on the sampled sites was dominated by a mixture of creeping red fescue and white clover. Four distinctive plant communities were identified. A lodgepole pine/willow/Lindley's aster community represented the most advanced stage of forest development, and was comprised primarily of indigenous species. Total plant cover averaged >85% in all community types with plant litter covering >75% of the ground surface. There were 123 plant species growing on the mine site with 77% native species, although they represented <5% of the total vegetation cover. **The occurrence of a large proportion of native species suggests that floristic diversification is occurring as a result of natural processes.** Despite establishment issues, the data indicated that height growth of the surviving trees was sufficient in almost all cases to meet or exceed local reforestation standards.

A vegetation establishment study was initiated in 2007 on land reclaimed at Coal Valley Mine between 1979 and 2003 (Longman 2007). Preliminary results indicated that creeping red fescue had the highest constancy in the surveyed plots (n=765) and dandelion had the second highest constancy. A total of 96 species were recorded in the plot and many of the species had a constancy of less than 10%. The species richness per plot ranged from 25 down to three, with a mean of nine. Of the plots sampled 83% had at least one native species present and the average number of native species per plot was three. An increase in native species richness was evident with time.

3.2.4.3.2 Obed Mountain

The 1985 growing season was the fifth since reforestation field trials were established in the spring of 1981 (Obed Mountain Coal Company Ltd. 1985). A status check was made on all seedlings in the spring of each year. Soil moisture and temperature were monitored during the summer, and in the fall all surviving seedlings were measured for the current years leader growth, total height above ground, mortality and vigour.

Of particular concern was the over-winter death of spruce foliage and seedlings, typically preceded by purple discoloration of the needles commencing at the bottom of the tree. This type of damage is caused by snow mould, the occurrence of which is exacerbated by alternating freeze-thaw conditions and the build up of ice around the seedlings. This was a concern because over winter mortality had tripled since the previous year for spruce seedlings, a species which had previously been relatively tolerant to adverse climatic conditions. Several factors had previously been identified as influencing seedling mortality including climatic damage, adverse surface water conditions, grass competition, and treatment effects. It was apparent that wind exposure alone was not particularly harmful, but could be devastating in combination with lack of snow cover and fluctuating freeze-thaw conditions. These conditions emphasize the risk and uncertainty associated with growing commercial tree crops on exposed high-elevation sites, and the need to provide favourable microsites for seedling establishment.

Trees in test plots simulating post mining reforestation conditions were measured in 1992 to determine if these plots were applicable in real mining situations (Obed Mountain Coal Company Ltd. 1992). All surviving trees at three test plots were measured to determine annual growth and total survival. It was observed that tree growth in these plots was inferior to trees growing in surrounding cut blocks. A literature search of early reports on these plots showed that the provenance limits on the spruce trees had been exceeded making them unsuitable for planting at that elevation. That data also revealed that the pine trees were in a poor state of health at planting time due to successive freeze thaw cycles at the greenhouse. To better estimate growth performance of trees planted in the area several Weldwood plantations in the area were measured. Several cutblocks that had undergone different reforestation regimes were measured to determine what sort of growth could be expected. A thorough review of past reforestation projects was carried out at this time and recommendations for future programs were suggested. These included comments on planting sites with regard to ground cover and erosion, and time of planting and moisture conditions. Comments were also provided regarding planting stock in terms of when to grow it, overwintering procedures, and species suitability for the exposures present.

A regeneration survey was carried out at the tree plantations in Obed North in 1992 to determine stocking rates and total survival (Obed Mountain Coal Company Ltd. 1992). Results of this survey indicated inadequate stocking and a very poor survival rate. This poor survival was attributed to stock condition at the time of planting, lack of ground cover at the time of planting, over abundance of ground cover, and browse of the planted trees by ungulates (deer) during winter months. The degree of natural invasion in the area was observed to be quite good with establishment of willow, poplar and alder.

A long term soil and vegetation monitoring program was initiated in 2002 which involved the establishment and baseline assessments of seven research plots that were monitored over several years (Leskiw et al. 2007). **It was determined that low survival and growth of reclaimed land plantations can be attributed mainly to initial vegetation competition and browse damage on pine seedlings. Dense vegetation produced by aggressive legumes included in the revegetation mix was interfering with the establishment of most newly planting tree seedlings. This interference resulted from overtopping/shading and by physically pressing or flattening the seedling. Browse damage on pine seedlings by mule deer was consistently high on most sites.** The deer eat terminal and lateral buds, leaders, needles and bark.

A number of other factors may be influencing seedling survival and growth on reclaimed lands (Leskiw et al. 2007):

- Seed Source: One of the early annual reclamation updates suggested that the seed used to produce seedlings was not from a local provenance and indicated difficulties with collecting locally produced seed. Current government regulations require seedlings being planted on Crown Lands to have been produced from seed originating within the same seed zone to reduce the risk of poor genetic/environmental match. Since the origin of some of Obed's earlier planting stock is not known, there is a possibility that inappropriate seed source contributed to lack of success.

- Stock Type: Recent plantings utilized summer stock. Planting was completed in early to late June and it is likely that summer stock would not have been physiologically adapted to site conditions that early in the season.
- Species: At least half of the plantations established since 1987 consisted of lodgepole pine. Given the evidence of high mortality of pine from deer browsing, this heavy reliance on pine would result in a corresponding high rate of mortality.

A number of suggestions were made to better achieve the land use objective and to reduce the limitations resulting from reclamation practices at Obed Mountain Mine (Leskiw et al. 2007):

- The seed mix should be reviewed with the objective of eliminating aggressive legumes such as sainfoin, cicer milkvetch, alfalfa, and alsike clover. White clover is an example of a non-aggressive legume. Red fescue is also a species of concern, and should either be reduced in composition or eliminated from the mix.
- Seed application rate should be reduced to 10 to 20 kg/ha of longer-lived species and an additional 10 to 40 kg of short-lived ryegrasses or barley. The slower growing, longer-lived species would provide for other objectives without competing too directly with reforestation efforts.
- It was recommended that spring 2+0 stock be used wherever possible. Spring 1+0 stock would also be appropriate under some conditions, but it was evident from observations that summer stock may not be physiologically adapted to site conditions.
- In areas subject to heavy ungulate use spruce should be the only conifer species considered, unless a cost-effective method of protecting pine becomes available.

3.2.4.3.3 Cardinal River Coals Ltd. – Luscar Mine

During 1980, a program was established to evaluate the success of the reclamation to date and set up a continuous monitoring system for future assessment. A series of vegetative transects was set up to study ground cover, success of each species, stand vigor, and the physical and chemical characteristics of the substrate. A summary of the initial findings is provided (Cardinal River Coals Ltd. 1981):

- **Floristic composition of old seedlings (6 to 10 years) indicated that creeping red fescue, upland bluegrass and timothy were capable of providing long term cover over a wide range of site conditions. Legumes which did best in the long-term were sainfoin and cicer milkvetch.**
- **A mixture of legumes and grasses provide the greatest ground cover and biomass yield.**
- Legume above ground biomass was higher in nitrogen and phosphorus than grasses. Grasses growing in mixed stands with legumes had significantly higher

nitrogen, phosphorus, potassium and suphur contents than grasses growing without legumes. This resulted in nutritionally superior forage in legume stands.

Reforestation efforts up to 1984 resulted in limited success (Cardinal River Coals Ltd. 1985). **Strong and persistent winter winds caused severe desiccation losses. Also, the abundant Rocky Mountain Bighorn Sheep population utilized the area as preferred winter range and caused seedling damage through casual browsing or trampling.**

Plots for planting of various native deciduous shrubs were established in 1984. The most successful varieties were to be alternated with the coniferous species during the normal planting program (Cardinal River Coals Ltd. 1985). Species included shrubby cinquefoil, wolf-willow (silverberry), common bearberry, willow, green alder, dwarf birch, balsam poplar, and red-osier dogwood.

Limited success in reforestation efforts led to an investigation in 1985 into such variables as planting techniques, planting stock, container size, selection of planting site, and impact of wildlife (Cardinal River Coals Ltd. 1986). It was generally agreed that the most substantial impact was as a result of exposure and that the planting site should offer some protection to the seedling. A test plot was developed on a previously established topsoil island where reforestation success was minimal. The topsoil was stripped off and the area divided into three relatively equal areas. Underlying materials in one area were moulded into rolling berms perpendicular to the prevailing wind direction using a dozer. The berms were approximately 5 feet high and topsoil was dozed back into the troughs. The central location remained flat with half culvert pieces installed on the west half and gouges excavated on the east half to provide seedling protection. The other area was similar but with small berms (3 ft. high (0.91 m)). The plots were planted with a total of 1,557 engelmann spruce seedlings in 1986. A fence to restrict wildlife access was not constructed. A windy, dry winter in 1986/87 resulted in high mortality of the spruce planted therefore replanting was completed in June 1987. The entire plot was seeded with a light application of white sweet clover to provide protection. The winter of 1987/88 was mild with almost no snow cover and visual inspections suggested that mortality rates were high. No further research activities were planned for this site. Results from the project were successful at demonstrating that (Cardinal River Coals Ltd. 1989):

- **Exposure was the most serious problem to reforestation establishment at Cardinal River Coals Luscar mine; topographic manipulation during mining or initial stages of reclamation are of primary importance to shelter seedlings from the effect of Chinook winds and promote snow accumulation.**
- Planting sites (topsoil island locations) must be carefully chosen to take advantage of natural shelter and available moisture.
- In difficult sites within a chosen planting location, individual seedling protection by microsite creation can effectively increase survival rates.
- Coniferous seedling stock must be very hardy and well acclimatized prior to outplanting.

Speculation as to the value of fibra mulch in terms of seed germination, rate of crop establishment, extent of crop cover, and economics led to a field scale hydroseeding trial conducted in October 1986 to determine the value of mulch addition on north facing slopes. Varied rates of hydromulch were added to plots which received an identical seed and fertilizer application. Visual assessments of the seeded areas in 1987 showed little difference in the extent of vegetative establishment. Vegetation performance appeared best in areas where 1,000 lbs/acre of mulch was applied, however the improvement did not warrant the cost of the material (Cardinal River Coals Ltd. 1988).

Cardinal River Coals Ltd. undertook an assessment of baseline tree growth and the minesite's reforestation program in 1992. This work was conducted by a contractor and resulted in recommendations to direct future reforestation efforts. Results of the research showed that though seedling survival on mine plantations had generally been low (below 10 to 25%), given the difficult circumstances under which almost all of the plantations were established, it was noteworthy that a number of sites had survival rates as high as 50 to 65% 6 to 20 years after planting (Brinker 1992). These plantations were generally in sheltered, protected areas. Most seedlings were planted in mid-summer, and were actively growing at planting time. In many cases, the planting stock had been held back for one or more years because of delays in planting and were thus in a deteriorated condition by the time they were planted. As such, most of the plantations were established at the driest, warmest time of year, in many cases without sufficient time to establish root growth before the onset of winter. On some of the reclaimed sites, the seedlings had originated from seed blown in from adjacent stands. These seedlings had slower growth than the plantation seedlings in early years, but at one site, had surpassed the best plantation by year 10. This suggested that the establishment phase is critical in the success of tree growth under conditions at the mine. It also suggested that suitable tree growth could occur if establishment conditions were suitable.

Throughout the field data collection period for this monitoring project, observations were also made on the establishment and growth of other woody species (Brinker 1992). These observations indicated a number of species which performed well, or would be appropriate, for the mine's reclamation program. These species included willow, alder, rose, elderberry, buffaloberry, dwarf birch, and shrubby cinquefoil. Species which did not appear to be appropriate included bearberry, red osier dogwood, ground juniper, and bracted honeysuckle.

The following recommendations were made regarding tree growth expectations and forest re-establishment at the Cardinal River Mine (Brinker 1992):

- Reforestation to commercial standards should not be attempted on exposed sites above 5,300 ft. (1,615 m) elevations.
- Spruce is the recommended conifer species for higher elevation plantations, particularly on more exposed sites. Pine should also be planted to increase species diversity, but at higher elevations it should form a lesser part of the plantation.
- Reclaimed site plantations have not yielded consistent success. However, many of the factors limiting their success are controllable.

- Based on experience at the Coal Valley Mine, and supported in the literature, plantations should be established under the following conditions:
  - Within 3 to 4 weeks after frost comes out (i.e. no later than late May).
  - Seedlings should be planted in completely dormant condition.
  - To achieve these two conditions, seedlings must be grown the year prior to planting, and over-wintered in protected shelters to avoid temperature fluctuations.
  - Planting stock should not be held in their containers for longer than what the containers are designed for.
  - Planting sites should be fully revegetated and self-sustaining prior to planting, and should have a wide variety of microsites.
  - Final topographic contours should be developed where possible to maximize irregularities, so that some inherent protection from prevailing winds is provided.

A vegetation analysis of reclamation sites was undertaken in 1999 to assess the success of the rough mounded topsoil placement technique. The assessment evaluated plant species composition, abundance and floristic diversity focusing on native and agronomic plant species. Significant differences in species abundance were found between regolith and directly placed and stockpiled topsoil sources (Strong 1999). Sites with regolith at the surface had less cover than those on topsoil from either stockpiled or directly placed topsoil surfaces. No clear distinction was found between sites with topsoil that was directly placed and derived from stockpiles. The most frequently encountered woody and semi-woody shrubs were willows and wild raspberry. Shrubs were more common on sites with topsoil than those with regolith at the surface and rough rather than smooth surface sites. No significant differences were found in the abundance of shrubs on different slope orientations or gradients. Although representing only 4.8% of the total plant cover, the number of native species was relatively high (47 of 56 taxa). Most native species had only trace occurrences within the vegetation. The native flora included bunchberry, red paintbrush, avens and wild rose.

Floristic diversity was considered to be relatively high on the sampled Luscar Mine sites (i.e. 96 species in 32 transects) compared to others (Strong 1999). The primary difference in reclamation approaches between this mine and others was the use of rough surfaces on some of the disturbed land within the Luscar Mine. **While no clear difference could be documented, the data suggested that directly placed topsoil tended to have greater abundance and probably greater levels of species richness than sites with stockpiled topsoils. Topsoil, whether stockpiled or directly placed, was better for promoting native plant diversity than was regolith.**

From the data, the following conclusions were drawn about reclaimed sites on the Luscar Mine:

- 75 of the 96 vascular plant taxa were considered native flora.
- Early successional and "weedy" species were most common on the youngest sites, usually less than 3 years old.

- Native species typically had a cover of 4 to 7%, with a weak trend of increasing cover with vegetation age.
- One early successional stage and three more mature vegetation-types were recognized within the sample stands.
- Species used for reclamation dominated all three of the more mature vegetation types, with red fescue, alfalfa, and Alsike clover being the most abundant species.
- The amount of exposed mineral soil on reclaimed sites decreased at an average rate of about 20% per annum during the first four years after reclamation.
- Plant foliar cover increased at a rate of about 30% per annum up to the fourth year of growth.
- Moss abundance increased with vegetation age.
- Species cover and floristic diversity were often greater on topsoil than regolith sites.

A tree monitoring program was undertaken in the fall of 2000 to assess tree survival, vigor and field conditions that may be affecting the reforestation program at the Luscar Mine. The field conditions primarily studied were soil spreading techniques, competition from grass/legumes and grazing pressures. Four small monitoring plots were established on reclaimed plantations. Results of the 2001 measurements at plots 1 and 2 indicated that surviving tree density was 2,000 to 3,000 stems/ha, and mortality over winter was negligible (less than 2%) (Brinker 2001). At plot 3, on the lower terraces of the dump where dozers had been used in soil placement operations, the microsite variability was not as high as on the upper slopes and grass/legume cover was much heavier. Most of this site was planted in 1995/96 and some fill-in planting was done in the spring of 2000. The remaining plot was planted in stages between 1992 and 1995, with additional planting in 1999 and 2000. Grass/legume cover was very heavy, and the rough-mounded soil had high microsite variability. Seedlings in this plot were severely browsed by mule deer.

In conjunction with the soil monitoring program three plots (two reclaimed and one natural) were established in 2001 to monitor vegetation growth and the development of forest ecosystems (Leskiw and Pollard 2002). The comparisons of vegetation percent cover, species richness, and species abundance among the natural and reclaimed plots indicated that there was little similarity between the natural plot and the reclaimed plot in the first year of reclamation. Percent cover data indicated that the reclaimed plots had mostly bare ground, whereas the natural plot had little to no bare ground. Species abundance data showed that there were more graminoid species on the reclaimed plots than the natural plot, a reflection of the fact that graminoid species were seeded on the reclaimed plots. The natural plot had more shrub species, mosses, horsetails and fern species.

3.2.4.3.4 Gregg River

A revegetation assessment to assess plant vigor, density, rooting depth, and fibre production on all vegetated areas was completed in October 1983 (Gregg River Resources Ltd. 1984). Fifty one plots chosen at random were assessed with a

Daubenmire frame. Observations indicated that timothy and orchard grass were the most common of all species planted over the previous two planting seasons and native and invading species had established in some areas. Species observed included fireweed, plantain, meadow fescue, tufted hair grass, Canada blue grass, foxtail barley, hairy wild rye and slender wheatgrass.

Tall grass cover prevented monitoring of some transplanted stock in 1993 which resulted in taller identification stakes being placed adjacent to all trees and shrubs found. Monitoring on some research plots showed (Gregg River Resources Ltd. 1994):

- Overall survival rates were high with reasonable growth rates for the white spruce.
- Evidence of wind desiccation and winter kill.
- Higher survival rates for lodgepole pine transplanted from Hillson containers compared to lodgepole pine started from Styro 20s.
- The majority of the pine was affected by browsing and winter kill.
- High survival rates for shrubby cinquefoil, wild rose and red willow; and high mortality rates for both poplar varieties due to heavy browsing.

Consequently, conifer plantings at Gregg River concentrated exclusively on white spruce transplant stock germinated from seed collected at the minesite. Monitoring of other plots showed severe mortality rates for all species planted except for shrubby cinquefoil and wild rose. **Reasons suspected for the low survival rates included dry location and low soil moisture, minimal snow cover, and browsing. Drier locations exposed to chinook winds showed the importance of establishing wind breaks and planting as much as possible on north and northeast facing slopes.**

In 2001 Silkstone Environmental Ltd. was contracted to contribute expertise to the mine's reclamation program, specifically the re-establishment of native trees and shrubs. A key part of this project was the establishment and monitoring of trials to demonstrate methods of woody species establishment techniques. The objectives of the trial program were to clearly identify and quantify those factors most limiting to woody species establishment and early growth and to assess a number of potential techniques that would address these limiting factors. Preliminary results in 2001 indicated that problems associated with browse damage and grass-legume competition on some reclaimed sites would need to be addressed to achieve successful re-establishment of woody species. Soil compaction on some sites also proved to be a potential problem that could be addressed, either by fine-tuning planting methodology or by physically correcting the problem (e.g. strip-disking/working soil prior to planting). The results after four years of monitoring led to the following conclusions (Brinker 2002, 2003, 2004, and 2005):

- It was recommended that soil be handled so as to prevent compaction. Techniques such as mounded soil placement and wintertime handling have been shown to reduce compaction during placement and were recommended.
- The establishment of overly productive, competitive grass-legume cover should be avoided. The most competitive species on fully established sites at the mine include alfalfa, alsike clover, cicer milkvetch and orchard grass. Creeping red fescue can be effective for erosion control but can become overly competitive if

it is a dominant part of the mix (i.e. greater than 15% by weight); annual ryegrass can also be competitive if seeded at too high a rate (although generally only during the first growing season).

- Spring 2+0 stock should be used wherever possible. Spring 1+0 stock would also be appropriate under some conditions, however it was evident that the summer pine stock was not physiologically adapted to site conditions. It was possible that 2001 was not representative of what would normally be expected for weather conditions and this should be considered.
- Spring stock should be planted in late May or by the end of the first week of June to give the seedlings more time to becomes established prior to the end of the season.
- Heavily grassed sites will need vegetation management to prevent high mortality from grass press and shading. The technique of strip-spraying with glyphosphate was effective in the first year. A light vegetative cover appeared to benefit seedlings by hiding them from browsing ungulates.
- In areas with heavy ungulate use, spruce should be the only conifer species considered.
- The shrub species that have strong survival from pre-2001 plantings include shrubby cinquefoil, wild rose and willow.
- Individual tree fertilizing appeared to be beneficial to seedling establishment in the first season.
- Vegetation competition is a limiting factor on many of the older reclaimed sites at Gregg River. The vegetation competes with, or physically smothers, establishing tree seedlings. Furthermore, it draws sheep and deer onto the site, resulting in increased browse damage.
  - On sites that have an existing grass/legume cover, spruce stock with a thick caliper (e.g. 2+0 stock) should be planted. Stock should be planted in favourable microsites, as far away from competing vegetation as possible, and planting should be done in spring when ground conditions are most favourable.
  - Vegetation management should be employed on those sites where the vegetation is too dense. Strip-or spot-application of glyphosphate gives at least two and possibly three years of effective control. This could be applied either the year prior to planting or the year following planting. If applied after planting, it should be done late enough in the summer that the tree seedlings are fully dormant.
  - On newly reclaimed sites where tree cover is desired, the seed mix should not include alfalfa, alsike clover, orchardgrass, cicer milkvetch or other dense cover producing species.
- High soil density appears to be a limiting factor on those sites where placement practices contributed to soil compaction, and on those sites where a combination of heavy grass cover and poor site characteristics (i.e. clayey soils) result in seasonally high soil densities. On such sites, two recommendations were made:
  - If soil densities are only seasonal, the site should be planted only in early spring, just after thawing. At this time, soil densities will tend to be at their lowest, and planting can be completed within quality expectations.

    - On those sites where soil compaction is a result of equipment operation, the site can be decompacted prior to planting using a modified ripper shank.
- Stock type and planting time appear to be extremely important considerations on the Gregg River site.
    - Spring planting (i.e. mid-to late-May) should be the first choice, unless soil characteristics on the planting site are not limiting. In this case, an early July planting date with summer stock would be acceptable.
    - Two-year stock is recommended for both pine and spruce. This stock will have stronger stem caliper than one year stock. Because of the stoniness of most of the soils, a slightly shorter root plug should be considered to avoid root damage during planting. A 410 or 412 (i.e. 4 cm wide and 10 to 12 cm deep) is suggested.
- Pine (or preferably a combination of pine and spruce) was recommended for those sites where the risk of browsing in the first 3 to 4 years is low and where vegetation competition is low or can be controlled. Spruce is recommended for all other sites that are capable of supporting a tree cover. Comments on other species include:
    - Shrubby cinquefoil is the strongest performing woody species observed, with excellent survival (over 95%) and strong growth on a number of different sites.
    - Green alder, dwarf birch and buffaloberry are performing well on most sites.
- The trials involving individual tree fertilizing using teabags did not provide conclusive results. Fertilizing appeared to have a slightly negative effect on sites where soil characteristics were conducive to tree survival and growth, and fertilizing on other sites tended to have a small positive effect. Therefore the following recommendations were made:
    - The extra cost of fertilizing is not considered to be warranted on those sites where soil conditions are nonlimiting (i.e. undisturbed soil or soil with some organic matter, relatively low coarse fragments, low compaction, winter placed or mounded).
- The establishment of willow and balsam poplar using unrooted cuttings was unsuccessful. No opportunities for the operational use of this technique were identified.

In 2005, the focus of the monitoring program was shifted from research and demonstration trials to the assessment of operational plantations (Brinker 2006). In 2006, the plantations established over the previous six years were formally surveyed on an operational scale (Brinker 2007). Previous monitoring focused on individual seedling survival and the provision of feedback into subsequent planting programs. It was decided that for the 2006 program the Alberta Forest Regeneration Survey Manual (RSM) would be used as the basis for the 2006 surveys, but modified in an attempt to address different climatic and end land uses than industrial cut-blocks.

3.2.4.3.5 <u>Grande Cache Area Operations</u>

The reclamation research program initiated by ARC in 1972 at the No. 8 Mine involved annual monitoring to demonstrate species suitability, desirability, stand composition, and fertilizer requirements. The research effort evolved into an operational program for reclaiming and managing the entire mine area and for transfer of approaches and techniques to the mine areas developed thereafter.

In 1972 experimental plots were established at several locations at No. 8 Mine to study 1) the growth of various grasses, legumes, tree seedlings and shrub cuttings, 2) the effect of fertilizer types and their application rates, and 3) the growth support capability of ash materials (Macyk 1980). Spring vetch and cicer milk vetch were found to be unsuited to the area, while alfalfa and birdsfoot trefoil appeared to be the best suited legume species tested in the area. Hard fescue, Erica creeping red fescue, Arctared creeping red fescue, and Nugget bluegrass were showing vigorous growth. Some of the species that did not do as well as anticipated included perennial ryegrass, tall wheatgrass and reed canary grass.

Most of the agronomics seeded initially became established and continued to thrive with many of the species producing viable seed. Very few of the grass and legume species utilized could be described as unsuitable for use in reclamation in this region. It was observed that the dominance of specific species and/or varieties was related to aspect and associated moisture conditions as well as the effect of competition.

A concern relative to utilization of native species was addressed early in the study, however in 1972 there was very little native seed available. Consequently, seed from loco-weed, alpine hedysarum, lupine, and hairy wildrye was collected from the undisturbed portions of the mine area and subsequently planted.

In 1976 experimental plots were established on south-facing and crown positions at No. 9 Mine to study the growth of various grasses, legumes and tree seedlings and to assess the effect of fertilizer types and application rates. Additional plots were established in 1977, 1978 and 1979. Of the grasses seeded, hard fescue, creeping red fescue, Russian wildrye, creeping foxtail and meadow foxtail were superior to the bromes, pubescent wheatgrass, timothy, crested wheatgrass and streambank wheatgrass. This rating was based on the growth of the various species, their fertilizer requirements and their appeal to wildlife.

In the initial years of the studies importance was placed on achieving a self-sustaining cover of grass and legume species in the area by the ARC staff and other researchers and observers. This led to assessing the species on the basis of their performance for long-term survival and to some extent optimizing productivity or total plant cover. With time and the withholding of fertilizers, alfalfa increased its share of the ground cover while the grasses, which tended to comprise a major portion of the initial cover in a mixed stand, declined in vigor. Alfalfa became a very important component of the seed mixtures used in the area and played a major role in achieving and maintaining a self-sustaining cover.

Work done to evaluate native species re-invasion indicated that the initial cover established does not have to sustain itself indefinitely or be maintained for much more than five years after initial establishment. What is required is the selection and use of species that provide the initial and necessary erosion control cover while at the same time rejuvenating or getting the reconstructed soil functioning to promote subsequent changes in cover.

From the early stages of the project, field observations indicated that native species were encroaching into the disturbed areas where a grass/legume cover had been established. The non-woody species that were naturally establishing included lichens, mosses, lupine, loco-weed, alpine hedysarum, and Indian paintbrush. Willow, alder, balsam poplar, spruce, pine, and subalpine fir were also found in the area. **Initially, the presence of natives was attributed to the germination of seed and sprouting of vegetative material that was present in the replaced soil topdressing. It also became apparent that dispersion of seed by wind and animals also plays a major role in native species invasion.**

Having some knowledge of the extent to which one can depend on invasion is critical in reclamation planning. Invasion increases species diversity, impacts the development of a self-sustaining vegetative cover, and increases the stability of the post-mining ecosystem. Identification and ranking of the factors influencing the invasion by native species had a bearing on the development of reclamation plans in the future.

Plant counts were undertaken in 5 m x 5 m plots to get an initial indication of the extent of invasion (Macyk and Widtman 1984). Data from these plots indicated a decrease in native species populations with increasing distance from the undisturbed forest. In 1986 a much more intensive study was undertaken to identify and rank the factors affecting the aerial extent and distribution of native species at the No. 8 Mine site (van Zalingen et al. 1988). Data collection involved cover estimates at 220 sampling locations predetermined by applying a 60 m interval grid pattern to a 1:3000 aerial photograph of the study site. The factors included distance from undisturbed forest, presence or absence of legumes in seed mixtures utilized, airborne seed dispersal, slope, aspect, dates of seeding and fertilization, and soil characteristics.

A total of 60 non-seeded species, including five native legumes, were identified on the site. Statistical analyses were undertaken to assess the parameters measured and these parameters or variables were ranked to determine their relative importance.

Overall, distance from the nearest westerly undisturbed area significantly influenced the distribution of native species in the area. With the exception of moss, all native species exhibited a decline in percent cover with increasing distance from the nearest westerly undisturbed area. Ranking of the independent variables indicated that coarse fragment rating was the most important variable contributing to the percent cover of native species. Northwest versus southeast aspect and distance from the nearest westerly undisturbed area ranked second in importance, followed by percent cover of alfalfa. Percent slope and soil depth ranked low in terms of importance compared to the above mentioned variables.

A comprehensive assessment of the herbaceous cover was completed in 2005 and 2006 to evaluate the long-term persistence of the introduced species and to continue identification of encroaching natives (Macyk 2007). The establishment of initial cover and the vegetation "succession" that occurred is best illustrated in a series of photographs involving a "before" and "after" approach. Plates 3.51 to 3.53 illustrate the revegetation of the first pit mined at the No. 8 Mine in 1971 to the status of vegetation in 2006. Plates 3.54 to 3.61 illustrate the establishment of the initial cover comprised of agronomic grasses and legumes in a portion of the No. 8 Mine seeded in 1974 and the change in cover with time resulting from the withholding of fertilizers two years after initial seeding. Plates 3.62 to 3.66 illustrate vegetation succession in a sloped area adjacent to a highwall.

Plate 3.51. Mining C east pit.

Plate 3.52. Initial cover in the graded pit area in 1975.

Plate 3.53. Vegetation cover in May 2006.

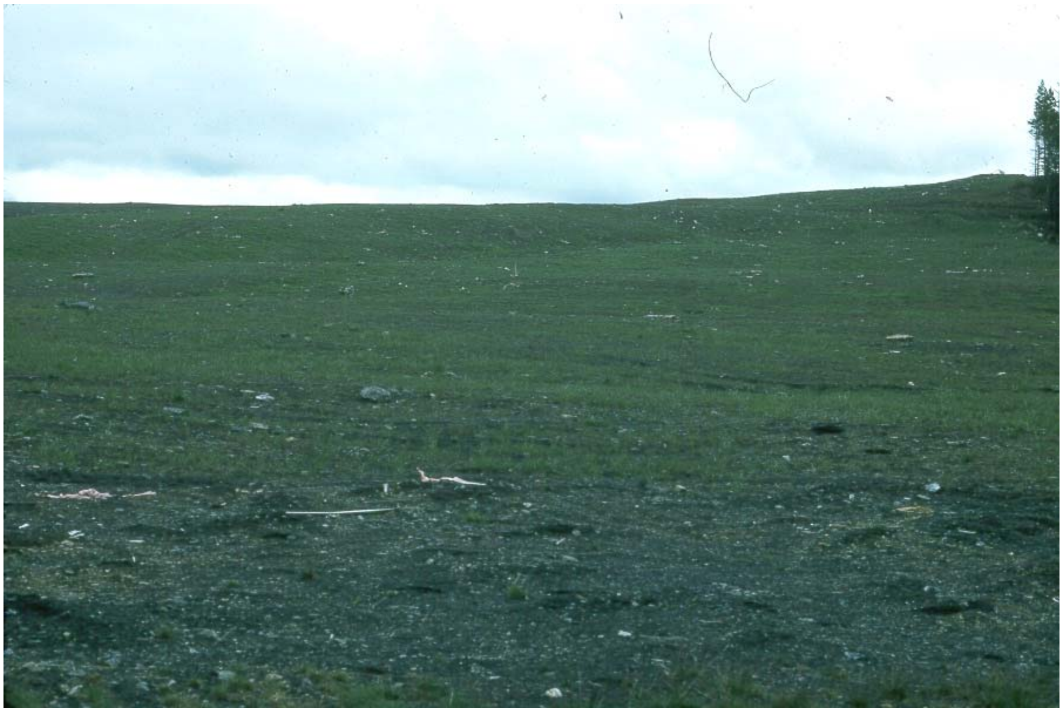
Plate 3.54. Area shortly after seeding in 1974.


Plate 3.55. Initial cover in 1975.


Plate 3.56. Dominantly grass cover in 1977.


Plate 3.57. Alfalfa more evident in 1979. Fertilizer withheld since 1977.

Plate 3.58. Natives well established in 1990.

Plate 3.59. Shrub and tree growth by 1996.


Plate 3.60. Vegetation cover in 1999.


Plate 3.61. Vegetation cover in 2005.

Plate 3.62. Grading operations prior to revegetation of this dominantly east-facing slope area (June, 1975).

Plate 3.63. Initial grass and legume cover in the same area as Plate 22 (September, 1976).

Plate 3.64. Vegetation cover ten years later (August, 1986).

Plate 3.65. Excellent mixed cover 23 years after initial seeding (August, 1999).

Plate 3.66. Vegetation cover 30 years after initial seeding.

Primary colonizers observed soon after initial cover establishment included mosses (Plate 3.67) and lichens (Plate 3.68). This was followed by numerous natives including American dragonhead, alpine milk vetch, aster (leafy and showy), bearberry, bluebell, cut-leaf anemone, fireweed, golden rod, alpine hedysarum, Indian paintbrush, narrow-leaved collomia, pussytoes, slender hawk weed, strawberry, vetch, and yarrow. Plates 3.69 and 3.70 provide examples of the commonly occurring species.

Bearberry was observed throughout the reclaimed area for several years. The cover in the reclaimed area compares quite favourably with the dominantly bearberry cover in an undisturbed location 200 m away (Plates 3.71 and 3.72).

A program to introduce trees and shrubs to the area was undertaken concurrently with the grass and legume establishment program. Utilization of the different propagation and planting techniques resulted in excellent tree and shrub establishment. **The results demonstrated that trees and shrubs will thrive when planted in areas having a grass and legume cover.**

Climatic limitations dictate that some form of protection for the young seedlings is critical in this region. During the winter it is not unusual to have the snow cover blown off by strong winds or melted down during periods of warm weather. Subsequent cold spells, especially if accompanied by strong winds, can be particularly detrimental to young seedlings. Winds averaging 60 to 70 km/hr for 6 to 8 hr/day are not unusual during the winter months. During the summer, surface and near surface soil temperatures can reach in excess of 45° C to 50° C for several hours on consecutive days (Macyk and Widtman 1986, Macyk and Widtman 1991).

Plate 3.67. Mosses become established soon after initial cover establishment.

Plate 3.68. Lichens are primary colonizers in the reclaimed areas.

Plate 3.69. Diverse cover and color associated with Northern sweet vetch, Northern goldenrod, and Indian paintbrush.

Plate 3.70. Ground cover species in August 2004.


Plate 3.71. Overview of ground cover including bearberry in this reclaimed site.


Plate 3.72. Bearberry is a dominant component of the vegetation cover at this undisturbed location.

The shrubs utilized in the study included alder, willow, buffaloberry, and caragana. In 1973, cuttings of alder, buffaloberry, and willow were collected at the No. 8 Mine area and rooted in containers in the greenhouse. Caragana was produced by placing seed in the containers. Cuttings of willow were also collected in early May and direct planted without any treatment or pre-rooting.

Five years after planting 65% of the willow cuttings, 80% of the alder and 60% of the caragana had survived and continue to thrive. Many of the willow that were planted in 1973 had achieved heights in excess of 3 m by 1987 and were continually clipped by browsing wildlife (Plates 3.73 to 3.75). The direct planted willow cuttings had a survival rate of 40% after five years.

Preliminary results of direct seeding trials indicated that alder can be readily produced by this method in the area (Macyk and Widtman 1991). Furthermore, this conclusion is supported by the number of alder plants that are becoming established by natural means.

The program to establish conifer species in the No. 8 Mine area was initiated in 1972. Plates 3.76 to 3.80 illustrate the growth of bare root lodgepole planted in 1972.

A major program was initiated in 1983 to compare the growth of conifer on unmined (natural) and reconstructed soils. Tree height measurements in the natural areas, which included regenerating cut-blocks and seedlings in natural stands, were compared with trees in the reclaimed areas (Plates 3.81 and 3.82). Initially emphasis was placed on height measurements only because the trees were relatively small. Basal diameter measurements were initiated in 1999 and continued thereafter. **Overall the growth data indicated that the reconstructed soils support tree growth that is equal to or better than that achieved on natural or undisturbed soils in the area (Macyk 2007).** This was attributed to the fact that the reconstructed soil areas offered the advantage of an open canopy (increased light) and potentially higher levels of available plant nutrients, however, these areas are also more exposed to the wind.

Plate 3.73. Willow cuttings four years after planting.

Plate 3.74. Willows three meters high.


Plate 3.75. Browsed willow.


Plate 3.76. Bare root pine planted in 1972.

Plate 3.77. Same trees in 1986.

Plate 3.78. Same trees in 1993.


Plate 3.79. Same trees in 1999.


Plate 3.80. Same trees in 2006.


Plate 3.81. Tree measurements in 1983.


Plate 3.82. Tree measurements in 2006.

Dendrology measurements using the image analysis system WINDENDRO for tree-ring measurement were completed on disks obtained from similar aged trees in the natural and reclaimed areas. Disks and measurements were obtained from 22 trees in reclaimed locations (11 engelmann spruce and 11 lodgepole pine) nine trees in adjacent undisturbed locations (3 engelmann spruce and 6 lodgepole pine) and three lodgepole pine from a reforested cut-block adjacent to Highway 40. The growth rings for lodgepole pine from a reclaimed and undisturbed location are illustrated in Plates 3.83 and 3.84 respectively. **Analysis of the ring data indicated that trees from the reclaimed sites were producing more fiber on an annual basis than trees from natural sites (Macyk 2007).**

The results of the long term monitoring program conducted by the ARC at the Grande Cache area operations indicated that time is the ultimate factor in achieving reclamation success and that climate is the most limiting factor to revegetation success.

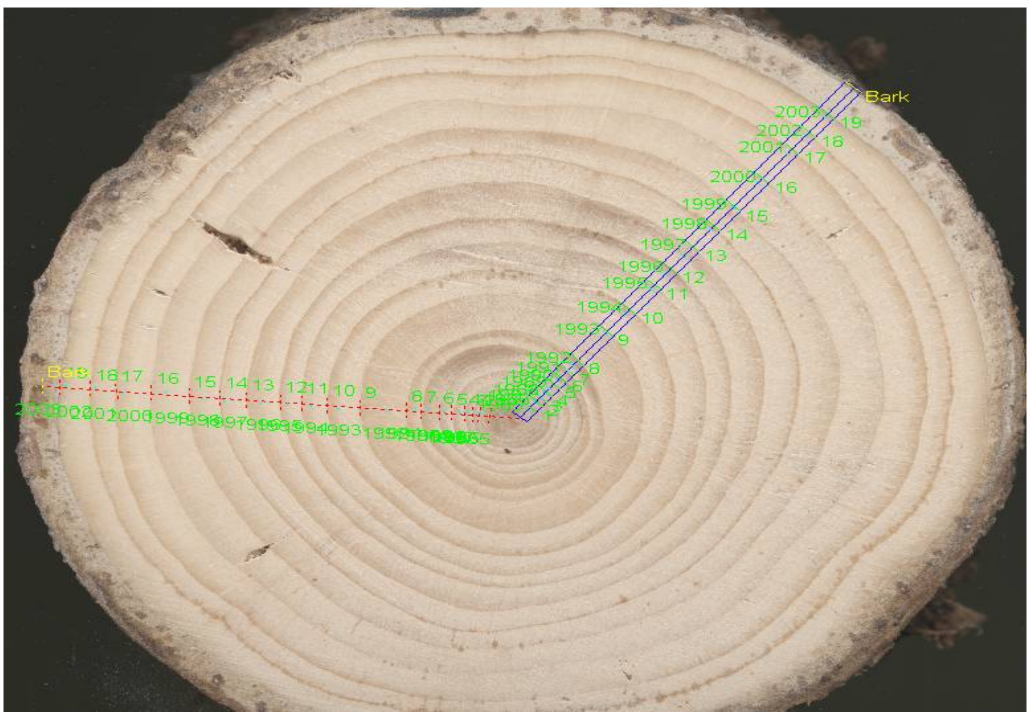

Plate 3.83. Growth rings for lodgepole pine from a reclaimed site.

Plate 3.84. Growth rings for lodgepole pine from an undisturbed location.

3.2.5 FERTILIZATION

3.2.5.1 Coal Valley

Fertilizer grid trials were established to determine the best fertilizer rates for reclamation. The trials consisted of various treatments of ammonium nitrate and ammonium phosphate applied to the standard mix used in 1979. Composite soil samples were taken from some of the subplots and each plot was harvested for biomass yield.

A large-scale fertilization program was conducted in 1986 to fertilize newly seeded areas and previously seeded sites which had not caught well. The 11-51-0 or 28-26-0 fertilizers were applied by helicopter in the last week of May at rates between 100 and 150 lb/ac (169 kg/ha). In 1987 and 1988, 125 lb/ac (140 kg/ha) of 12-51-0 fertilizer was applied on newly seeded areas shortly after seeding and 100 lb/ac (112 kg/ha) of 28-26-0 fertilizer was applied on areas with established grass with a broadcast spreader. In 1989, 125 lb/ac (140 kg/ha) of 28-26-0 fertilizer was applied on newly seeded areas shortly after seeding and on areas with established grass at the same rate. It was broadcast by a helicopter.

From 1998 to 2004 it was standard practice to fertilize all areas as they were seeded. The fertilizer commonly used was a blend of ammonium phosphate (27-27-0) applied at a rate of approximately 180 kg/ha.

3.2.5.2 Obed Mountain

Information regarding fertilizer application provided in "Revegetation" section.

3.2.5.3 Cardinal River Coals Ltd. – Luscar Mine

Most areas in 1979 had not received fertilizer for approximately two years. When a forage crop was established on a substrate low in nutrients, it was common practice to apply heavy fertilizer for at least three years until the organic matter cycle was considered established.

Soil sampling conducted in 1980 indicated a general deficiency in the levels of nitrogen and phosphorus, while potassium and sulphur levels were usually adequate for vegetative propagation (Cardinal River Coals Ltd. 1981). Although fertilizer was included with the seed application additional amounts, of particularly nitrogen, were required. Maintenance fertilization in areas which had been revegetated for some time was undertaken where the results of soil and plant tissue analyses deemed it necessary. During 1980, the west slope of the Gregg dump was refertilized with 34-0-0 at 168 kg/ha and 11-51-0 at 224 kg/ha. As the majority of the areas were on sloped terrain, a helicopter was utilized to spread the fertilizer.

In 1980, a test plot was established in two grids (Cardinal River Coals Ltd. 1981). One set was located on a 1972 seeding area which was well established and the other on a 1979 seeding area with a very low percentage of ground cover. Each grid was divided into subplots and rate of ammonium nitrate (34-0-0) applied varied from 0 to 250 kg/ha along one axis, while the rate of ammonium phosphate (11-51-0) applied varied similarly along the other. Soil macronutrient measurements were conducted prior to fertilization application, then 1, 2, 3 and 6 weeks after addition. Results were as follows:

- Potassium and sulphur contents in the natural soil were adequate to support plant establishment.
- 1972 seeding showed high fluctuations in ammonium nitrate upon heavy nitrogen application while 1979 seeding did not, indicating that the ammonium component spread on exposed soil is largely lost due to volatilization and applications of these types of areas should be beneath the surface rather than broadcast on top.
- 1 to 2 weeks lag time is common before the full effect of fertilization becomes apparent in the soil analysis.
- High rates of nitrogen additions result in low levels of available phosphorus; converse also true due to resultant plant activity.
- Rate of nitrogen loss is very rapid due to the combination of plant utilization and leaching. In order to reduce the loss to leaching, more frequent applications at decreased rates are desirable.
- Phosphorus is retained in the soil due to its low solubility. Heavy applications are not lost as readily as nitrogen and were recommended with initial seeding.

Based on these results, Cardinal River Coal Ltd. developed the following maintenance fertilization program (Table 3.22).

Table 3.22. Maintenance fertilization rates used at Luscar Mine.

Year	34-0-0 (kg/ha)	11-51-0 (kg/ha)
Initial seeding	-	200
Second Year Applic. #1	100	50
Applic. #2	50	50
Third Year	100	50
Fifth Year	50	50
Seventh Year	50	50

During 1982, refertilization was limited to roadsides and areas accessible to the truck mounted hydroseeder utilized. Fertilizers applied included: 34-0-0 at 168 kg/ha and 11-51-0 at 224 kg/ha.

An intensive refertilization program was completed in 1984 following the maintenance fertilization program guidelines (Cardinal River Coals Ltd. 1985). In most situations the fertilizer was mixed with water and applied with the hydroseeder. In 1986 the refertilization program utilized helicopter application on 112 acres and again in 1987 on the largest areas. By 1988, helicopter broadcast application was the primary refertilization method utilized and smaller sites were refertilized manually.

Refertilization methods remained the same until 2001 when the fertilizer was changed to 13-16-23 and applied at a rate of 220 lb/ac (247 kg/ha) (Cardinal River Coals Ltd. 2002). Maintenance fertilizer rates after the first application year increased by 10 kg/ha since the program was developed. The application rate in 2002 was 180 lb/ac (202 kg/ha). In 2003, 13-16-25 fertilizer was applied at a rate of 232 lb/ac (261 kg/ha).

3.2.5.4 Gregg River

No information available.

3.2.5.5 Grande Cache Area Operations

Fertilizer trials were established in 1972 to determine the most appropriate fertilizer types and analyses to be used, as well as timing and rate of application (Macyk 1972). The plots were maintained throughout the life of the ARC reclamation program to get an appreciation of the long term need or lack of need for refertilization. The study was originally undertaken to respond to the concern that fertilizer applications would be required annually to maintain the established vegetation cover. Plates 3.85 to3.89 illustrate the plots in 1972 and one year after establishment and the status of some of the treatments in 1974, 1997, 1999, and 2006. The plots that received fertilizer in 28 of the past 35 years maintained a thick grass cover while the plots fertilized 5 times in 35 years were invaded by trees and shrubs (Plates 3.90 and 3.91).

Conventional fertilizers, including 34-0-0, 11-48-0, and 0-0-60, were used initially in the plot work and in the initial operational reclamation. Blending of the three fertilizers was required to achieve the nutrient levels applied in one application (Plate 3.92). Shortly thereafter as new fertilizer analyses became available, 28-14-0, 14-14-7, 10-30-10, 46-0-0, and other conventional types were used. Slow release fertilizer types including SCU (32-0-0), Agriform (16-7-12), and thiourea in conjunction with 46-0-0 were tested early in the program.

Fertilizers were applied at rates which would result in equal amounts of nutrients being provided to the plants. Study results in 1975 indicated that (Macyk 1976):

- Fertilized plot segments produced at least double the dry matter as those not fertilized.
- Segments which were not fertilized every year were producing as well as those segments fertilized each year.
- Agriform (16-7-12 + iron) provided adequate levels of N, P and K for the duration of the growing season.

Application rates in 1975 ranged from 200 lb/ac (225 kg/ha) to 350 lb/ac (393 kg/ha) depending on the area. By 1980 rates had been decreased to a rate of 180 lb/ac (202 kg/ha) to 200 lb/ac (225 kg/ha) and by 1986 rates were decreased to 125 lb/ac (141 kg/ha).

A fertilizer spreader with a hydraulic motor mounted on a D4 Cat was constructed by McIntyre Mines in 1980 for fertilizer application. Areas with greater than 27° slopes were refertilized by hand seeders. From 1986 to 1988 the methods of application included broadcast seeding and hydroseeding.

In 1992, fertilizer was applied at the same time as seed using the hydroseeder and was applied at a rate of 125 lb/ac (141 kg/ha). In 1993 fertilizer was applied separately from the seed and mulch mixture approximately two weeks after initial seeding. A study completed by the ARC (Macyk and Widtman 1992) demonstrated a decrease in seed germination potential and germinant survival for seed applied in combination with the fertilizer. **The work demonstrated that "residence" time of a seed and fertilizer mix held longer than 30 minutes in the hydroseeder tank resulted in reduced germination and growth potential.** Fertilizer application in 1994 was initiated approximately two weeks after the seed was spread.

In 1999 fertilizer was applied one year after seed was spread and growth was evident. This approach was used to minimize fertilizer losses and to allow for a larger percentage of seeds to germinate. The fertilizer was applied at a rate of 142 kg/ha.

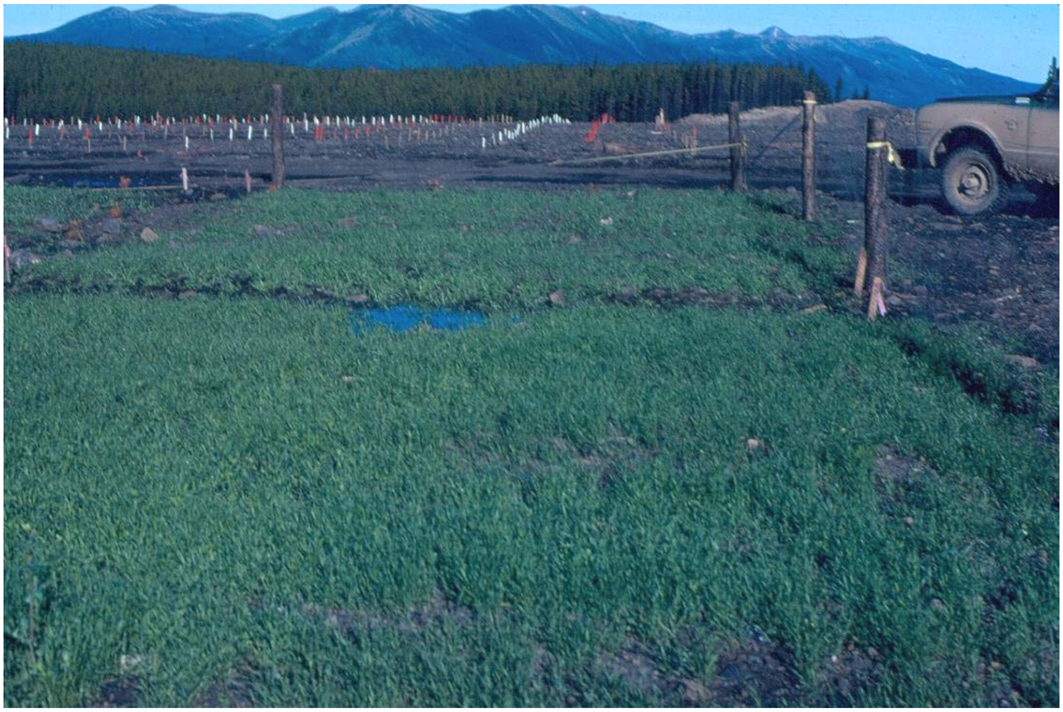
Plate 3.85. Fertilizer trial in 1972.


Plate 3.86. Fertilizer trial in 1973.

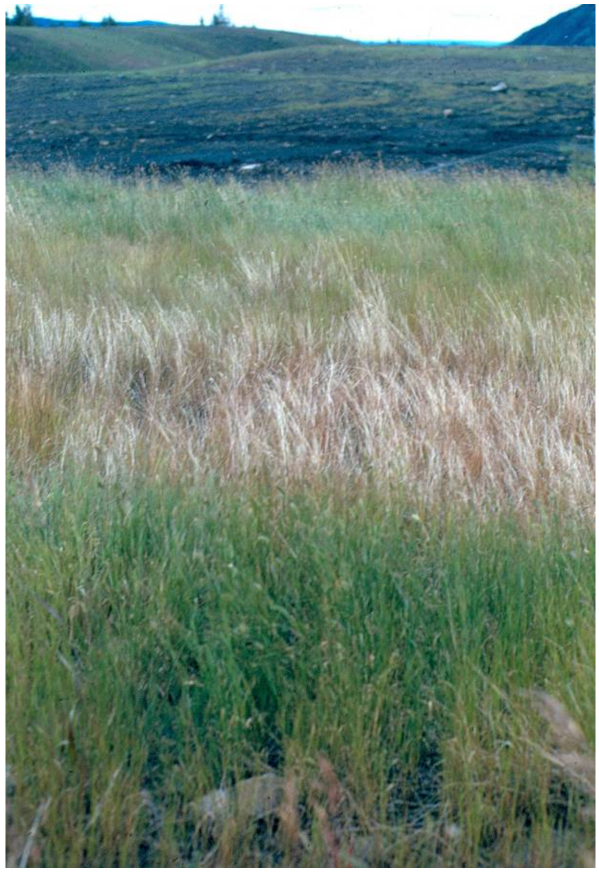
Plate 3.87. Fertilizer trial in 1974.


Plate 3.88. Fertilizer trial in 1997.

Plate 3.89. Fertilizer trial in 1999.

Plate 3.90. Grass cover in a treatment that was fertilized 28 times in past 35 years.

Plate 3.91. Grass cover in a treatment that was fertilized only five times in the past 35 years.


Plate 3.92. Blending of the three fertilizers.

3.2.6 WEED MANAGEMENT

Although weed management was conducted at each mine, information was only available from the mines listed below.

3.2.6.1 Coal Valley

A weed control program was initiated in 1993 to eradicate scentless chamomile and was continued in 2004. The control program consisted of picking and burning the chamomile. No herbicide spraying was completed in 1998 to 2003 to control this species. Roundup was used to control Canada thistle in 2002 and 2003.

3.2.6.2 Obed Mountain Mine

Early in 1990, scentless chamomile was observed along the access corridor of the mine. Weeds were hand pulled where accessible before they reached the seed stage. In difficult areas Tordon 22K herbicide was applied to weeds as per the manufactures recommendations, in mid-August.

The weeds were less prevalent in 1991, and when found were hand picked and disposed of. No additional herbicide application was required for weed control from 1991 to 1997.

Weed awareness at the minesite took on a higher profile in 1998 as Obed Mountian Mine provided financial support and weed control leadership as an industry partner in the Weed Awareness Partnerships Program. Monitoring for noxious weeds continued on site with the primary focus being Scentless Chamomile. Locations around the plantsite and access road were regularly checked throughout the summer for the presence of the weed. When plants were observed, they were hand picked and disposed of.

A licensed industrial herbicide applicator was employed to spray on site for scentless chamomile and oxeye daisy in 2001.

3.3 WETLANDS

3.3.1 COAL VALLEY

Two research projects relevant to lake development were initiated at Coal Valley in 1985 (Luscar Ltd. 1986). Rainbow trout fingerlings were stocked by Alberta Fish and Wildlife in three water treatment ponds at Coal Valley to provide some background information on fish growth and productivity. The second project involved dredging a natural pond in the Coal Valley area and trucking the dredged material (grasses and aquatic organisms) to inoculate the lake at Coal Valley.

Lake development in 1985 consisted of some levelling and topsoiling and a channel being excavated to a depth of 1.6 to 3 m below water line which connected the main lake with a smaller pond (Luscar Ltd. 1986). Landscaping around the lakes (locally named Lovett Lake and Silkstone Lake) was completed mid-year 1986, and water levels were allowed to rise in both.

The lakes were monitored regularly in 1987. Water levels in both lakes remained relatively constant and water clarity was also more consistent than the previous year.

Two new demonstration trials were initiated involving lake inoculation techniques in 1988. Approximately 300 water plants were transplanted from a local lake into sites at each of Coal Valley's two lakes (Cardinal River Coals Ltd. 1988). These sites were monitored to determine if modifications of this technique could be considered for establishing plants in the lakes. Several straw bales were placed in a natural pond in the Coal Valley area, and left for several weeks. The bales were then placed at a site in the Silkstone lake. This technique was being evaluated for transplanting benthic organisms because the straw bales are a preferred habitat for many aquatic species.

3.4 TAILINGS

3.4.1 COAL VALLEY

In October 1988 the ARC initiated a research project to develop an alternative to the existing method for reclaiming areas affected by coal cleaning waste (tailings) disposal at the Luscar Sterco (1977) Ltd. Coal Valley Mine. The coal tailings are the reject or waste associated with the coal cleaning process and not overburden materials resulting from coal extraction. Previous reclamation practices included capping the tailings with 3 to 6 m of rock overburden to meet operational requirements, although only 1.2 m were required by regulation. In addition to this "biological" study a geological study was completed by Stahl and Sego (1992).

The "biological" study included tailings and soil sampling and characterization, a greenhouse experiment and a field experiment (Macyk 1993). Tailings placement in the 20 ha pit (Plate 3.93) was initiated in 1978 and discontinued in May 1989. The sampling program (Plate 3.94) completed in October 1988 included acquisition of samples of coal tailings, salvaged soil and slack coal materials.

The coal tailings were analyzed for several chemical and physical properties, soluble ions in saturated paste extracts, plant available trace elements and total elemental content. The analytical results indicated that in evaluating the coal tailings as a root zone material they would have a "good" rating for most parameters except pH and SAR. For the greenhouse experiment the soil and tailings treatments included control (soil only), waste only, 15 cm soil overlying waste, and a 1:1 mixture of soil and waste. The crops included alfalfa and reed canary grass. For both forage species the highest yield was obtained from the soil over tailings treatment and lowest yield from the tailings only treatment.

In the field experiment four soil replacement over tailings options were utilized including no soil replacement, 0.15 m soil, 0.30 m soil (Plate 3.95), and 0.30 m soil/1.05 m spoil over tailings. Two different seed mixtures were utilized for each of the soil replacement options. Vegetation rooting depth (Plate 3.96) was directly proportional to moisture availability and the coal tailings did not have any negative impact on the rooting characteristics of the vegetation. The plants grown directly on the tailings had tissue elemental characteristics similar to plants grown on the soil treatment plots. The highest forage yield occurred on the 1.2 m soil topdressing treatment, however the yield obtained on the 0.15 and 0.30 m soil treatments and directly on tailings was more than adequate to mitigate any site management problems that might occur.

Plates 3.97 to 3.101 illustrate the development of vegetation cover in the area with time. **The results obtained from the work completed indicated that both dryland and wetland reclamation techniques should be considered for these tailings areas. This would result in a landscape with a diverse vegetation cover and a variety of land uses.**

Plate 3.93. Tailings area (pit) in 1988.

Plate 3.94. Sampling of tailings material.

Plate 3.95. Soil cap over tailings.

Plate 3.96. Rooting depth in tailings materials.

Plate 3.97. Initial growth on tailings in 1989.

Plate 3.98. Growth in 1991.

Plate 3.99. Growth in 1997.


Plate 3.100. Pond vegetation in 1997.


Plate 3.101. Pond vegetation in 1997.

3.4.1 GRANDE CACHE AREA OPERATIONS

3.4.1.1 Coal Ash

The H.R. Milner Generating station, operated by Alberta Power, was built at a location along the banks of the Smoky River and adjacent to the office and plant site of McIntyre Porcupine Mines Ltd. in 1970. Due to its location (Plate 3.102) there were limitations to the space available for storage and disposal of the fly ash and bottom ash generated. In 1977 ash was extracted from the tailings ponds in the Smoky River Valley and transported to mine pits at No. 8 Mine (Plate 3.103). This resulted in the need to assess the suitability of the ash materials as a medium for plant growth. In June 1977 a field experiment was established on a mixture of bottom ash and fly ash placed in the A zone and adjacent to a highwall at the No. 8 Mine (Plate 3.104). Results of the monitoring activities in 1977 and 1978 (Macyk 1978) indicated that grasses and legumes would germinate and grow in the ash materials but fertilization was required to maintain a healthy and vigorous vegetation cover. The ash was also observed to be highly susceptible to water erosion (Plate 3.105). **From this work it became apparent that the most practical way of revegetating areas of ash disposal was to cap the waste material with a layer of soil material.**

Plate 3.102. H.R. Milner Generating Station adjacent to coal preparation and office facilities.


Plate 3.103. Ash placement in C West Pit at No. 8 Mine.

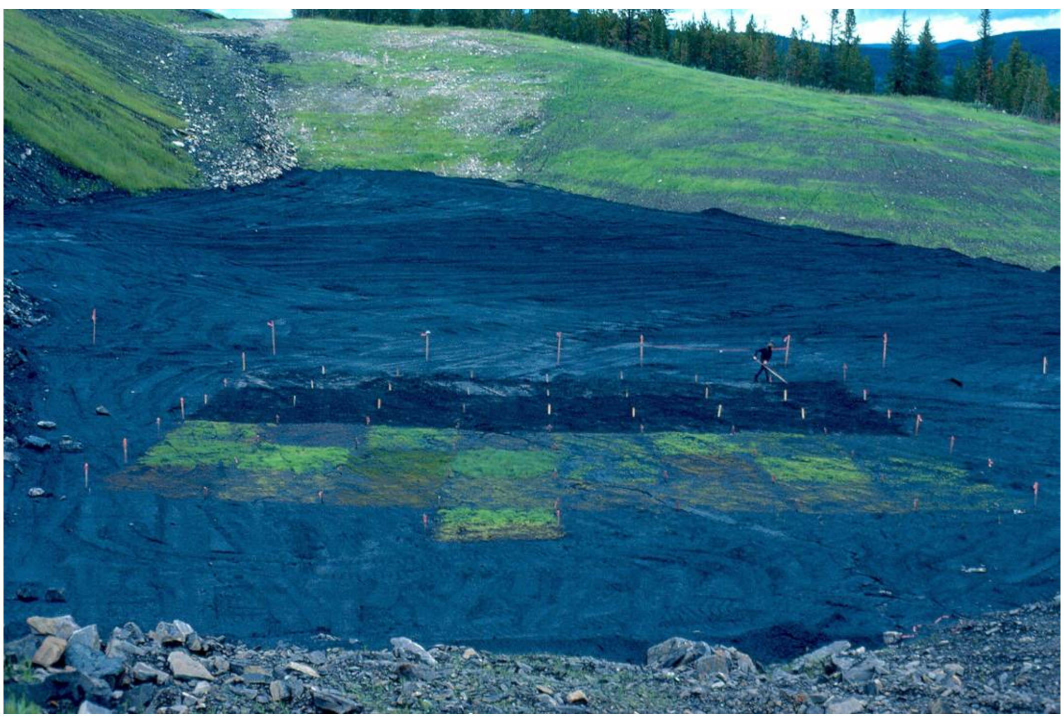
Plate 3.104. Experimental area in A zone near highwall at No. 8 Mine.

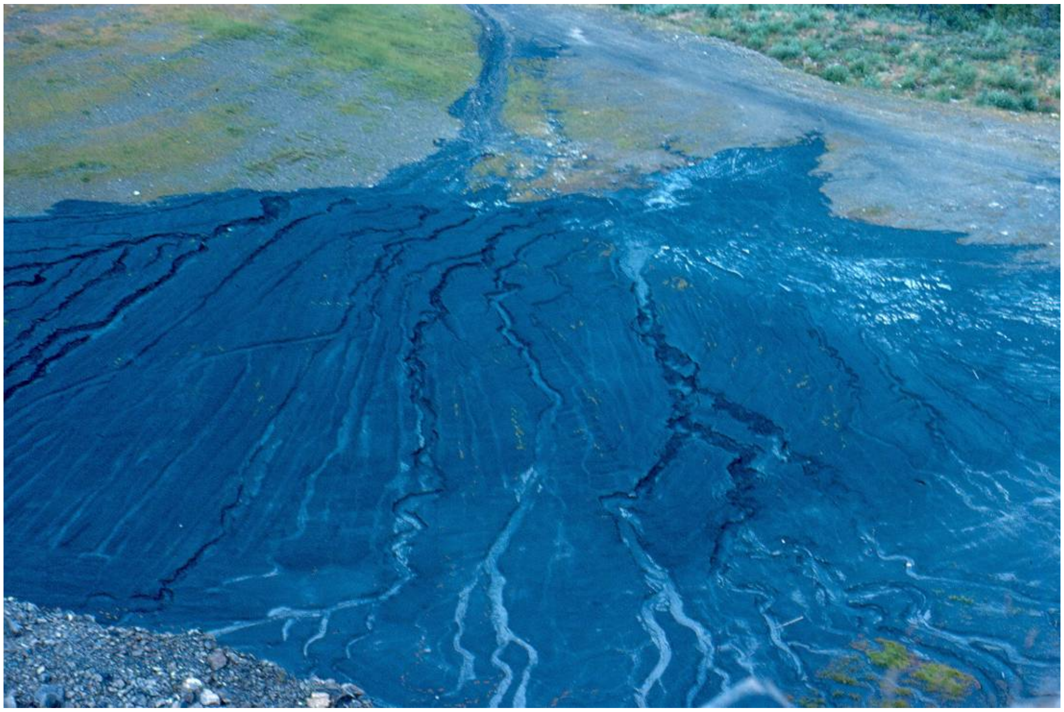

Plate 3.105. Eroded ash material at plot site.

In 1979 a comprehensive field study was undertaken to:

- Determine the minimum depth of overburden required to overcome any potential problems that may arise in regard to establishment of a vegetation cover in areas of fly ash disposal.
- Determine which elements show concentrating effects when plants are grown in fly ash affected substrates and those which may pose a potential hazard to animals.

Two plot areas were established in the Sheep Creek Valley below the No. 8 Mine area (Macyk and Widtman 1986). Plate 3.106 illustrates one of the plot areas. The plot treatments included bare ash, ash and soil incorporated, and soil caps 0 to 0.15 m, 0.15 to 0.30 m, 0.30 to 0.45 m and 0.45 to 0.60 m. The agronomic seed mixture was comprised of Nordan crested wheatgrass and Algonquin alfalfa. The native seed mixture was comprised of alpine fescue, northern wheatgrass, big bluegrass and loco-weed. The following conclusions were based on six years of monitoring.

- The best growth (highest yield and percent plant cover) occurred on the soil and ash incorporated plots followed by the soil depth treatments.
- There was no relationship between vegetative cover production and soil depth (Plate 3.107).
- The elements that concentrated in the plant tissue grown on ash included boron, chromium, lithium, molybdenum and strontium. Boron and molybdenum were of greatest concern because of their effect on plants and animals, respectively. One of the major concerns related to the potential for copper induced molybdenosis in big horn sheep**. It was recommended that ash be capped with a layer of suitable soil or overburden material approximately 0.15 to 0.30 m thick.**

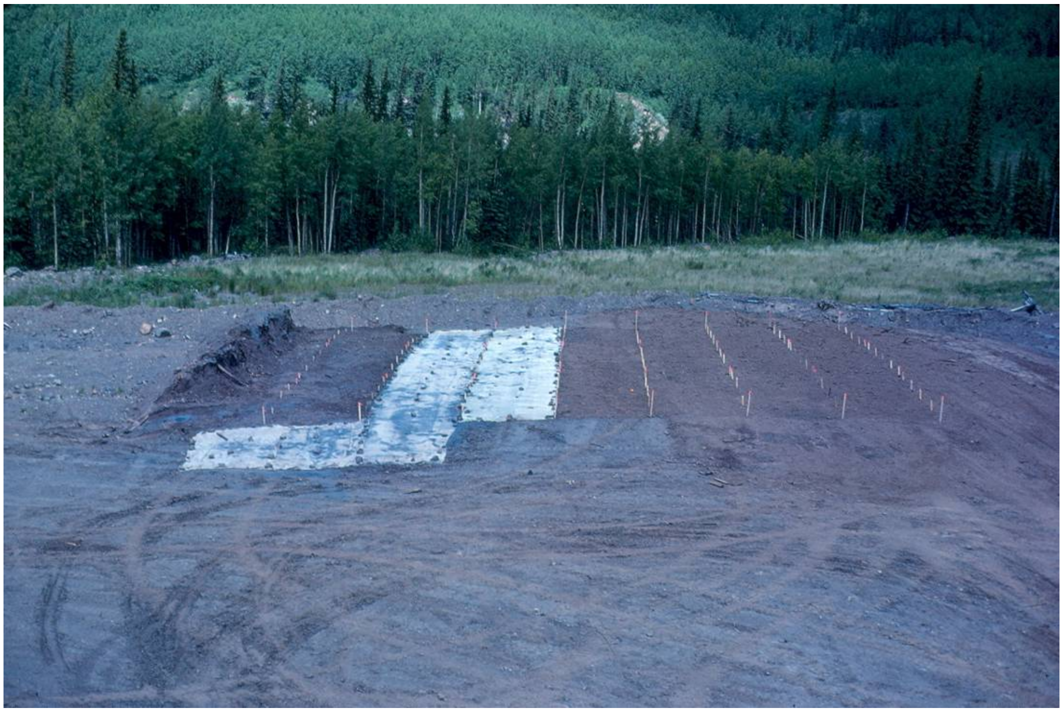

Plate 3.106. Plot area at Sheep Creek.

Plate 3.107. Vegetation cover established in the plot area.

3.5 BIODIVERSITY

3.5.1 COAL VALLEY

A program was initiated in 1986 to allow for long-term monitoring of wildlife (ungulates) winter-use of reclaimed lands. Transects were established in four areas of the mine and were monitored regularly for track crossings and pellet counts during winter and spring seasons. Preliminary results from the 1986/87 survey indicated that deer (whitetail and mule) and elk were the most common ungulates using the reclaimed areas, with 50% and 47% of tracks counted, respectively, involving these animals. Areas most heavily used were southern, exposed slopes and areas with open water. Grasses and legumes (particularly Dutch white clover) were grazed the most, although any deciduous shrubs were heavily browsed.

3.5.2 GRANDE CACHE AREA OPERATIONS.

Research and monitoring on the Red Rock Prairie Creek mountain caribou herd began in 1989. The research data included items such as; telemetry tracking, spring and fall migration direction, alternative route usage and fence deflection. The fence deflection study was initiated to evaluate whether or not caribou migration patterns could be changed. Results suggested that caribou could be deflected and that the deflection of caribou away from proposed mining areas was possible (Smoky River Coal 1997).

4.0 OPERATIONAL RECLAMATION PRACTICES AT THE PLAINS COAL MINES

4.1 BACKGROUND

Information was obtained primarily from documents supplied by the mine operators in the prairie coal mine regions and Alberta Environment Archives. The documents included "Annual Reclamation Reports", approval documents and a variety of publications pertinent to the topic. A complete list of documents is provided in the reference section.

4.1.1 COMPANY OVERVIEWS

The following information provides brief "historical" information for each company and their operations in terms of reclamation.

4.1.1.1 Genesee Coal Mine

The Genesee Mine, located approximately 70 kilometres southwest of Edmonton, has been producing coal for electricity since 1988. Fording Coal Limited operates the mine under the terms of a Joint Venture Agreement with Edmonton Power Inc. The Genesee Coal Mine provides 5.5 million tonnes of coal per year for the Genesee Generating Station, operated by Edmonton Power Inc.

With the start-up of its second 400-megawatt generating unit in late 1993, the Genesee Generating Station has the capacity to produce enough electricity to serve a city of 500,000 people.

EPCOR and Luscar Ltd. share a commitment to reclaim disturbed land to a state equal to or better than pre-mine conditions based on the agricultural capability rating system, which includes areas containing native trees and bushes. The area surrounding the Genesee Generating Station is a mixed-farming and cattle-producing community, and coal mining represents only a temporary use of the land before it is reclaimed. At Genesee, land reclamation involves recontouring mined areas and ensuring they are covered with good quality subsoil before the topsoil is replaced. Recontouring operations are specifically designed to ensure that water drainage will enhance the various land uses.

4.1.1.2 Highvale Coal Mine

The Highvale Mine is a sub-bituminous coal strip mine located 80 km west of Edmonton on the south shore of Wabamun Lake. The mine is currently owned by TransAlta Utilities Corporation (TransAlta) and is operated under contract by Luscar Ltd. The mine currently consists of six open pits that supply thermal coal to the TransAlta owned Sundance and Keephills Thermal Generating Plants. Mining operations at Highvale Mine commenced in July 1970. The mine has been supplying coal to Sundance since November 1970 and to Keephills since February 1983 (TransAlta 2007).

Agricultural land capability has been the underlying philosophy for reclamation requirements at the Highvale Mine since January 1983. Since 1983, lands disturbed for the purposes of mining must be reclaimed to an equivalent agricultural land capability. At the time that land capability became a reclamation requirement, not all land disturbed by mining had been completely reclaimed.

As the Highvale Mine is located within the White (agricultural) zone of Alberta, reclamation is primarily oriented to the return of agricultural capability (vs. forestry), however, this does not restrict the adoption of many alternate land uses other than agriculture. Reclaimed lands with low agricultural capability (Classes 6 and 7) provide the opportunity to adopt alternate land uses such as wildlife and waterfowl habitat, recreation and stock watering. The objectives of the land management program at the Highvale Mine are to implement soil conservation practices and to maintain and/or enhance soil quality on reclaimed land. This management system is designed to produce stable landscapes with minimal erosion on areas designated for low intensity use and productive agricultural fields which can sustain typical farming practices used in the Highvale region.

The total mine area is 5,392 ha, of which 1,413 (26%) is Class 3, 1,906 ha (35%) is Class 4, 1,379 ha (26%) is Class 5, 513 ha (10%) is Class 6, and 181 ha (3%) is Class 7 (TransAlta 2006).

4.1.1.3 Whitewood Mine

The Whitewood Mine, owned by TransAlta, is a sub-bituminous coal strip mine located 64 km west of Edmonton at Wabamun, Alberta and has operated since 1962. The mine currently consists of the West Pit, supplying coal to the Wabamun Thermal Generating Plant. Coal mining operations are performed under contract by Luscar Ltd. The mine permit area covers 3,330 hectares.

Mining activities include overburden stripping, gravel recovery, coal loading and hauling, and removal of overburden. Currently all overburden at Whitewood is stripped by dragline using the conventional sidecast method. Coal loading is performed by front end loaders and the coal is delivered by 145 tonne bottom dump trucks.

The objectives of reclamation at the Whitewood Mine are to:

- Construct post-mine landscapes and soil that have an equivalent agricultural land capability to that which existed prior to mining in a manner generally consistent with the Whitewood end use plan.
- Manage reclaimed land in a sustainable manner.
- Certify reclaimed land in a timely manner and sell land to individual landowners.

Land mined since January 1, 1983 has been reclaimed with the objective of matching the equivalent land capability for agriculture to that which existed prior to mining. Lands mined before 1983 were reclaimed to standards in effect at the time of the disturbance.

Reclaimed lands at Whitewood are either leased to local farmers or managed by TransAlta's Reclamation Centre. The Centre generally controls newly reclaimed areas that require intensive management practices such as rock and root picking or seedbed levelling. In the first two growing seasons, these areas are usually cereal cropped unless they are designated for wildland purposes, which would then require them to be seeded to perennial plant species immediately.

Once areas are fully established, the land is leased to local area producers. Prior to leasing the reclaimed land, TransAlta requires potential leases to submit a suitable land management plan that meets TransAlta's expectations for soil conservation, crop nutrition, and weed management.

4.1.1.4 Diplomat Mine

The Diplomat Mine is located approximately 15 km southwest of Forestburg, Alberta. Mining began in 1949 by Forestburg Collieries Ltd., a subsidiary of Luscar Ltd. The Diplomat Mine was a surface strip mine operation which used draglines to remove the overburden. Mining operations were completed in 1983.

4.1.1.5 Paintearth Mine

The Paintearth Mine is located approximately 200 km southeast of Edmonton, Alberta and 5 km south of the Diplomat Mine. Surface mining operations began in 1981 to supply coal to the Battle River Generating Station owned by ATCO Electric. In October 1998, the operations of the Paintearth and Vesta Mines were amalgamated. The Paintearth Mine is a conventional surface strip mining operation which utilizes draglines to remove the overburden. Reclamation at Paintearth Mine involves re-establishing the soil to conditions which will support agricultural land use common to the region. Reclamation activities include the replacement of subsoil and topsoil materials and seeding the land for crop production.

4.1.1.6 Vesta Mine

The Vesta Mine is located approximately 20 km north of Halkirk, Alberta. It is situated between the Diplomat Mine to the north and the Paintearth Mine to the south. Mining operations date back to 1906 but the "official" start-up date was 1949 with a major expansion in 1959 (B. Martens personal communication). When Luscar Ltd. acquired Manalta Coal Ltd. in 1998, the Vesta Mine was integrated with Luscar's Paintearth Mine.

4.1.1.7 Montgomery Mine

The Montgomery Mine was previously known as the Roselyn Mine and was operating in the late 1950s. The Montgomery Mine began large-scale dragline operations and was approved as one of the first mines that went through an EIA and formal public hearing in

1978 (B. Martens personal communication). When Luscar Ltd. acquired Manalta Coal Ltd. in 1998, the Montgomery Mine was integrated with Luscar's Sheerness Mine.

4.1.1.8 Sheerness Mine

The Sheerness Mine, located approximately 30 km southeast of Hanna, Alberta began operations in 1995 to supply coal to the Sheerness Generating station jointly owned by TransAlta Utilities and ATCO Electric. In late 1998, the Sheerness Mine and the adjacent Montgomery Mine were integrated into a single operation. The Sheerness mine is a conventional surface strip mining operation which uses draglines to remove overburden and expose the coal. The mine is located in a particularly dry area which presents a challenge for cereal crop production. The mine's land management program strives to return mined land to perennial forage crop production.

4.1.2 APPROVALS

4.1.2.1 Genesee Coal Mine

Edmonton Power's 1979 Development and Reclamation Approval stated that:

- Organic and mineral material suitable for soil reclamation was to be removed by the Operator in sufficient quantities necessary for the reclamation of the lands to the approved post-disturbance land use from lands having slopes less than 2:1 (27°). Soil stripping was to be carried out in a manner acceptable to the Council.
- Whenever it was necessary to store soil and other surficial material suitable for reclamation, each storage site required approval of the Council prior to construction, the foundations of the sites used for storage were to be stable, the storage sites were to be protected from wind and water erosion, and the storage sites were to be accessible and the material retrievable for futures use.
- The reconstructed soil for use on all disturbed areas other than research plots detailed in the Application was to have chemical, physical, and biological characteristics which permitted reclamation to an agriculture land use which was at least as productive as it was prior to disturbance.
- Depths of replaced soil were to be at least sufficient to provide reclamation to the post-disturbance land use prescribed in the Approval.
- Disturbed areas were to be revegetated with plant species compatible with the prescribed post-disturbance land use within the growing season immediately following final recontouring or surface soil reconstruction.

A 1982 Amendment to the Development and Reclamation Approval stated that:

- All topsoil materials (A horizon) were to be salvaged from all lands to be disturbed for the purpose of resurfacing reclaimed areas to at least the quality that existed prior to disturbance. The depth of replaced topsoil was to be a minimum of 0.2 m.
- The subsoil in the reclaimed soil profile was to be of at least the quality that existed prior to disturbance. The depth of replaced subsoil was to be a depth of

1.1 m in Mining Block 1788-01 and of the same depth and sequence as existed prior to mining in Mining Block 1788-02.

- The reconstructed soil profile was to have chemical and physical properties and characteristics which resulted in the reclaimed land having a sustained capability equal to or better than the capability for the same land prior to mining according to the methodology described in *Soil Quality Criteria for Reclamation of Disturbed Lands* (Alberta Agricluture 1981).
- Ash and material reject from the coal supply by the power plant to be disposed of in mined areas, was to be buried not less than 1.6 m below the reconstructed soil surface, unless otherwise approved by the Chairman.

A 1988 Amendment to the Development and Reclamation Approval stated that:

- Through appropriate conservation and replacement of soil materials; spoil placement, backfilling and recontouring; revegetation; and reclamation research; the reclaimed land surface shall have characteristics and properties (topography, drainage, soils, vegetation) that will result in the return of a land capability that is equivalent to that which existed prior to disturbance.
- All suitable topsoil materials were to be salvaged from all land to be disturbed for the purpose of resurfacing reclaimed areas. These materials were to be evenly spread over the recontoured landscape.
- The operator was to ensure that a sufficient quantity of suitable materials was salvaged such that a minimum of 1.0 m of suitable subsoil materials would be present in the reclaimed profile.
- All overburden materials and interburden materials not designated as suitable subsoil materials were to be buried not less than 1.2 m below the reconstructed soil surface.
- The operator was to develop and maintain a soils and plant growth testing program to monitor the long term adequacy of the materials handling and reclamation procedures utilized.

A 1997 Amendment to the Development and Reclamation Approval stated that:

- The approval holder was to direct place salvaged subsoil and topsoil on contoured portions of the disturbed land whenever possible. When subsoil and topsoil were stockpiled, the stockpiles were required to be separated by at least five meters, stabilized to control water erosion and revegetated if they remained in place for more than one growing season.
- The approval holder was to recontour slopes to achieve natural landscape diversity.
- The approval holder was granted permission to substitute suitable spoil for subsoil in areas to be returned to Canada Land Inventory (CLI) agricultural capability classes 4, 5, or 6, or as otherwise authorized in writing by the Director.
- The approval holder was to replace all salvaged topsoil such that a minimum of 0.12 m and an average of 0.18 m of topsoil was present in the reclaimed profile on land to be returned to CLI agricultural capability classes 2, 3, 4, or 5.

- The approval holder shall replace topsoil on land to be returned to agricultural capability class 6 only at the direction of a Conservation and Reclamation Inspector.
- The approval holder was to ensure that the introduction of noxious weeds to the area was minimized by using Canada #1 seed in the mixes for revegetation.

Epcor Generation Inc.'s 2005 Approval for the construction, operation and reclamation of the Genesee Coal Mine stated that the approval holder shall reclaim land through appropriate conservation and reclamation methods to construct land having characteristics (soils, topography and drainage) that result in a return of land capability equivalent to or better than that existing prior to disturbance. Specific requirements included:

- The approval holder shall replace salvaged subsoil such that a minimum of 1.0 meter of subsoil will be present in the reclaimed profile, unless otherwise authorized in writing by the Director.
- The approval holder shall replace all salvaged topsoil such that a minimum of 0.12 m and an average of 0.18 m of topsoil will be present in the reclaimed profile on the land in the East Field to be returned to agricultural capability classes 2, 3, 4, or 5.
- The approval holder shall replace all salvaged topsoil such that a minimum of 0.12 m and an average of 0.14 m of topsoil will be present in the reclaimed profile on land in the West Field to be returned to agricultural capability classes 2, 3, 4, or 5.
- The approval holder shall only use the following types of seed for revegetation:
    - for agronomic species seed that is equivalent to Canada #1 seed and is free of prohibited and primary noxious weeds,
    - for native species seed that: 1) is free of prohibited and primary noxious weeds, 2) has a count of 5 or less secondary noxious weed seeds per 25 g of seed, and 3) has a count of 50 or less for other weed seeds per 25 g of seed.
- The approval holder shall develop and maintain a soil and plant growth testing program to monitor the long-term adequacy of the materials handling and reclamation procedures utilized at the mine. The program should provide a suitable database for considering any possible revisions to the materials handling and reclamation procedures at the mine.

4.1.2.2 Highvale Coal Mine

Calgary Power Ltd. was granted the initial Development and Reclamation Approval in 1979 for the operation of the Highvale Mine. Specific requirements pertinent to reclamation included:

- All organic and mineral soil material above the B soil horizon was to be salvaged for revegetation purposes from all areas to be disturbed.
- In addition to the topsoil recovered, sufficient subsoil and parent material was to be salvaged from disturbed areas for replacement on the land surface, so that no

material considered unsuitable for revegetation would be found within 0.45 m of the reconstructed land surface. The criteria of the suitability was as follows: pH (6.5 to 8.2), SAR (less than 10), % saturation (less than 70), conductivity (less than 8 mmhos/cm).

- Whenever it was necessary to store soil and other surficial material suitable for reclamation, each site required approval of the Council prior to construction, the foundations for the sites were to be stable, sites were to be protected from wind and water erosion, and accessible and the material retrievable for future use in reclamation of the lands.
- Oversize material rejected by the power plant was to be disposed of by burial not less than 1.6 m below the reconstructed soil surface.
- Where ash was to be disposed in mined out areas, it was to be disposed of by burial not less than 1.6 m below the reconstructed soil surface.
- The reconstructed soil surface was to have chemical, physical, and biological characteristics which would permit upland reclamation to an agricultural use which would be at least as productive as it was prior to disturbance.
- Disturbed areas and backfilled pits were to be revegetated with plant species compatible with the prescribed post-disturbance land use within the growing season immediately following final re-contouring or surface soil reconstruction.

TransAlta Utilities Corporation's 1981 Development and Reclamation Approval stated that:

- The operator was to salvage all topsoil and mineral soil materials above the B horizons from all areas to be disturbed, for replacement of the rootzone.
- The operator was to salvage and replace sufficient suitable subsoil and parent geological material such that the sustained growth capability for agriculture production of the replaced soil shall be equal to or better than the agricultural productive capability of the same land areas prior to their disturbance.
- After December 31, 1981, any material unsuitable for plant growth, in accordance with criteria used to determine suitability submitted to council, was not to be placed closer than three meters to the recontoured land surface where in the pre-mining condition such material did not exist within three meters of the land surface.
- Where, in the pre-mining undisturbed condition, material unsuitable for plant growth did exist within three meters of the land surface, the operator was to replace suitable subsoil and parent geological material to the same depth that suitable soil material for plant growth existed in the pre-mining undisturbed condition.

TransAlta's 1983 Development and Reclamation Approval stated that:

- Through appropriate conservation and reclamation of soil materials, spoil placement, backfilling and recontouring, revegetation, and reclamation research, the reclaimed land surface shall have characteristics and properties (topography, drainage, soils, vegetation) that will result in the return of a land capability that is equivalent to or better than that which existed prior to disturbance.

- All topsoil materials (A horizon) were to be salvaged from all lands to be disturbed for the purpose of resurfacing recontoured areas to at least the quality that existed prior to disturbance. The depth of replaced topsoil was to be a minimum of 0.20 m.
- The subsoil in the reclaimed profile was to be of at least the quality that existed prior to disturbance. Within the areas where greater than 1.0 m of suitable subsoil materials were available sufficient material was to be salvaged to enable replacement of a minimum of 1.5 m of subsoil material over an equivalent area. Within the areas where less than 1.0 m of suitable subsoil materials were available sufficient material was to be salvaged to enable replacement of a minimum of 0.5 m of subsoil material over an equivalent area.
- Final highwalls were to have a maximum slope angle of not greater than 27°. All other recontoured slopes were to be no greater than 10°, were to conform as closely as possible to the original surface contour, maximize open surface drainage and minimize ponding.

A 1986 amendment stated that all suitable topsoil materials (A horizon) were to be salvaged from all lands to be disturbed for the purpose of resurfacing recontoured areas to at least the quality that existed prior to disturbance. The topsoil was to be replaced evenly over the recontoured areas. Depths replaced and proposed for replacement were to be documented in the Annual Report.

A 1989 amendment to the Approval stated that:

- Suitable subsoil material was not to be buried or used for other purposes unless approved by the reclamation officer. Suitable subsoil materials meant having been classified according to *Soils Quality Criteria Relative to Disturbance and Reclamation* (ASAC 1987).
- The operator was required to replace 1.5 m of suitable subsoil materials on lands which were to be returned to a CLI class 3 agricultural capacity.
- The operator was required to replace 0.35 m of suitable subsoil materials on lands which were to be returned to a CLI class 4, 5, or 6 agricultural capability, unless otherwise approved by the reclamation officer.
- The operator could substitute spoil materials for suitable subsoil materials, in areas that were to be returned to CLI class 4, 5, or 6 agricultural capability providing that the following criteria were met:
    - Documentation that spoil material met the soil quality criteria applied to suitable subsoil materials was provided to the reclamation officer.
    - Reclamation officer approval was given regarding quality, quantity and location of spoil material placement.
    - Documentation of depths and locations of spoil application and site monitoring details were provided in the annual report.

A 1991 amendment indicated that the operator was to ensure that a sufficient quantity of suitable subsoil material was salvaged such that a minimum of 1.0 m of suitable subsoil material would be present in the reclaimed profile on lands which were to be returned to a CLI class 3 agricultural capacity.

A 1998 amendment stated that the approval holder:

- Replace salvaged subsoil such that a minimum of 1.0 m of subsoil was present in the reclaimed profile on land to be returned to agricultural capability class 2 or 3 (*Agricultural Capability Classification for Reclamation: Working Document,* 1993).
- Replace salvaged subsoil such that a minimum of 0.35 m of subsoil would be present in the reclaimed profile on land to be returned to agricultural capability class 4, 5, or 6.
- May substitute suitable spoil for subsoil in areas to be returned to agricultural capability class 4, 5, or 6, and class 2 or 3 only as authorized in writing by the Director.
- Replace topsoil on land to be returned to agricultural capability class 6 only at the direction of a conservation and reclamation inspector.

TransAlta's 2006 Approval for the construction, operation and reclamation of the Highvale Coal Mine stated that the approval holder shall reclaim land through appropriate conservation and reclamation methods to construct land having characteristics (soils, topography, and drainage) that result in a return of land capability equivalent to or better than that existing prior to disturbance. Specific requirements included:

- The approval holder shall salvage all topsoil from disturbed land.
- The approval holder shall conserve all topsoil for reclamation.
- The approval holder shall salvage sufficient subsoil and suitable spoil from disturbed land to meet reclamation objectives.
- The approval holder shall direct place salvaged subsoil and topsoil on contoured portions of the disturbed land whenever possible.
- The approval holder shall stockpile all salvaged subsoil and topsoil as follows:
    - Topsoil and subsoil shall be stockpiled separately.
    - Stockpiles shall be separated by at least five meters.
    - Stockpile foundations must be stable.
    - Stockpiles shall be stabilized to control water erosion.
    - Stockpiles that will remain in place for more than one growing season shall be revegetated to control weeds.
- The approval holder shall create a final landscape with free draining and non-erosive slopes.
- The approval holder shall ensure that 1.2 m of subsoil or suitable spoil is present in the reclaimed profile in land using bottom ash.
- The approval holder shall replace salvaged subsoil such that a minimum of 1.0 meters of subsoil is present in the reclaimed profile on land to be returned to agricultural capability class 2 or 3.
- The approval holder may substitute suitable spoil for subsoil in areas to be returned to agricultural capability class 2 or 3, only as authorized in writing by the Director.

- The approval holder shall replace salvaged subsoil such that a minimum of 0.35 meters of subsoil will be present in the reclaimed profile on land to be returned to agricultural capability class 4, 5, or 6.
- The approval holder may substitute suitable spoil for subsoil in areas to be returned to agricultural capability class 4, 5, or 6.
- The approval holder shall develop and implement a soil and vegetation assessment program to monitor the long-term capability of areas reclaimed using suitable spoil.
- The approval holder shall replace all salvaged topsoil such that a minimum of 0.17 m of topsoil will be present in the reclaimed profile and with an average of 0.20 m of topsoil present in the reclaimed profile.
- The approval holder shall replace topsoil on land to be returned to agricultural capability class 6 only at the direction of a Conservation and Reclamation Inspector.
- The approval holder shall only use the following types of seed for revegetation:
    - for agronomic species that is equivalent to Canada #1 seed and is free of seed prohibited and primary noxious weeds,
    - for native species seed that: 1) is free of prohibited and primary noxious weeds, 2) has a count of 5 or less secondary noxious weed seeds per 25 g of seed, and 3) has a count of 50 or less for other weed seeds per 25 g of seed.

4.1.2.3 Whitewood Mine

Manalta Coal Ltd. was granted the initial Development and Reclamation Approval in 1975 for the operation of the Whitewood Mine. A 1977 amendment to the Approval stated:

- The approval holder was to carry out all surface disturbing activities in such a manner as to ultimately permit the reclamation of the land surface to ensure that the mined or disturbed land would be returned to a state which would be self-supporting of both plant and animal life or be otherwise as productive as it was before it was disturbed.
- All organic and mineral material suitable and necessary for revegetation purposes was to be stripped, stockpiled and protected for ultimate reclamation purposes.

Development and Reclamation Approval No. C-12-77 dated September 12, 1977 and issued to Manalta Coal Ltd. was granted to Calgary Power Ltd. in 1979.

Calgary Power Ltd.'s 1983 Development and Reclamation Approval stated the following pertinent to reclamation:

- The reclaimed land surface shall have physical characteristics and properties (topography, drainage, soils, vegetation) that shall result in the return of equal to or better than land capabilities as existed prior to mining.
- All topsoil materials (A horizon) were to be salvaged from previously cultivated lands and all other lands where the depth of topsoil (A horizon) is greater than 15 cm for the purpose of resurfacing recontoured areas to at least the quality that

existed prior to disturbance. The depth of replaced topsoil was to be a minimum of 0.15 m.

- After topsoil removal, overburden spoiling was to be conducted in a manner that would provide suitable materials at the recontoured surface. All unsuitable overburden materials (sand, gravel, bedrock) and coal seam partings were to be prevented from occurring within 1.6 m of the recontoured surface.
- Final highwalls were to have a maximum slope angle of not greater than 27°. All other recontoured slopes were to be no greater than 10°, conform as closely as possible to the original surface contour, maximize open surface drainage and minimize ponding.
- Ash from the power plant, which was to be disposed of in the mined out areas, was to be buried not less than 1.6 m below the reconstructed soil surface, unless otherwise approved by the Chairman.

Calgary Power Ltd. changed it's company name to TransAlta Utilities Corporation in March, 1983.

A 1986 amendment stated that topsoil materials designated as suitable for reclamation were not to be used for any other purpose, unless otherwise approved by the Chairman. The land use criteria to be used in achieving specific types of land uses in certain areas included, but was not limited to the following:

- Grazing, Wildland/Off Highway Vehicle Park (G/OHV)
  - In the G area, slopes were not to exceed 10°. In the OVH area, slopes were not to exceed 20°.
  - Topsoil was not to be replaced in areas to be reclaimed as OHV zones.
  - Ponding of water and closed drainage was to be provided in the G and OHV zones.
  - A diverse mix of vegetation was to be provided in the G areas.
- Annual Crop, Pasture (AP)
  - Slopes were not to exceed 5°.
  - Open, positive drainage was to be provided such that the ponding of water was minimized.
- Pasture, Grazing (PG)
  - Slopes were not to exceed 10°.
  - Ponding and closed drainage was to be provided.

A 1989 amendment included the following clause:

- The operator shall salvage lake bottom materials to a depth of 0.4 m and these materials shall be used as a soil amendment for reclamation purposes.

A 1991 amendment required that all suitable topsoil materials (A horizon) be salvaged from land to be disturbed for the purpose of replacement on the recontoured landscape. These materials were to be evenly spread over the recontoured landscape and at a minimum depth of 0.20 m. Suitable topsoil material meant having topsoil having the same rating as described in *Soil Quality Criteria in Relation to Disturbance and Reclamation* (ASAC 1987).

The Off-Highway Vehicle (OHV) land use designation was removed in 1992. The Grazing, Wildland (G) designation therefore had the following criteria:

- Slopes shall not exceed 10°.
- Topsoil shall not be replaced in areas to be reclaimed as G zones.
- Ponding of water and closed drainage shall be provided in the G zone.

TransAlta Utilities Corporation's 1998 Approval for the opening up, operation and reclamation of the Whitewood Coal Mine stated the following pertinent to reclamation:

- The approval holder was to salvage all topsoil from land to be disturbed.
- The approval holder was to conduct direct placement of salvaged topsoil on contoured portions of the disturbed land whenever possible.
- Topsoil stockpiles were to be stockpiled separately from other materials, separated by at least five meters, stabilized to control water and wind erosion, accessible and retrievable and revegetated.
- The approval holder was required to replace topsoil over 1.0 m of material having a good, fair, or poor rating in the *Soil Quality Criteria Relative to Disturbance and Reclamation* (ASAC 1987).
- The approval holder shall immediately suspend topsoil replacement when:
    - Wet or frozen conditions will result in the admixing, degradation, or compaction of topsoil.
    - High wind velocities, any other field conditions or mine operations will result in the admixing, degradation or loss of topsoil.
- For areas of the mine disturbed between 1983 and 1991, the approval holder was to replace all salvaged topsoil such that a minimum of 0.15 m was present in the reclaimed profile in all areas identified in the Reclamation Plan.
- For areas of the mine disturbed between 1992 and 1997, the approval holder was to replace all salvaged topsoil such that a minimum of 0.20 m was present in the reclaimed profile in all areas identified on the Reclamation Plan.
- For areas of the mine disturbed between 1998 and 2002, the approval holder was required to replace all salvaged topsoil to achieve a predetermined percentage of land in agricultural capability class 2, 3, 4, 5, 6, and 7.
- The approval holder was required to maintain a weed control program to standards mutually agreed upon with the local municipal authority.

TransAlta's 2003 Approval stated that the approval holder shall ensure that areas of the mine in the 1998 to 2014 mining area are reclaimed to have an agricultural capability that is equivalent to or better than that existing prior to disturbance.

To achieve the required agricultural capability classes the Approval states that:

- The approval holder shall replace topsoil over 1.0 meter of material having a good, fair or poor rating in the *Soil Quality Criteria Relative to Disturbance and Reclamation* (ASAC 1987).
- For areas of the mine disturbed after 2002, the approval holder shall replace salvaged topsoil such that a minimum of 0.15 m is present in the reclaimed profile of all agricultural capability class 2 and 3 lands.

- The approval holder shall develop and maintain a soil, groundwater and plant growth testing program to monitor the long term adequacy of the materials handling or reclamation procedures utilized at the mine.
    - The program shall include sampling and analyses to provide a suitable database for considering any revisions to the material handling or reclamation procedures at the mine including, but not limited to, the following materials: ash, spoil, topsoil, and any other material as directed in writing by the Director.

4.1.2.4 Paintearth and Vesta Coal Mines

Forestburg Collieries Ltd.'s 1980 Development and Reclamation Approval for Paintearth Coal Mine was amended in 1983. This amendment stated that through appropriate conservation and replacement of soil materials, spoil placement, backfilling and recontouring, revegetation, and reclamation research, the reclaimed land surface shall have characteristics and properties (topography, drainage, soils, vegetation) that will result in the return of a land capability that is equivalent to or better than that which existed prior to disturbance. Specific requirements relevant to reclamation included:

- All topsoil materials (A horizon) were to be salvaged from all lands to be disturbed for the purpose of resurfacing reclaimed areas to at least the quality that existed prior to disturbance. The operator was required to replace all topsoil materials salvaged in such a manner that the materials were evenly spaced over the recontoured landscape.
- Within areas where greater than 1.0 m of suitable subsoil materials were available, sufficient material was to be salvaged to enable replacement of a minimum of 1.5 m of subsoil material over the deep zone. Within areas where less than 1.0 m of suitable subsoil material was available, excluding the stabilization zone, sufficient material was to be salvaged to enable replacement of a minimum of 0.5 m of subsoil material over an equivalent area.
- Whenever it was necessary to store soil and other surficial material suitable for reclamation of disturbed land, each storage site required approval by the Reclamation officers prior to construction of the stockpile. Storage sites were required to have stable foundations, be protected from wind and water erosion, and materials had to be accessible and retrievable.
- To ensure soil salvage plans were being adhered to the operator was required to provide a training program and on-site supervision for equipment operators.
- Ash and material reject from the coal supply by the power plant to be disposed of in mined out areas was to be buried not less than 1.6 m below the reconstructed soil surface.

Forestburg Collieries Ltd.'s 1995 approval for the operation and reclamation of the Paintearth Coal Mine stated:

- The approval holder was required to salvage soil material from the disturbed land and conserve it exclusively for reclamation of the disturbed land.
- The approval holder was to direct place salvaged soil material on contoured portions of the disturbed land whenever possible. When stockpiled, topsoil and

subsoil stockpiles were required to be stockpiled separately, Stockpiles were to be separated by at least one meter, stabilized to control wind and water erosion, accessible, retrievable and revegetated to control weeds.

- The approval holder was required to salvage all topsoil from all land to be disturbed
- The approval holder was required to salvage all subsoil to a maximum depth of 1.5 m.
- The approval holder was not to bury or use soil material for any purpose other than reclamation unless directed by the conservation and reclamation inspector.
- The approval holder was to ensure that the introduction of new weeds to the area was minimized by using Canada #1 seed in the mixes for revegetation.

When Luscar Ltd. acquired Manalta Coal Ltd. in 1998, the Vesta Mine was integrated with Luscar's Paintearth Mine. Luscar's 2005 Approval for the construction, operation and reclamation of the Paintearth and Vesta Coal mines stated that the approval holder shall reclaim land through appropriate conservation and reclamation methods to construct land having characteristics (soils, topography and drainage) that result in a return of land capability equivalent to or better than that existing prior to disturbance. Specific requirements include:

- The approval holder shall recontour slopes to achieve landscape diversity which is compatible with slopes in the mine area that are not disturbed land.
- The approval holder shall create a final landscape with free draining and nonerosive slopes.
- The approval holder shall immediately suspend topsoil replacement when:
    - Wet or frozen conditions will result in the admixing, degradation, or compaction of topsoil.
    - High wind velocities, any other field conditions or mine operations will result in the admixing, degradation or loss of topsoil.
- The approval holder shall only use the following types of seed for revegetation:
    - for agronomic species seed that is equivalent to Canada #1 seed and is free of prohibited and primary noxious weeds,
    - for native species seed that: 1) is free of prohibited and primary noxious weeds, 2) has a count of 5 or less secondary noxious weed seeds per 25 g of seed, and 3) has a count of 50 or less for other weed seeds per 25 g of seed.

4.2 DRY LAND RECLAMATION

4.2.1 SOIL SALVAGE

4.2.1.1 Genesee Coal Mine

Grazing activities and management were established and maintained for a minimum of five years before mining (Genesee 1987). This allowed for stable land use and weed control in advance of mining, conservation and development of soil organic carbon, and sod conditioning for topsoil salvage. **Pre-mine soil management activities create fiber-rich topsoil that is not as prone to wind and water erosion as cultivated topsoil.**

In 1988 treed areas were dozed, grubbed and burned. Topsoil was salvaged in 1988 and stockpiled or spread on low areas in the adjacent fields. Topsoil was recovered primarily by scrapers, but dozers and graders were also utilized. Within a year areas stripped were usually scheduled to be mined from the late fall to the following summer. All topsoil recovery was suspended with the onset of frost conditions. Typically, the scrapers handled the salvage from areas with normal ground conditions. The PC300 backhoe was used to directly strip and load topsoil into 210M ash haulers or scrapers in areas of soft or wet ground conditions. In some areas of soft ground a backhoe with a smooth lipped bucket was used to windrow topsoil for pickup by scrapers. The 922C loader/510E truck combination was used to maximize productivity and efficiency when long haul situations were encountered. Dozers skimmed topsoil into piles suitable for the loading equipment. All topsoil was placed in strategically located storage sites. Stockpiles were groomed and seeded with reed canary grass, creeping red fescue and timothy to prevent wind and water erosion and mitigate weed propagation.

Currently, the normal practice for topsoil recovery is to schedule salvage operations for summer and fall periods when conditions are driest (Genesee 2006). Equipment used for topsoil salvage includes dozers, 992C front end loaders, and 510E haul trucks. This process involves dozing up the topsoil into uniform piles and loading into haul trucks. The topsoil is then hauled either to stockpiles or to reclamation sites and placed in cells of a prescribed length, width and height on top of the prepared subsoil. **The calculated average topsoil salvage thickness has ranged between 0.15 m and 0.24 m since 1996 (Genesee 2006).** Alberta Environment granted approval in 2001 for winter topsoil salvage due to abnormally low snow cover, therefore salvage has occurred in winter.

4.2.1.2 Highvale Coal Mine

Timber from the Highvale Mine has low commercial value and normally is not harvested. Trees and brush were cleared during winter months when the ground was frozen in preparation for soil salvage, drainage ditch construction and power line installation. Trees and brush were tramped, cleared and windrowed using dozers. The windrows were eventually dozed into piles during topsoil salvage and the piles were placed in the bottom of the mine pit and covered with spoil.

Ninety percent of the area surveyed in 1977 for the Highvale Mine West Extension consisted of soils having capability for agriculture ratings of Class 4 and Class 5 (Calgary Power Ltd. 1978). The most productive soil of the area was Class 3, but it was limited to 6% of the total. The principle materials at the Highvale Mine are surface soils, overburden, coal and partings. The surface soils consist of a layer of organic material (topsoil) and an underlying layer of rootzone material, composed mainly of glacial tills and glaciolacustrine clays. Initially, suitable surface soils were removed by scrapers ahead of the overburden stripping operation and used in the reclamation operation. Spoil piles were contoured, covered with surface soil materials and reseeded and reforested as required (Calgary Power Ltd. 1978).

In 1978 the materials handling procedure was to progressively remove the top 0.15 m layer of soil with scrapers or loaders and trucks and transport to the contoured area to be deposited over the subsoil layer. The remaining subsoil was then removed by scrapers to various depths (0.30 m to 2 m) and deposited over levelled spoil areas in a layer 0.30 m deep. If soil compaction occurred as a result of equipment movements, the compacted soil was ripped just ahead of topsoil placement.

All the volumes of topsoil and subsoil salvaged between 1982 and 1985 were calculated on the basis of replacing a 0.20 m deep layer of suitable topsoil and 1 m of suitable subsoil where available. In areas covered by less than 1.2 m of “suitable” soil, all suitable soil was salvaged. Topsoil stripping was completed when soils were dry and was usually stockpiled instead of directly placed on reclamation areas.

Development and Reclamation Approval C-2-81 (1986) required the recovery of all topsoil and all suitable subsoil material for use in reclamation in 1986. To ensure that only suitable soil materials were salvaged, three quality control steps were taken. First, a soil survey was conducted on the proposed salvage area, to develop detailed soil maps. This survey confirmed the boundaries of each soil type and the depth of suitable material within each boundary. Before salvage started each year, the second step was to stake the soil boundaries and mark the salvage depth on the stakes. The third step in quality control was to have a soils inspector present during salvage operations to supervise salvage depth and area (TransAlta 1987).

Soil salvage techniques have not changed significantly over the lifespan of the mine. Currently, topsoil salvage is performed by scrapers supported by dozers. Winter salvage of topsoil materials is generally required in wet areas and normal salvage operations are conducted when ground conditions allow complete salvage and maintenance of soil quality. Topsoil is directly replaced wherever possible to avoid stockpiling and double handling. Otherwise, topsoil is stockpiled.

Subsoil salvage is performed by either the prestrip mining fleet or scrapers supported by dozers. Subsoil is directly replaced whenever possible.

4.2.1.3 Whitewood Mine

Brush clearing was conducted using dozers and scheduled for winter months whenever possible to take advantage of frozen ground conditions.

The Development and Reclamation Approval for Whitewood Mine required the salvage of all topsoil (A horizon) with an in-situ depth of 0.15 m or greater (TransAlta 1996). Salvaged topsoil is directly placed over an equivalent area of contoured mine spoil. Steps in topsoil salvage are:

- identification and quantification of salvageable topsoil
- dozing topsoil into windrows
- loading and transport of topsoil
- dumping and respread of topsoil on contoured spoil areas.

4.2.1.4 Diplomat Mine

When mining began in 1949 the soil and overburden were placed in mounds referred to as spoil heaps (Alberta Environment 1981). In 1975, a topsoil salvage program was begun at Diplomat and became an integral part of the mining operation.

4.2.1.5 Paintearth Mine

Topsoil and subsoil salvage were an integral part of mining operations when mining began in the early 1980s. With the exception of the initial phase of mining when topsoil and subsoil were stockpiled, direct placement of these materials occurred to the extent possible thereafter. In 1996 the soil salvage program was based on the removal of all topsoil, plus up to 1.5 m of suitable subsoil where such materials existed and where practically recoverable.

4.2.1.6 Vesta Mine

Topsoil salvage became a part of the mining operations following the enactment of the Land Conservation and Reclamation Act of 1973. Reclamation methods in 1979 at the Vesta Mine consisted of contouring mine spoil with dozers to final grades designated by the end land use of an area. Topsoil was stripped from areas in advance of the pit and was normally replaced on leveled and contoured land in one lift. In cases where there was insufficient topsoil, bottom ash was substituted at an average depth of 0.15 m up to the permitted maximum of 24 ha. The average depth of topsoil salvage and replacement was 0.15 m between 1979 to 1985 and in poorer soil areas salvaged depths averaged 0.10 m.

In 1981 subsoil materials were included in the prestripping operations. The average replacement depth of subsoil material was approximately 0.70 m to 0.90 m. Direct placement was the preferred reclamation technique at the Vesta Mine. Stockpiling of salvaged topsoil and subsoil materials was discouraged to minimize the need for rehandling.

4.2.1.7 Montgomery Mine

Although no reclamation activities were conducted in 1982, previous practices involved the removal of approximately 0.30 m of topsoil from the mine stripping areas and the stockpiling of this material for future reclamation use. In 1983 and 1984 approximately 0.20 m of topsoil material was salvaged and stockpiled, or directly placed, for reclamation purposes.

No topsoil or subsoil was replaced in 1985 or 1986. All soils were stockpiled.

4.2.1.8 Sheerness Mine

No soil salvage information was available.

4.2.2 SOIL PLACEMENT

4.2.2.1 Genesee Coal Mine

Reclamation at the minesite began by levelling the dragline spoils. Subsoil was direct placed by dozers from dragline salvaged subsoil. Before topsoil was replaced onto reclaimed spoils, sites were levelled and suitably prepared with approximately 1.0 m of subsoil. The subsoiled sites were prepared for topsoil placement by first scarifying traveled areas with a subsoiler. The subsoil was then worked with a breaking disc to bring rocks to the surface. The rocks were then raked and picked as the final step before replacing the topsoil. The topsoil was then hauled to the reclamation site and placed in "topsoil cells" of a prescribed length, width and height on top of prepared subsoil. Dozers were then used to float the topsoil into a uniform layer, 0.18 m thick, over the subsoil (Genesee 1996). Spot checks were performed on the topsoil after the soil had been spread with dozers. Additional topsoil thickness checks were also performed by an independent Consultant approximately one year after the topsoil had been spread. This information is valuable for reclamation re-certification purposes.

An abnormally low snow cover early in 2001 allowed for spreading of topsoil during the winter. A D-11 dozer spread the topsoil over a frozen layer of subsoil. Operational practices will continue to employ the successful method of using topsoil cells for topsoil replacement.

4.2.2.2 Highvale Coal Mine

Spoil material was characterized by high concentrations of sodium, high SAR, and a large percentage of expanding clays which caused the material to be a very poor rooting medium. A better root zone material was therefore required to promote revegetation and a covering layer of about 0.45 m of suitable material was placed over the contoured and smoothed spoil (Montreal Engineering Company Ltd. 1977).

Spoil piles and ramps were reclaimed in 1978 using dozers and scrapers to contour the land to an acceptable slope (10º) to permit the use of agricultural equipment. The area was then subsoiled with 0.30 m of spoil, followed by 0.15 m of topsoil material. Some of the soil placed had low pH levels. Lime or flyash were added to raise the level to a neutral pH value of approximately 6.5. The ameliorant was spread over the newly placed topsoil and thoroughly mixed in using a disc before seeding took place the following spring. Rates were determined from tests taken after the topsoil was placed (Calgary Power Ltd. 1978).

Rootzone reconstruction was defined as the replacement of subsoil and topsoil over level spoil. Soil used for rootzone reconstruction was obtained directly from salvage operations or from stockpiles constructed during previous salvage operations. Subsoil and topsoil were replaced in accordance with the requirements of Development and Reclamation Approval C-2-81 as summarized in Table 4.1.

Table 4.1. Soil replacement requirements outlined by Development and Reclamation Approval C-2-81.

Years of Mining	Subsoil Replacement Depth (m)	Topsoil Replacement Depth (m)
Pre 1982	0.3	0.15
1982*	1.0	0.2
1983 to 1985	1.5 & 0.5	0.2
1986 to 1991	1.5 & 0.35	0.2

* This replacement depth only applied to Pit 02. Subsoil replacement depths for Pit 03, which mining commenced in late 1982, were 0.5 m and 1.5 m for 1982 to 1985.

In 1980 it was felt that reclamation could be satisfactorily achieved by using the following practices:

- Salvaging sufficient growth material to provide a 0.45 m layer over the spoil area.
- Regrading the spoil piles and haul roads through the spoil piles to a maximum average grade of 10º for agriculture and 15º for wildlands.
- Grading and backfilling the final mining cuts to a grade of 26.5º, if not utilized for ash disposal.

The presence of sodic material in the Highvale North and non-sodic materials in the Highvale South areas indicated that the land use objectives and tillage practices would be different in each area. In general, subsoil was replaced on sodic spoil to a thickness of either 1.0 m (Class 3) or 0.35 m (Class 4 to 6) prior to replacing 0.20 m of topsoil.
In both areas the principle objective of tilling the surficial material was to prepare an acceptable seedbed prior to seeding and fertilizing (TransAlta 1986, 1987, 1988, and 1990). Apart from preparing a seedbed, tillage was also used to reduce surface crusting, minimize moisture loss, reduce salinization, break up large clods, improve drainage characteristics in the rooting zone, improve soil aeration and gaseous exchange, help incorporate organic matter and improve soil structure. Tillage practices consisted of disking and harrowing to prepare the seedbed combined with proper contouring and benching practices to minimize erosion. With the establishment of the initial vegetation

cover, tillage practices were discouraged until the organic matter levels in the reclaimed areas were restored.

Topsoil and suitable subsoil were either directly replaced over contoured spoil or stockpiled for later use. **The minimum depth of topsoil replacement has remained consistent at 0.20 m since 1991 and the minimum depth of subsoil replacement has varied depending on the area of reclamation.** In 1990 subsoil was replaced to a depth of 1.5 m in Pit 03 and in 1991 the minimum depth of subsoil replacement at Pit 03 was 0.35 m. The minimum depth of subsoil replacement in Pit 02 was 0.35 m in 1992 and in Pit 02S the minimum depth of subsoil replacement was 1.0 m. Replacement depths in 1992 for Pit 03 were the same as 1991.

4.2.2.3 Whitewood Mine

Spoil pile contouring in 1987 resulted in maximum slope angles of 10º. In general, spoil was contoured so that slopes did not exceed 15% in order to achieve class 3 to 4 topography. The minimum depth of topsoil replacement, as stated in the D&R Approval, was 0.2 m.

There were several land use zones approved by the Whitewood Direct Control District including Annual crop (AP), Improved pasture (PG), Unimproved pasture/grazing (G), Off-highway vehicle recreation (OHV) and Lakes (L). For each of these land use zones the Approval regulates slope angles, allowable ponding, and topsoil replacement.

During 1990, spoil levelling and topsoil replacement occurred within the G land use zone defined as having maximum slopes of 10º, ponding and closed drainage, and a minimum topsoil replacement of 0.2 m (TransAlta 1990). AP land use areas are defined as having a maximum slope of 5º and minimal ponding of water. PG land use areas are defined as having a maximum slope of 10º, ponding and closed drainage and OHV areas have a maximum slope of 20º and no topsoil replacement required.

4.2.2.4 Diplomat Mine

Soil placement at Diplomat mine occurred following the initiation of soil salvage operations in 1975. Prior to that the box cut operations resulted in the parallel ridges illustrated in Plate 4.1. From 1950 to 1966 the peaks were levelled slightly (Alberta Environment 1981) as shown in Plate 4.2.

In 1967, revised reclamation guidelines required that the spoils be levelled with peaks no higher than five feet. Over the next five years, 144 ha were levelled to new standards using new larger earth-moving equipment. In 1976 Alberta Environment worked with the County of Flagstaff to revitalize the 65 ha that had been mined but not reclaimed. The program was established to try to restore topsoil to areas where all topsoil had been lost. The department also purchased adjacent land and began reclamation of a further 81 ha disturbed by pre-legislation mining.

In 1977, areas were levelled and worked over with a “subsoiler”, a machine that helped break up soil compacted by heavy equipment. On the 65 ha parcel, sweet clover was planted and left for two summers. Plate 4.3 provides an overview of the different soil or spoil management techniques including spoil heaps with no levelling or modification, areas with some levelling of the heap or ridge tops and areas levelled and “subsoiled”. Plate 4.4 provides a close-up of the area that was “levelled” and worked with a “subsoiler”.

In the early 1980s topsoil was placed on the levelled spoil as shown in Plate 4.5 (Macyk 1986).

Plate 4.1. Parallel ridges.

Plate 4.2. Peaks levelled.

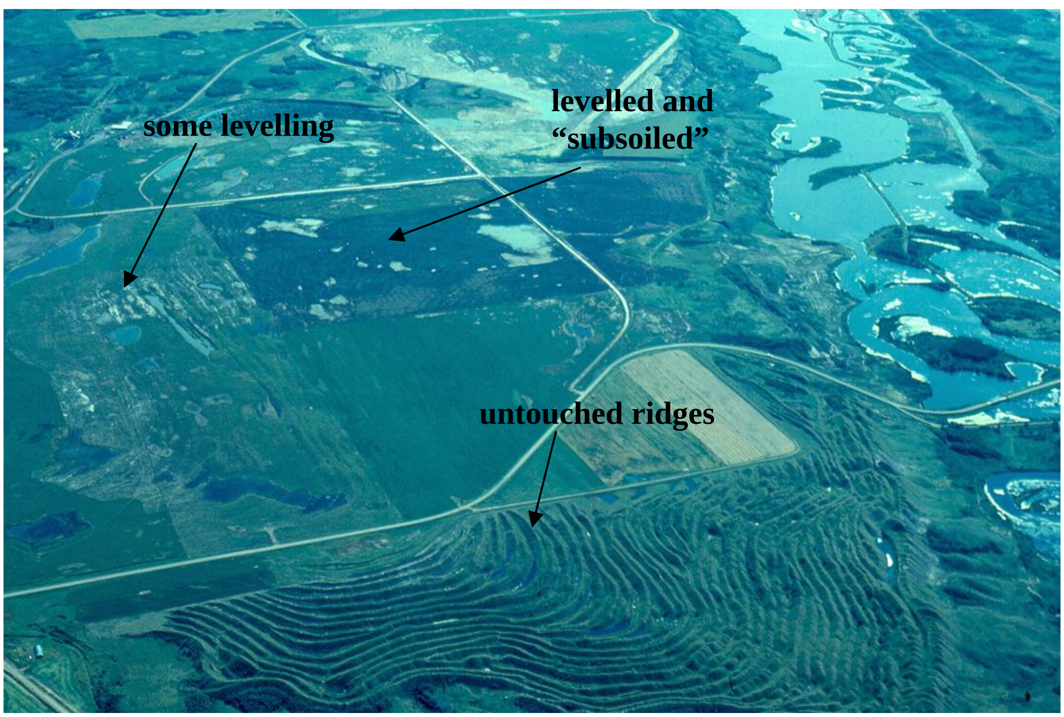

Plate 4.3. Range of “soil” and “spoil” management techniques – Lower part – untouched ridges, mid to upper left – some levelling, mid to upper right – total levelling and “subsoiling”.

Plate 4.4. Area “levelled” and worked with “subsoiler”.


Plate 4.5. Topsoil over spoil at Diplomat Mine prior to revegetation.

4.2.2.5 Paintearth Mine

Topsoil and subsoil were replaced since the inception of reclamation activities at the Paintearth Mine. Beginning in 1982 an average depth of 0.15 m of topsoil was replaced. Subsoil replacement depths ranged from 0.50 m to 1 m.

4.2.2.6 Vesta Mine

The average depth of topsoil replacement was 0.15 m in 1979 to 1985. In 1981 subsoil materials were included in the soil handling. The average replacement depth of subsoil material was approximately 0.70 m to 0.90 m. In 1984 and 1985 subsoil replacement depths ranged from 0.3 m to 1.5 m (Plate 4.6). Subsoil salvage and replacement depths ranged from 0.3 m to 1.5 m in 1984 to 1985. Subsequently topsoil and subsoil salvage and replacement depths have varied (Table 4.2).

Table 4.2. Topsoil and subsoil replacement depths at Vesta Mine.

Year	Topsoil Replacement Depth	Subsoil Replacement Depth
Prior to 1993	0.10 to 0.15 m	0.70 to 0.90 m
1993	0.13 m	0.54 m
1994	0.15 m	0.45 m
1995	0.19 m	0.34 m
1996	0.25 m	0.45 m
1997	0.15 m	0.30 m

Plate 4.6. Topsoil, subsoil, spoil sequence at Vesta Mine.

4.2.2.7 Montgomery Mine

In 1987 the majority of salvaged topsoil was directly placed on leveled spoils. Topsoil and subsoil replacement depths from 1987 to 1997 were variable (Table 4.3).

Table 4.3 Topsoil and subsoil replacement depths at Montgomery Mine.

Year	Topsoil Replacement Depth	Subsoil Replacement Depth
Prior to 1982	0.30 cm	n/a
1983 to 1984	0.20 cm	n/a
1987	0.15 cm	0.49 m
1988	0.14 m	0.59 m
1989	0.15 m	0.80 m
1990	0.11 m	0.49 m
1991	0.18 m	0.72 m
1992	0.12 m	0.55 m
1993	0.18 m	0.71 m
1994	0.17 m	0.62 m
1995	0.15 m	0.62 m
1996	0.14 m	0.95 m
1997	0.15 m	0.77 m

4.2.2.8 Sheerness Mine

No soil placement information was available.

4.2.3 SOIL MONITORING

Soil monitoring specific to each of the mine sites was conducted by the individual companies or their contractors. Several studies were also conducted under the auspices of the Plains Coal Reclamation Research Program and the Reclamation Research Technical Advisory Committee (RRTAC) which developed and administered research in four major program areas which corresponded to Alberta's major industrial activities and biophysical regions (RRTAC 1989). The Plains Coal Reclamation Research Program (PCRRP) was designed by the provincial government and members of the coal industry to answer questions relating to groundwater and soil reconstruction in plains coal mining zones. PCRRP programs specific to individual mine sites, such as the Highvale Soil Reconstruction Project, will be discussed in the section specific to the Highvale Mine. Results specific to individual projects were not always available, therefore are not presented in this document.

The Battle River Soil Reconstruction Project was established in 1979 to determine the most effective method of reclaiming lands disturbed by surface mining of coal in the Battle River Coal Fields (Leskiw 1989). Cropping and soil sampling began in 1982 (RRTAC 1989). Grass and forage yields were evaluated on a series of plots referred to as the Torlea plots, Bottom Ash plots, Subsoil Depth plots, and Slope Drainage plots.

Treatments included depth of subsoil (0 to 3.35 m thicknesses) over spoil, reconstruction of solonetzic soils, and use of bottom ash and gypsum as amendments to sodic spoil. Salt movement and crop growth on spoil slopes were also studied. A summary of the findings (Leskiw 1989) indicated that:

- Forage yields were good, but cereal yields were very low in comparison to other studies and by farmers in the region.
- Topsoils and subsoils are required for successful reclamation.
- Topsoils and upper subsoils improved as a result of downward salt leaching.
- Amendments were more effective in increasing crop yields when placed on the surface than when placed above the spoil, and bottom ash was more helpful than gypsum.

Between 1979 and 1988 the Plains Hydrology and Reclamation Project (PHRP) conducted by the Alberta Research Council investigated interactions of groundwater, soils, and geology as they affect successful reclamation of surface coal mines in the plains of Alberta (Moran et al. 1990). The overall goal of the project was to predict the long term success and the hydrologic impacts of current reclamation practices and to develop reclamation technology that will allow modification of current practice to assume long-term success and mitigate deleterious environmental consequences.

The study included characterization and instrumentation of the Battle River study area which included Diplomat, Vesta, and Paintearth Mines and the Lake Wabamum area which included the Highvale and Whitewood Mines (Moran et al. 1990).

The work related to soils and revegetation was included in the overall objective to complete development and evaluation of a capability rating system for agricultural land use of reclaimed sites by assessing productivity of reclaimed landscapes relative to similarly managed unmined sites and assessing changes in productivity over time. One component of this work involved mapping and characterization of reconstructed soils (Macyk 1986).

In addition to mapping and evaluating the pre-mining soils, the reconstructed soils of the post-mining landscape were "mapped" and characterized. The mapping of reconstructed soils was done on the basis of topography, drainage and materials handling procedures or practices. This was followed by a relatively extensive sampling program to characterize the soils in the areas representing different materials handling/replacement techniques (Plate 4.7). The major techniques assessed included untouched spoil piles, spoil piles levelled, spoil piles levelled and covered with topsoil, and spoil piles levelled and covered with subsoil and topsoil (topsoil/subsoil/spoil sequence). Although all of the different materials handling procedures were characterized, ranging from no levelling (untouched spoil piles) to topsoil/subsoil/spoil sequences, emphasis was placed on the more recently adopted procedures which were likely to remain in place for some time in the future.

Sampling sites were selected randomly and total sampling depth ranged from 0.30 m to 5.0 m. This range was manifested by the ease of collecting the samples – in the case of sites exemplifying the shallow depths there was some form of hindrance to the coring tube. As the sampling program was conducted over a three-year period, techniques were modified on the basis of the results obtained. For example, in 1983 it was deemed appropriate to sample only the top 1.5 m of material and to have three holes drilled at close proximity for each site selected to provide an indication of the within-site variability as compared with between-site variability. Virtually all sampling was done according to the following depth (cm) intervals: 0 to 15, 15 to 30, 30 to 45, 45 to 60, 60 to 75, 75 to 90, 90 to 120, and 120 to 150 cm, and in 30 cm increments thereafter to depth. A total of 1588 samples were collected. Analyses conducted included pH (water and $CaCl_2$ methods), % saturation, electrical conductivity, sodium adsorption ratio, extractable sodium, calcium, potassium and magnesium, sulphate, calcium carbonate equivalent, and particle size distribution (% sand, silt, clay).

Plate 4.7. Sampling at Battle River sites.

Soils created by the mining process were different from soils that existed prior to mining; the major differences being that mine soils or reconstructed soils had no pedogenic profile development and were characterized mainly by materials handling procedures.

A capability rating system for reconstructed soils was developed (Macyk 1987) that paralleled the Canada Land Inventory (CLI) soil capability for agriculture rating system (Canada Land Inventory 1965). The work done indicated that the initial capability of the reconstructed soil reflected a mix of the pre-mining capability. **The agricultural**

capability of reconstructed landscapes is more uniform than, and is generally not as good as the best, however, it is not as poor as the lowest capability in the pre-mining landscape. This initial capability is altered with time as the site equilibrates. Some of these changes, such as leaching of soluble salts improve the capability whereas others such as differential subsidence and ephemeral ponding result in degradation of the capability (Moran et al. 1990).

4.2.3.1 Genesee Coal Mine

Three reclamation test plots were established in 1981 (Fording Coal Ltd. 1988) in the Genesee area to generate data prior to mining. The sequence of geology in the three plots was representative of the mining areas. Topsoil was salvaged prior to plot construction and evenly distributed over the established plots in spring 1982. The plots were seeded with Bonanza barley and a pasture forage mix of brome grass, alfalfa, and timothy and fertilized with a mixture of 23-23-0 at a rate of 40 kg/ha. Continuous cropping procedures were used for the life of the plots with cultivation in the spring and fall.

A comprehensive subsoil quality management program is used at the Genesee minesite to provide a means to identify and verify suitable subsoil material for reclamation purposes. The approach taken to develop this system combined geological assessments with a computerized mine planning system to develop a computer model capable of forecasting the availability of suitable material anywhere in the mine license area. The computer model of subsoil is used to locate suitable areas to obtain subsoil for reclamation programs. Chosen sites are surveyed in the field to enable proper prediction of depth of suitable material. Samples are taken from those sites to confirm suitability.

The monitoring program at Genesee consists of topsoil thickness data collection in pre-mined and post-mined areas.

4.2.3.2 Highvale Coal Mine

A reclamation and revegetation study was established at the Highvale Mine in 1976 for the purpose of evaluating the relative productivity of increasing depths of favourable growth media when placed on unfavourable spoil (sodic mine spoil) and mine run spoil, and monitoring the upward movement of exchangeable sodium from the mine spoil into the favourable growth media (McAllister Environmental Services Ltd. 1980).

The results indicated that Modeste sandy loam applied as a cap on sodic mine spoil produced substantially greater hay yields than did surface mine spoil or soil surfaced with Wabamum clay. The application of gypsum increased the yields of hay. Field observations found little difference in crop height or density of stand on wedge thicknesses of 0.30 to 0.90 m. Growth was reduced as media thickness decreased from 0.30 to 0 m. No increases in salinity in the soil cap were found and small increases in SAR values over baseline 1976 values were found in the 0.30 m of soil in direct contact with the mine spoil (McAllister Environmental Services Ltd. 1980).

Soil samples were taken annually between 1980 and 1985 from areas to be revegetated and from those previously revegetated (Moneco Limited 1982). Each soil sample was a composite of 10 to 15 subsamples collected from the top 0.15 m of soil within each management area. The samples were analysed to detect trends in soil conditions. A post-mining inventory of the reconstructed rootzone was conducted prior to revegetation. Newly revegetated spoil was surveyed during the first growing season, and two and five years after the seeding of each area.

The Highvale Soil Reconstruction Project was initiated in 1982 by government and coal industry representatives to provide interpretive data for reclamation planning and post-mine land management of sodic strip-mined soils (Graveland et al. 1988). The project objectives were to: 1) determine the optimum depth of subsoil replacement over sodic minespoil to ensure adequate crop productivity; 2) examine slope configurations which could minimize soil quantities needed to restore the original productivity of reclaimed land; and 3) assess the sustainability of crop production on soil replaced over sodic minespoil by monitoring upward soluble salt migration into the root zone.

A subsoil depth experiment was established to determine suitable subsoil thicknesses (0.00, 0.55, 0.95, 1.35, 1.85, and 3.45 m underlying 0.15 m topsoil) for reclaiming sodic minespoil and maximizing production of an annual barley cereal crop or a perennial alfalfa-smooth bromegrass forage mixture. A slope experiment was established to determine the effects of slope types (5° and 10° slopes, north and south aspects) and slope positions (lower, mid and upper) on alfalfa-smooth bromegrass forage crop productivity. Soil water movement, salt/sodium migration, and bulk density were monitored throughout both experiments.

For the subsoil depth experiment, crops yields increased as subsoil thickness increased from 0.00 to 0.55 m, while optimum yields were generally achieved with the replacement of at least 0.95 m subsoil. The forage crop developed a deeper effective root zone, had better root penetration into minespoil and reduced soil bulk density more than the barley crop. Soil moisture levels above the subsoil/minespoil interface tended to decline over time under forage, likely due to higher consumptive use of soil moisture compared to the barley crop. The potential for moisture accumulation above the interface when seeded to barley may enhance upward migration of soluble sodium, although movement has generally been limited to the first 15 cm increment above minespoil after five years. For the slope experiment, forage yield was generally highest on north-facing aspects, 5° slopes and mid to upper slope positions. There was no consistent trend in downslope migration of soluble sodium, likely due to utilization of soil moisture by the forage crop. Upward migration of soluble sodium was similar to the subsoil depth experiment.

Problems in cultivating, establishing crops and harvesting reclaimed fields as a result of subsurface compaction incurred during subsoil and topsoil replacement were identified, and a research project was initiated in 1986 to study the long-term effects of deep ripping and organic matter (peat and manure) input on soil tilth (TransAlta 1992). Results after five growing seasons indicated improved tilth in the ripped and amended plots, with reduced penetration resisitance and increased rooting, plant biomass and organic matter. The addition of peat or manure to the topsoil improved seedling establishment, reduced surficial bulk density and increased water infiltration rates. On soils with high sodicity, ripping alone resulted in improved growth of grasses and legumes and reduced weed invasion (TransAlta 1994).

The objectives of the reclamation monitoring program were to document changes in reclaimed land soil characteristics over time and to record annual crop productivity and species composition. The information was used to support applications for certification of reclaimed land and to assist in land management operations. Sites representative of various CLI agricultural capability classes were selected for monitoring.

Plots were established in 1990 to test the effectiveness of phosphogysum and fly ash as soil amendments for improving soil structure, internal drainage and preventing surface crusting. Treatments included application of either phosphogysum or fly ash at one of four rates (6, 13, 26, or 53 Mg/ha) and incorporated to 10 cm. Preliminary results in 1990 indicated that soil moisture, surface bulk density, and penetration resistance were not significantly different from baseline values. Surface crusting appeared to diminish with increasing levels of phosphogypsum (TransAlta 1991).

A field experiment initiated in 1991, to assess the feasibility of amending spoil with sulphur and gypsum, found gypsum to be the most effective amendment for reducing sodicity (SAR) of the mine spoil and sulphur to be effective for reducing SAR, however sulpur took longer to have an effect on sodic mine spoil (Transalta 1992). Sulphur and gypsum elevated concentrations of Na, Ca, Mg, K and SO_4 in the amended mine spoil layer.

4.2.3.3 Whitewood Mine

Topsoil evaluation plots were established in 1981 to determine the effect of topsoil on crop and forage yields at Whitewood. The project was discontinued after the 1986 growing season (TransAlta 1988). Results from the project indicated that forage yields from plots with 0.2 m of topsoil over spoil were not significantly different from plots with bare spoil. Barley yields on topsoiled plots were higher than bare spoil plots when little or no fertilizer was applied, and with adequate fertilization, there was no significant difference between barley yields from topsoiled plots and bare spoil plots.

Reclaimed lands are monitored to evaluate the long term adequacy of the materials handling and reclamation procedures used at Whitewood. Information on topography, drainage, soil fertility, soil reaction, soil salinity, rooting conditions, crop growth and yields and crop quality were gathered and evaluated to determine suitability of the reclaimed lands for the intended use and agricultural land capability.

4.2.3.4 Paintearth Mine

The Torlea soil reclamation trials were established in 1978 to determine techniques of returning land disturbed during surface coal mining to their previous productive capability (Luscar Ltd. 1989). A significant portion of the land was comprised of Dark Brown Solodized Solonetzic soils, most of which were used for native forage production. **The basic reclamation technique investigated through the trials was that of a simulation of the "deep ripping" technique used to increase agricultural production in the region.** Soil materials at the mine were selectively handled by equipment, separately removing topsoil (A horizon) material, followed by a mixture of subsoil (B and C horizon) materials. The trials consisted of a series of reclamation treatments, all of which included the subsoil mixture over mine spoil, with various surficial amendments. The treatments consisted of different topsoil and gypsum applications. Each plot was divided into two cropping sub-sections where either forage or continuous cereal production was assessed. The trials were maintained, and crop performance and soil conditions monitored annually over a 10 year study period.

Soil monitoring results indicated that the horizon mixing in the reclamation treatments resulted in soil material of similar or slightly improved suitability characteristics compared to the natural soil. The mixed subsoil resulted in elevated calcium and magnesium levels which persisted over a 10 year period and served to ameliorate soil structural conditions (Luscar Ltd. 1989). Reclamation treatments resulted in increased effective rooting depths under forage crop production when compared to natural conditions, as roots were found throughout the replaced subsoil. The addition of topsoil improved seedbed condition, enhanced crop production and quality, and increased overall soil suitability slightly. Gypsum applications were inconsistent and generally less effective than topsoil.

The Alberta Research Council and Luscar Ltd. initiated a study in 1983 to monitor the physical and chemical properties of newly mined and reconstructed soils at the Paintearth Mine (Macyk et al. 1995). The objective was to determine what changes were occurring and the impact of these changes on long-term soil quality and productivity. Replaced soils were compared to unmined soils adjacent to the mine area. Soil moisture and bulk density were monitored annually during the growing season for eight years, forage crops harvests were completed in three different years to determine yield and forage quality, and soil sampling was completed in 0.15 m intervals to a depth of 2.1 m for analytical purposes in seven of the ten years. Measurements ten years after establishment indicated that in terms of soil moisture regime, bulk density status and forage yield, the reconstructed soils were similar to unmined soils in the area. It was thought that soil reconstruction utilizing the shallow subsoil (0.45 m) layer rather than the thicker (0.90 m+) subsoil layer could result in the increased potential for upward movement of salts and crop production limitations due to less available moisture. **However, the analytical data obtained from this project indicated that landscape position and moisture regime have much more bearing on salt movement and salinity status than the thickness of replaced subsoil.**

4.2.3.5 Vesta Mine

A reclamation monitoring program was initiated in the fall of 1983 on three previously reclaimed areas (Manalta Coal Ltd. 1990). Two subsoil replacement depths (1.2 m and 1.5 m) were chosen for examination. Neutron probe access tubes were installed to monitor soil moisture and samples of soil were collected and analyzed for salinity and particle size distribution. The materials were assessed for suitability for reclamation in accordance with the *Proposed Soil Quality Criteria in Relation to Disturbance and Reclamation* (ASAC 1981). Results showed that composition and depth of the reconstructed root zones at the Vesta Mine were extremely variable. Previous reconstruction practices ranged from no soil salvage and replacement to salvage and replacement of 1.5 m of subsoil plus 0.15 m of topsoil. Topsoil depth ranged from 0.15 to 0.25 m with quality ranging from good to unsuitable and subsoil depth ranged from 1.1 to 2.1 m with quality ranging from fair to unsuitable.

Soil monitoring results from established sites on reclaimed lands in 1989 indicated that topsoils and upper subsoils had improved considerably during the monitoring project (1983 to 1989). Subsoil layers immediately above the spoil were not exhibiting a change in quality, however were variable at greater depths. Soil quality changes at greater depths were influenced both by salt accumulation and salt leaching. Topsoil densities appeared to be in the normal range for the unmined soils, and subsoil densities remained high. Crop yields indicated no relationship to subsoil depth or site topography and were comparable to the regional averages. Lower slope positions exhibited the poorest soil quality, however no relationship was observed between slope position and crop yields.

A monitoring program was initiated in 1991 to monitor newly reclaimed areas and reclamation operations (Manalta Coal Ltd. 1991). The program included an inventory and suitability evaluation of reconstructed soils.

4.2.3.6 Montgomery Mine

A soil survey and assessment of reclaimed lands was conducted in 1982 by Pedology Consultants on behalf of Manalta Coal Ltd (Manalta Coal Ltd. 1983). Sites were sampled to a depth of 3 m in both topsoiled reclaimed areas and non-topsoiled reclaimed areas. Results indicated that topsoiled areas were generally of better quality than non-topsoiled areas. Sodicity was found to be the most limiting soil property determined for the reconstructed soil profiles. Four additional sites were sampled in 1983 and soils were analyzed for salinity characteristics and particle size distribution. Replaced topsoil material was rated good to fair in quality according to Alberta Agriculture's *Proposed Soil Quality Criteria in Relation to Disturbance and Reclamation* (1981). Spoil characteristics were rated good to fair except for sodicity (SAR) which ranged from fair to unsuitable (5.8 to 19.3). Revegetation was also assessed in 1982. Poor density and cover were associated with poor or unsuitable soil materials in the upper 0.50 m, and where no topsoil had been placed.

A reclamation trial was established in 1983 at the Montgomery Mine by Manalta Coal Ltd. and Luscar Ltd (Manalta Coal Ltd. 1984). The site was mined out in 1976 to 1977 and levelled in 1980. The major objectives of the project were to determine the suitability of various soil and overburden materials for the use in soil reconstruction and to examine soil replacement depth requirements for mined lands. A total of eight soil material plots were included in the program (Table 4.4) that evaluated topsoil replacement over mine spoil, subsoil replacement at different depths between topsoil and mine spoil, horizon mixing (B and C horizons) of subsoil material, and use of coally spoil at different depths. Each plot was divided into a cereal and a forage subplot. The plots were fallowed during 1984 due to extreme drought conditions and seeded in 1985.

Table 4.4. Soil prescriptions evaluated at Montgomery mine.

Plot No.	Description
1	Mine Spoil. No soil materials – bedrock and glacial till
2	Topsoil (0.15 m) over Mine Spoil. Chernozemic (A horizon) topsoil.
3	Solonetzic Subsoil (0.45 m) plus Topsoil (0.15 m) over Mine Spoil.
4	Chernozemic Subsoil (0.35 m) plus Topsoil (0.15 m) over Mine Spoil.
5	Deep Chernozemic Subsoil (1 m) plus topsoil (0.15 m) over Mine Spoil.
6	Topsoil (0.15 m) over Coally Spoil.
7	Topsoil (0.15 m) plus Chernozemic Subsoil (0.45 m) over Coally Spoil.
8	Chernozemic subsoil (0.5 m) over mine spoil.

Monitoring of salinity over time indicated a slight change from 1984 to 1987. Salts (EC) decreased slightly in some topsoils, but generally remained unchanged at the 0.20 to 0.50 m depth. The SAR levels were approximately the same in 1987 as in 1984. Exchangeable sodium levels showed little change in the topsoil (0 to 0.20 m depth) over time but exhibited large increases (1984 to 1985) and decreases (1986) in the 0.20 to 0.50 m depth. Topsoil was rated as fair to good quality for reclamation, coally spoil was rated as fair quality, bedrock spoil was rated as poor quality, solonetzic and chernozemic subsoil (mixed B and C horizons) was rated as poor to unsuitable quality and chernozemic subsoil (B horizon) was rated as good quality.

There were differences in EC, SAR and exchangeable sodium values between the cereal and forage subplots from 1984 to 1987. Values were generally higher in the forage subplots than the cereal subplots. Highest total forage yields (alfalfa plus crested wheatgrass) and wheat yields were obtained on plot 4, although plots 3 and 7 were also high. The poorest yields were obtained on plots 1 and 6.

Results after five years of monitoring indicated no apparent benefits to crops or moisture storage from having more than a 0.35 to 0.50 m depth of subsoil. The plots demonstrated that there was little difference in crop productivity between good quality and saline-sodic subsoil treatments. A salt accumulation horizon developed at 0.15 to 0.40 m below the surface in both chernozemic and solonetzic subsoils which was the same for natural, undisturbed soils in the area. It was determined that forage crops were a better crop choice than cereals for establishing cover and providing reliable production given the frequency of drought in the Sheerness area. Forage production was highest on plots constructed with topsoil and subsoil as opposed to topsoil over spoil alone.

Annual monitoring of these sites was discontinued in 1991, however they were revisited every three to five years thereafter in order to assess long term changes in soil quality and crop production (Manalta Coal Ltd. 1992).

4.2.3.7 Sheerness Mine

No soil monitoring information was available.

4.2.4 REVEGETATION

4.2.4.1 Genesee Coal Mine

The first disturbed land returned to agricultural production in 1992 was seeded at a rate of 10 lb/ac (11.2 kg/ha) with a seed mix developed through the Genesee Power Project Advisory Committee. The seed mix consisted of 43.8% Algonquin alfalfa, 21.8% Climax timothy, 17.2% Canada #1 alsike clover, and 17.2% Canada #1 red clover. The seed rate was increased to 12 lb/ac in 1993 and boreal creeping red fescue was underseeded at a rate of 4 lb/ac (4.5 kg/ha) and blended with a Cascade oats cover crop seeded at 1 bu/ac.

In 1996, 14.1 ha of land was returned to agricultural production at the mine site. The reclaimed areas were seeded with Cascade oats at 1.25 bu/ac and boreal creeping red fescue at 4 lb/ac (4.5 kg/ha). The underseed mix, developed through the Genesee Power Project Advisory committee and used in this area consisted of the same species used in 1992. Seed was applied at a rate of 12 lb/ac (13.5 kg/ha). These reclaimed areas were fertilized with a blend of 9-39-10-5 (N-P-K-S) at a rate of 385 lb/ac (433 kg/ha).

Revegetation methods and mixes remained the same from 1997 to 1999. In 2000 areas were reclaimed and seeded into pastures. The seed mix consisted of 8% Algonquin alfalfa, 22% basho timothy, 35% kay orchard grass, and 35% boreal creeping red fescue. It was applied at a rate of 12.5 lb/ac (14 kg/ha) combined with a fertilizer blend of 17-21-13-6 (N-P-K-S) applied at a rate of 230 lb/ac (258 kg/ha). A cropped field was seeded to Seebe barley at a rate of 2 bushels/ac and a N-P-K-S blend of fertilizer was applied at 260 lb/ac (292 kg/ha).

In 2001 reclaimed areas were seeded with Cascade oats (1.25 bu/ac), Boreal creeping red fescue (4 lb/ac (4.5 kg/ha)) and were underseeded with a forage mix (11 lb/ac (12.4 kg/ha)). The underseed mix consisted of 43.8% Algonquin alfalfa, 21.8% Climax timothy, 17.2% #1 alsike clover and 17.2% #1 red clover. These reclaimed areas were fertilized with an N-P-K-S blend of 9-39-10-5 applied at a rate of 385 lb/ac (433 kg/ha).

The cropped fields were seeded to Libred 561 RR canola (Roundup ready variety) at a rate of 5.7 lb/ac (6.4 kg/ha). The crop was fertilized with 24-14-8-6 at a rate of 250 lb/ac

(281 kg/ha). The crop was sprayed in June with Roundup Transorb to control grassy and broadleaf weeds. An additional field was seeded to Derby oats at a rate of 2 bu/ac. The oat crop was fertilized with 26-15-5-5 at a rate of 192 lb/ac (216 kg/ha). The oats were sprayed with MCPA for broadleaf weeds in July.

In 2002 no additional hectares of land were returned to agricultural production because of drought conditions.

An additional 3,000 trees were planted in the Weyerhaeuser tree research plot in 2003. The area planted in 2002 was sprayed with Roundup in June to control forage stand re-growth prior to planting.

The cropped portion of reclaimed NW21 was underseeded to Tuuka timothy (4 lb/ac (4.5 kg/ha)). The cover crop was Intrepid Wheat (2 bu/ac) treated with Dividend XL RTA for disease control. An application of 214 lb/ac (241 kg/ha) of 28-18-6-0 fertilizer was broadcast spread and incorporated prior to seeding the wheat. The crop was sprayed in June with Refine Extra. Due to extreme drought conditions there was no grain yield.

The north portion of the reclaimed land on NE 20 was surface seeded to DeKalb 34-55 roundup ready canola (5.5 lb/ac (6.2 kg/ha)). Blended fertilizer (24-16-6-6) at a rate of 242 lb/ac (272 kg/ha) was placed with the seed at the time of seeding in May 2003. The field was harrowed and packed with a land roller.

EPCOR planted over 1,900 trees in shelterbelts (1.2 km) and potential wildlife zones in 2003. To maximize survival, plastic mulch was applied to control weeds during the establishment period. Tree species planted within shelterbelts included Acute willow, Walker poplar and white spruce. Tree species planted within wildlife zones included Walker poplar, Acute willow, and Saskatoon. Previously planted varieties within wildlife zones included hawthorn, lilac, and chokecherry.

The standard reclamation blend used was modified in 2005 to reduce the percentage of clover from 34% to 17%. Meadow brome grass was incorporated at a rate of 17%.

A total of 1,980 trees were planted in shelterbelt areas in 2004 and 1,100 were planted in 2005. Species included Walker poplar, white spruce, Acute willow and Saskatoon.

No reclamation seeding was done in 2006.

4.2.4.2 Highvale Coal Mine

Mined areas were considered reclaimed after they had been revegetated. In the early 1980s all reclaimed land was managed by utilizing conventional agricultural methods of cultivation, crop rotation and fertilization. Activities included tillage, deep ripping, seeding, fertilizing, and harvesting. The reconstructed rootzone was smoothed with steel beam floats pulled by tractors. The surface was disked and harrowed to prepare the seedbed. Revegetation and crop management are the final steps of the reclamation process.

In 1978 the crop was seeded and disked into the newly placed soil to create a firm, uniform seedbed. In the spring of 1979, the reclaimed area was seeded with a grass legume mixture using a press drill. The seed mixture consisted of alsike clover (5.6 kg/ha), timothy (5.6 kg/ha), tall wheatgrass (5.6 kg/ha) for a total seeding rate of 16.8 kg/ha.

Between 1981 and 1985 the seed mixture of grasses and legumes was introduced at a rate of 25 kg/ha with a 0.15 m seed row spacing. The seed mixture included alfalfa (Rambler, Vernal or Peace) at 10 kg/ha, crested wheatgrass (Nordan) at 9 kg/ha, timothy (Climax or Common) at 3 kg/ha, and rough fescue (Common) at 3 kg/ha. Cereal crops were sown at 45 to 65 kg/ha on a 0.15 m seed row. Fertilizer was introduced into the seed row at the time of seeding. Rates and blends were determined from soil analyses and the requirements of the crop planted. Phosphorus, potassium, and sulphur fertilizer was broadcast over contoured spoil before seeding and annually over all reclaimed areas scheduled for cropping. Application of nitrogen fertilizer was split, with half applied in spring and the remainder after harvest of the first cut in June.

From 1986 to 1990, the seed mix consisted of Rambler alfalfa (15%), Climax timothy (10%), frontier reed canary grass (15%), Reubens Canada bluegrass (25%), Boreal creeping red fescue (20%), and Magna smooth brome (15%). The seeding rates were 15.6 kg/ha on lands not deep-ripped and 22.4 kg/ha on deep-ripped lands. Cascade oats was seeded as the cereal crop at 77 kg/ha and 66 kg/ha as a cover crop. In 1989 Jackson barley was seeded in Pit 03 at a rate of 107 kg/ha. All seed and fertilizer was applied with a cyclone type broadcast spreader.

Deep ripping proved to be effective in improving soil tilth and moisture infiltration on reclaimed lands therefore beginning in 1989 all reclaimed fields were deep-ripped prior to initial seeding, unless soil moisture levels were too high.

Land management in 1990 was focused on establishing and maintaining soil organic matter at 4% (2.5% organic carbon) (TransAlta 1990). This was done by seeding plant species with high root/shoot ratios and by maximizing biomass production. To minimize erosion, oats or barley were seeded as a nurse crop during forage establishment.

A number of seed mixes have been designed for use at Highvale depending on the intended use of the land (Tables 4.5 and 4.6). Seed mixes have been designed for forage production, ditches and waterways, and areas designated for wildlands. In 1991 a special seed mix was developed for seeding waterways established on reclaimed lands, and another special mix was used to seed Keephills generating plant ash lagoon surfaces to control dust (Table 4.5).

Table 4.5. Seed mixes used in 1991 at Highvale Mine.

1991 General Purpose Mix[1]	1991 Grassed Waterway Mix[2]	1991 Ash Lagoon Mix[3]	1991 Cover Crops[4]
37% alfalfa	25% reed canary grass	28% creeping red fescue	Cascade oats
3% timothy	53% creeping red fescue	28% timothy	Fall rye
9% reed canary grass	22% meadow foxtail	28% Alsike clover	
3% Canada bluegrass		16% rye grass	
11% creeping red fescue			
37% smooth brome			

[1]Application rate: 22 kg/ha, broadcast with cover crop of oats or fall rye
[2]Application rate: 224 kg/ha, broadcast, with cover crop of fall rye
[3]Application rate: 56 kg/ha, broadcast with cover crop of fall rye and chopped hay mulch
[4]Application rates: oats 57 kg/ha and fall rye 100 kg/ha

All seed mixes and application rates remained the same from 1992 to 1998. The application rate for the general purpose mix was increased to 25 kg/ha in 1999 and the grassed waterway seed mix rate was reduced to 100 kg/ha. The application rate for an oats cover crop in 2000 was 40 kg/ha, 67 kg/ha for barley, and 25 kg/ha for rye. The application rate for a barley cereal crop in 2000 was 107 kg/ha, 85 kg/ha for Cascade oats, 88 kg/ha for wheat, and 6.7 kg/ha for rye. The application rate for the grassed waterway seed mix was reduced to 50 kg/ha in 2002.

The revegetation of non-agricultural lands was directed at allowing the establishment of a permanent self-sustaining vegetation cover based on commercially or readily available local species. Non-native species were used to establish an initial vegetation cover for erosion control. Islands and clump locations of trees and shrubs were then established to break up the landscape visually while also providing cover for wildlife. Ground cover was initially established using a combination of a cover crop such as oats or barley and a wildland mix for upland areas, or a riparian mix for drainage courses (Table 4.6).

Table 4.6. Additional seed mixes used at Highvale Mine.

1997 Wildland Mix[1]	**1997 Cereal Crops**[2]	**2001 Riparian Mix**[3]	**2006 Aquatic Seeding**
12% creeping red fescue	Cascade Oats	14% fowl bluegrass	White top[4]
12% sheep or rough fescue	Leduc Barley	16% meadow foxtail	Slough grass[5]
34% western wheatgrass		7% reed canary grass	
42% white clover		53% tall wheatgrass	
		10% tufted hairgrass	

[1]Application rate:25 kg/ha, broadcast
[2]Application rate: 107 kg/ha
[3]Application rate: 25 kg/ha, broadcast with a cover of oats or fall rye
[4]Application rate of 50 kg broadcast over pond area
[5]Application rate of 30 kg broadcast over pond area

4.2.4.3 Whitewood Mine

Mined areas at the Whitewood Mine are considered to be reclaimed after they have been revegetated. Conventional farm management practices have been used on all reclaimed areas.

Seedbed management in 1980 involved breaking large clods with a steel beam float, and cultivating the root zone material with a disc and harrows (Monenco Ltd 1982). Initially seed mixes were designed to produce a dense cover, to be productive and tolerant of potential drought and to add nitrogen and organic matter to the spoil. Drill seeding was completed in April or May unless excessive moisture resulted in postponing seeding until late August or September.

The seed mixtures used for revegetation in 1987 to 1990 were selected to maximize the development of soil organic matter in the first four to five years after initial seeding. The species selected had high root/shoot ratios, were proven species for the area and were commercially available (Table 4.7). Oats or barley were seeded as a nurse crop for establishing forage. A cyclone type broadcast seeder was used for seeding. The objective of soil and crop management on reclaimed land in 1989 was to bring soil quality to a level to sustain typical farming practices for the area. To accomplish this, reclamation efforts focused on maintaining soil organic matter at 4% (2.5% organic carbon). **A number of seed mixes have been designed for use at Whitewood based on intended land use (Tables 4.8 to 4.10). Seed mixes have been designated for forage production, seeding riparian areas and seeding the ash disposal areas. To minimize the potential for erosion, oats or barley were seeded as a cover crop during forage establishment.**

Table 4.7. Seed mixes used at Whitewood Mine in 1987 to 1990.

Forage Mix[1]	Cereal Crops
15% Rambler alfalfa	Cascade oats (77 kg/ha)
25% Slender wheatgrass	Klondike barley (81 kg/ha)
10% Carlton brome	Leduc barley (67 kg/ha)
25% Boreal creeping red fescue	
25% Ruebens Canada bluegrass	

[1] seeded at a rate of 22.4 kg/ha

Table 4.8. Seed mixes used at Whitewood Mine in 1991 to 1994.

Grassed Waterway Mix (1991)[1]	Forage Mix (1991 to 1994)[2]	Cereal Crops (1991 to 1993)	Ash Disposal Mix (1991 to 2006)[3]
25% Reed canary grass	29% Alfalfa	Jackson Barley (108 kg/ha)	28% Creeping red fescue
53% Creeping red fescue	40% Slender wheatgrass	Cascade Oats (76 kg/ha)	28% Timothy
22% Meadow foxtail	19% Smooth brome	Derby Oats (76 kg/ha)	28% Alsike clover
	10% Creeping red fescue		16% Rye grass
	2% Canada bluegrass		

[1]Application rate: 224 kg/ha, broadcast with cover crop of fall rye at a rate of 100 kg/ha
[2]Application rate: forage at 22 kg/ha, broadcast with a cover crop of fall rye at 100kg/ha or oats at 57 kg/ha
[3]Application rate: 56 kg/ha, broadcast with a cover crop of fall rye at a rate of 100 kg/ha and chopped hay mulch

Table 4.9. Seed mixes used at Whitewood Mine from 1994 to 1997.

East Pit Gravel Area Mix (1994 and 1997) [1]	Wildland Mix (1995 to 1997)[2]
25% Northern wheatgrass	12% Creeping red fescue
25% Hard Fescue	12% Sheep or rough fescue
20% Streambank wheatgrass	34% Western wheatgrass
15% Slender wheatgrass	42% White clover
5% Canada bluegrass	
10% fall rye	

[1]Applicate rate: broadcast at 15 kg/ha in trafficable areas, 30 kg/ha on side slopes and slope crests
[2]Application rate: 25 kg/ha, broadcast

Table 4.10. Seed mixes used at Whitewood Mine from 1997 to 2006.

Grass Mix (1997 to 2006)[1]	Riparian Mix (1999 to 2006)[2]	Hay Blend (2004 to 2006)[3]
39% Alfalfa	14% Fowl bluegrass	66% Ameristand 201+2 Alfalfa
6% Timothy	16% Meadow foxtail	17% Grindstad Timothy
22% Crested wheatgrass	7% Reed canary grass	17% A.C. Knowles Hybrid Brome
29% Smooth brome	53% Tall wheatgrass	
4% Creeping red fescue	10% Tufted hairgrass	

[1]Application rate: 25 kg/ha, seeded with an air drill and a cover crop of oats at 48 kg/ha
[2]Application rate: 25 kg/ha, broadcast with cover crop of fall rye at a rage of 11.2 kg/ha
[3]Application rate: 25 kg/ha, seeded with an air drill and a cover crop of barley

4.2.4.4 Diplomat Mine

From 1950 to 1966 spoil peaks were levelled slightly and planted with grasses, legumes and 25,000 trees (Alberta Environment 1981). Plates 4.8 and 4.9 illustrate the cover achieved by 1982. In 1967, revised reclamation guidelines resulted in 144 ha of spoil heap levelling to new standards over the next five years. Land was again seeded and approximately 18,000 trees were planted (Alberta Environment 1981).

Some topsoiled fields at Diplomat were directly seeded to cereal crops wheat, barley and oats without first seeding them to legumes (Alberta Environment 1983). Forages (Plate 4.10) and canola have also been grown successfully.


Plate 4.8. Vegetation cover on spoil heaps (1982).


Plate 4.9. Vegetation cover on spoil heaps (1982).

Plate 4.10. Forage crop at Diplomat Mine.

4.2.4.5 Paintearth Mine

Initial seeding activities occurred in 1984 following placement of topsoil. A forage mixture comprised of brome grass, crested wheatgrass, and alfalfa was seeded with a nurse crop of oats (Plate 4.11) in the spring of 1984 (Macyk et al. 1995). Fertilizers applied included 100 kg/ha 34-0-0 (broadcast) and 50 kg/ha 11-51-0 (drilled). Drought conditions during 1984 had a deleterious effect on initial forage establishment. The crop (Plate 4.12) was refertilized with 50 kg/ha 46-0-0 and 100 kg/ha 11-51-0 in 1985, 90 kg/ha 28-28-0 in 1986, and 100 kg/ha 46-0-0 in 1987.

Plate 4.11. Oats nurse crop at Paintearth Mine.

Plate 4.12. Forage crop at Paintearth Mine.

4.2.4.6 Vesta Mine

The revegetation program in 1978 included the use of mixtures of agronomic grasses and legumes which were recommended for the region. Actual mixtures were selected on the basis of site specific conditions such as soil moisture and soil chemical properties, and seed availability. Species with characteristics conducive to erosion control, final land uses and good growth were preferred. Cereal grains were used as cover crops to protect against erosion and to shelter establishing perennial species at a rate of 25 kg/ha.

During the 1975 to 1976 reclamation season trees and shrubs were planted in areas considered too steep for farmland (Manalta Coal Ltd. Undated). The trees and shrubs were transplanted from areas to be mined with a Vermier tree spade mounted on a Nodwell crawler. This technique had a very successful transplant survival rate but was expensive and slow. Tree and shrub plantings were carried out in 1978 in rough grazing or wildlife areas and around ponds.

Seeding and fertilizing in 1979 were conducted using standard agricultural practices. The seed mix consisted of crested wheatgrass, Russian wild rye grass, brome grass, tall or intermediate wheat grass, and alfalfa in equal proportions by weight. Seed and fertilizer (50-50 N and P mixture) application rates were 20 kg/ha and 50 to 100 kg/ha, respectively.

The seed mixture used in 1980 to 1982 consisted of crested wheatgrass (4.5 kg/ha), bromegrass (4.5 kg/ha), and alfalfa (4.5 kg/ha). The cover crop of oats or barley was drill seeded into the prepared seedbed, and fertilization consisted of a single application of 23-23-0 applied at a rate of 112 kg/ha. The seeding rates were changed in 1983 to 3.4 kg/ha of crested wheatgrass, 3.4 kg/ha of brome grass, 4.5 kg/ha of alfalfa, and 57 kg/ha for the cover crop. The fertilizer rate was also changed to a single application of 23-23-0 at a rate of 56 kg/ha. The types of fertilizer used were changed in 1985 to 11-51-0 for newly reclaimed areas and custom mixed blends for other areas.

Intermediate and tall wheatgrass were used in 1986 because crested wheatgrass was not available. Beginning in 1986, fertilizer blends were based on field tests and stage of development of the reclamation area. The application rate of the oats cover crop was decreased to 39 kg/ha in 1987 and fertilizer rates were increased depending on site requirements.

In 1989 the practice of planting a grass/legume crop on first year reclamation areas was revised to planting a cereal crop in the first two years to allow for herbicide application for weed control.

In 1990 a consultant was contracted to prepare a farm management plan for the Vesta minesite. The following practices were implemented for the custom farming area in 1990 and continued in 1991 to 1997:

- The recommended fertilizer rate was determined in the first year of reclamation based on a soil test.
- A cereal crop was seeded at variable rates in the first year in all newly reclaimed lands to allow for maximum weed control.
- A cereal crop was underseeded to a forage legume and grass crop (1/3 streambank wheatgrass, 1/3 crested wheatgrass, and 1/3 slender wheatgrass) in the intermediate potential agricultural zones (0.3 to 0.5 m of subsoil).
- A cereal crop of oats, barely or wheat was seeded in the high potential agricultural zones (0.7 to 1.3 m of subsoil).

The hay seed mixture consisted of 5.6 kg/ha of sweet clover, 5.6 kg/ha brome grass, and 3.4 kg/ha of alfalfa in 1990. Beginning in 1993 all cereal crop straw and stubble were returned to the soil to increase the organic matter in the soil and provide erosion control.

4.2.4.7 Montgomery Mine

No seeding or fertilizing activities took place from 1982 to 1984. The lands topsoiled in 1983/1984 were cultivated during the year to keep them free of weeds.

Land preparation and leveling was done prior to the farming operation. A float was dragged across the topsoil to remove ridges from the topsoil replacement process. The land was then worked on a diagonal with a 50 foot heavy duty double disc. Grass seed mixtures were generally seeded with an air seeder and the cover crop of oats was under sown with a set of hoe drills along with the fertilizer.

In 1985 topsoiled lands were seeded with a mixture consisting of crested wheatgrass and alfalfa at rates of 5 kg/ha and 2 kg/ha, respectively. Oats were seeded as a companion crop with the grass-legume forage mixture. Fertilizer was broadcast at 20 kg N/ha and 25 kg P_2O_5/ha.

In 1987 stockpiles received a mix of streambank wheatgrass, crested wheatgrass and alfalfa, and ditches received a mixture of pubescent wheatgrass, crested wheatgrass, Russian wildrye, tall wheatgrass and alfalfa. A “problem areas mix” consisting of Russian wildrye, crested wheatgrass, tall wheatgrass, sweet clover and alfalfa was developed for areas with no topsoil or subsoil. Soil tests were done to determine the appropriate fertilizer rates. Seeding rates in 1988 were 64.75 kg/ha for both the “problem area mix” and the “general area mix” which consisted of crested wheatgrass and alfalfa. Cereal crops of oats and fall rye were seeded in the spring and fall, respectively to provide cover crop protection for forage crops. In addition the cereal crops were seeded to reduce wind erosion and provide snow entrapment during the winter for moisture in the spring.

In 1990 seeding rates were reduced to 7.28 kg/ha for crested wheatgrass and 4.8 kg/ha for alfalfa for the “general area mix”. Rates were similar in 1991.

Native grass seed was first introduced at Montgomery mine in 1992. Elbee Northern wheatgrass, Walsh western wheatgrass, Indian ricegrass, green needlegrass and Blue grama were seeded along with oats and alfalfa.

In 1993 no herbicides were used as a means to control weeds. Weed control was performed where necessary on topsoiled areas prior to seeding. Weed control measures consisted of summer fallowing, disking and grass seeding to choke the weeds.

4.2.4.8 Sheerness Mine

No information was available.

4.2.5 REVEGETATION MONITORING

Coal mine operators have been performing revegetation monitoring and research activities since the early 1980s. The information presented in this section has been obtained from annual conservation and reclamation reports which did not always provide the results for the projects completed, therefore results are not available for each project.

4.2.5.1 Genesee Coal Mine

Test plots have been operated since 1981 at the Genesee Coal Mine. The plots were operational until the late fall of 1989. The plots were then seeded to forages and managed according to farm practices on the surrounding fields.

During 1990, a research program was initiated to demonstrate the suitability of various sources of subsoil on available sections of dormant mine areas. A small parcel of grassed reclaimed land was taken out of production in 2001 to accommodate the Weyerhauser tree research plot where approximately 800 trees were planted. These plots were monitored yearly after establishment. During the 2005 assessment it was noted that a number of trees were lost to rodent damage. Many trees were trimmed to encourage suckering from the root which was moderately successful. Weed control within the plots was provided through mowing and herbicide application. Herbicide (2,4-D *amine 500*) and Lontrel were spot sprayed using a controlled droplet applicator and back pack sprayer.

The agricultural monitoring program at Genesee involves tracking reclamation materials and procedures as well as crop yield.

Two new reclamation projects, the "Live Root Transplant" and Genesee Mine Marsh Reclamation Research" projects were initiated at the Genesee Mine in 2003. The "Live Root Transplant" project was designed to examine the potential for taking fresh topsoil containing live tree roots from recently grubbed areas and applying it immediately to prepared subsoil within the post-mine area. The direct placement of woody topsoil while roots are active was a change from the current practice of stockpiling topsoil. The project area was monitored for vegetation

establishment and development of potential improvements based on experience. Results showed that "live root transplant" was a viable reclamation technique in areas requiring reforestation.

4.2.5.2 Highvale Coal Mine

Agricultural yields were determined annually on a variety of representative soils in the vicinity of the Highvale Mine since 1977. The purpose of the program was to provide crop yield, land management and soil capability information to further the knowledge of soil behaviour and response to land management practices. This program provided information on the range of agricultural crops and management practices normally used on the various soils in the Highvale area, and provided baseline yield data for comparison with reclaimed lands (TransAlta 1991).

Methods of evaluating revegetation success in the first six years of revegetation included monitoring each unit every third year (twice during one rotation) to quantify species success and effectiveness of management practices. Basic plant performance characteristics recorded for each sample site included average vegetation height, root density, dominant species composition, and weed invasion (TransAlta 1980).

Observations made in the field before 1981 and the results of research indicated the need to establish a grass and legume mixture for at least five years before cereal crop production could succeed (TransAlta 1981).

The objective of the tree and shrub trials initiated in 1982 was to

- Establish shelterbelts and groves of trees and shrubs for erosion control, wildlife habitat, and aesthetics,
- Determine the most effective tree and shrub species for use in reclamation, and
- Determine the most effective methods of propogation, planting, and maintenance of woody vegetation.

Cuttings were taken from several varieties of local native tree and shrub species for rooting experiments. In 1986 after two growing seasons, high survival rates were recorded for rose, dogwood, honeysuckle, and several species of willow and poplar. Overall results in 1987 indicated that domestic poplars, willows, wild rose, and red osier dogwood were the best species for use at Highvale.

4.2.5.3 Whitewood Mine

A tree and shrub trial project was undertaken to determine effective methods of establishing trees and shrubs on levelled mine spoil. Cuttings of various woody plant species were rooted in a greenhouse during the winter of 1982 to 1983 and were outplanted on reclaimed land in the fall of 1983. Field work was completed in 1988. Results of the five years of investigation indicated that wolf willow, Saskatoon, pincherry, Siberian elm and tartarian honeysuckle had greater than 70% survival over five years and wild rose and dogwood exhibited greater than 70% survival over three years. Slope and aspect and soil moisture were determined to be the most limiting factors to plant survival and weed control was determined to be the most important management technique.

During 1988 a summary report outlining results of woody plant success and habitat improvement since 1976 was completed. The report indicated that native white spruce, 50 to 125 cm tall when planted, had survival rates greater than 90% while small nursery grown spruce had survival rates less than 25%. All deciduous plantings had survival rates less than 25% with best results from Manitoba maple, Siberian elm, and villosa lilac. Deer use of the enhanced area increased 332% over the ten year life of the project and grouse use increased 71%.

4.2.5.4 Diplomat Mine

Sweet clover was planted in areas levelled and worked with a subsoiler in 1977. Measurements demonstrated yields of 0.4 T/ha compared to an average yield of 0.5 T/ha for undisturbed land in the area (Alberta Environment 1981).

4.2.5.5 Paintearth Mine

Forage production was evaluated as part of the project involving long term measurements in reconstructed soils at the Paintearth Mine (Macyk et al. 1995). Harvests to determine yield were completed at six sites in the latter part of June in 1985, 1986, and 1987 (Plates 4.13 and 4.14). Conditions were relatively dry leading up to the time of harvest and the forage crop was under some moisture stress in each of the three years of assessment, particularly in 1985 and 1987. The average yield for the sites in 1986 was very similar to the 1970 to 1979, 10 year average yield for the region.

Plate 4.13. Replicates harvested to determine yield.

Plate 4.14. Forage cover harvested to determine wet and dry weight.

4.2.5.6 Vesta Mine

Annual monitoring of reclaimed land production was initiated at Vesta Mine in 1979. The method of data collection consisted of clipping vegetation to a level 2.5 cm above the ground in three randomly selected meter square plots. The vegetation was then air dried and weighed. Vegetation from ash plots was also tested for boron content.

Visual examinations in 1980 indicated that plant vigour was generally very good in previously reclaimed areas. There were no obvious toxicity symptoms, even on sites where coal bottom ash was substituted for topsoil material.

In 1994 native seed based test plots were established at the Vesta East ash dump to evaluate the growth success of native seed on soil deficient areas (Manalta Coal Ltd. 1994). The plots were designed to compare the success of selected native seed (Table 4.11) with conventional agronomic seed mixes typically used for reclamation in the area. One plot was seeded to an oats cover crop on 120 cm of organic soil capping material, one plot was seeded to an oats cover crop on 60 cm of spoil capping, and one plot was seeded to an oats cover crop on 120 cm of spoil capping. Preliminary results indicated that the wheatgrass species showed growth comparable to that of the agronomic species, however were not as effective as the agronomics for erosion control (Manalta Coal Ltd. 1997).

Table 4.11. Seed mixes evaluated in 1994 at Vesta Mine.

Native Seed Mix #1	Native Seed Mix #2	Native Seed Mix #3	Agronomic Seed Mix
30% Northern wheatgrass	30% Northern wheatgrass	20% Alfalfa, rangelander	20% Sweet clover
25% Slender wheatgrass	25% Alkali nuttal grass	20% Alkali nuttal grass	20% Alfalfa
25% Western wheatgrass	15% Western wheatgrass	20% Canada bluegrass	20% Crested wheatgrass
10% Alkali nuttal grass	10% Slender wheatgrass	10% Northern wheatgrass	20% Russian wildrye
10% Alfalfa, rangelander	10% June grass	10% Slender wheatgrass	10% Tall wheatgrass
	10% Canada bluegrass	15% Rocky mountain fescue	10% Green needlegrass
		5% Tufted hairgrass	

In 1995, the Vesta Mine initiated a test transplant program to recover large trees from areas to be mined. These trees were transplanted with a tree spade to the perimeter of ponds within the reclaimed landscape. In 1996 there was a total of 240 trees transplanted and 184 were planted in 1997.

4.2.5.7 Montgomery Mine

Three test areas were established in 1993 to evaluate the use of native grass seed mixtures on selected reclaimed areas. The test area was reclaimed with a subsoil laydown and a shallow top dressing of topsoil and seeded with an "upland mix" and a "lowland mix". An additional area was seeded with a "native mixture" (Table 4.12).

Table 4.12. Seed mixes evaluated at Montgomery Mine in 1993.

Lowland Mix	Upland Mix	Native Mixture
Alfalfa	Alfalfa	Elbee Northern Wheatgrass
Crested wheatgrass	Crested wheatgrass	Walsh western wheatgrass
Walsh western wheatgrass	Walsh western wheatgrass	Indian rice grass
Nuttal alkali grass	Nuttal alkali grass	Green needlegrass
Canada blue grass	Indian rice grass	Blue grama
Reed canary grass	Green needlegrass	

4.2.5.8 Sheerness Mine

No information was available.

4.2.6 FERTILIZATION

4.2.6.1 Genesee Coal Mine

Information was presented in the revegetation section.

4.2.6.2 Highvale Coal Mine

A comprehensive soil fertility program is in place at Highvale to ensure there are no nutrient imbalances on the reclaimed land. Soils are sampled and analyzed to determine nutrient requirements and a fertilizer blend consisting of nitrogen, phosphorus, potassium and sulphur is created. Fertilizer is broadcast annually on reclaimed hay fields and placed with the seed on fields scheduled for cropping. **Application rates are determined by the difference between the maximum fertilizer the crop can use during the year, and the nutrients available in the soil at the time of sampling.** Maintenance fertilizer applications are made to areas not intensively cropped.

4.2.6.3 Whitewood Mine

Rate of fertilizer application and nutrient blends varied depending on the lessee and the type of crop. Soils were sampled annually and analyzed to determine nutrient requirements. Each soil sample was a composite of 10 to 15 subsamples collected within each reclaimed field. Fertilizer was broadcast annually over all reclaimed areas scheduled for cropping. Application rates were determined by the difference between the maximum fertilizer the crop can use in a year, and the nutrients available in the soil in the fall. Application of nitrogen fertilizer is split with half applied in spring and the remainder after harvest of the first cut of hay.

Starting in 1997, fertilizer was broadcast in spring before a newly topsoiled area was seeded for the first time. Fertilizer was also broadcast annually over all reclaimed areas scheduled for cropping.

4.2.7 WEED MANAGEMENT

4.2.7.1 Genesee Coal Mine

In an effort to evaluate mowing as a good cultural weed control practice, no agricultural herbicides were applied in reclaimed areas between 1993 and 2000.

The reclaimed cropped field in 2000 was sprayed with *Buctril-M* to control broadleaf weeds and *Achieve* herbicide to control wild oats.

A small amount of Escort was spot sprayed in 2001 to control a common tansy outbreak in the active mine area. The areas sprayed were along the edge of topsoil stockpiles and the fringe of trees between stockpiles. Mowing was used to control the remaining weed concerns within the mine license boundary.

No herbicide was used in non-cropped areas for weed management in 2003.

4.2.7.2 Highvale Coal Mine

Weeds were controlled wherever possible by mowing with rotary mowers, manual string or blade trimmers and cultivation. In places inaccessible to equipment or when weeds were particularly troublesome, herbicides such as Dyvel or Tordon 22K (1986), Gleen (1987), Round-up or Banvel (1990) were applied with back-pack sprayers or hand gun and hose. Problematic weed species include noxious weeds, scentless chamomile, Canada thistle and common tansy.

4.2.7.3 Whitewood Mine

Problem weeds (tansy, thistle, scentless chamomile) were controlled at Whitewood with cultivation and mowing where possible, or by spraying with Banvel (1987 to 1988), Tordon (1987 to 1995), Glean (1989 to 1992), Lontrel (1991 to 1995), Ally (1992 to 1995) or Roundup (1994 to 1995).

4.2.7.4 Diplomat Mine

No information was available.

4.2.7.5 Paintearth Mine

No information was available.

4.2.7.6 Vesta Mine

Weed control in 1985 consisted of spot application of Tordon to control the spread of scentless chamomile. Herbicide Buctril M was used in 1987. The results were satisfactory, but due to the difficulty of achieving total kill of the weed it was necessary to cultivate a large amount of established forage. Areas most affected by the weed were seeded to cereal crops which allowed application of the required herbicides for weed control.

Scentless Chamomile infestations and other weeds were later controlled with various herbicides (Buctril-M, Avadex BW Granular, Spike TVC sterilant) and hand picking.

In 1996 there was a Scentless Chamomile outbreak. Measures undertaken to control the week included chemical spraying, summerfallow and hand picking.

4.2.7.7 Montgomery Mine

No information was available.

4.2.7.8 Sheerness Mine

No information was available.

4.3 WETLAND RECLAMATION

4.3.1 GENESEE COAL MINE

Wetland reclamation can provide important contributions to landscape aesthetics, wildlife habitat, and regional biodiversity. **To help the reclamation team better understand management and reclamation of wet soil habitats the "Genesee Mine Marsh Reclamation Research" project was initiated.** The project partnered with the University of Alberta, EPCOR, Luscar Ltd. and the Natural Sciences and Engineering Research Council of Canada. The objectives of the project were to:

- Establish and test the suitability of a hydraulic regime for the establishment of wetland plants from the seed bank of a transferred marsh soil.
- Test the efficacy of intact transfers of marsh soils containing an established natural seed bank in establishing a wetland plant community within two years.
- Identify and explore potential limiting factors in marshland reclamation at the Genesee Mine.

The marsh reclamation plots were covered with donor spoil in the spring of 2003.

4.3.2 WHITEWOOD MINE

Construction of a replacement lake in the East Pit commenced in 1987. Contouring and levelling of spoil piles surrounding the East Pit box cut was carried out using dozers and the dragline to reduce slopes to a maximum of 10º. Construction and grading was done to provide potential for features such as a beach, boat launch, and picnic areas. The earthmoving activities were completed in 1988. Several erosion gullies which developed during heavy summer storms in 1988 received erosion control treatments including re-contouring and placement of riprap, installation of willow cuttings and fascine drains in wet areas, and ripping and seeding of small gullies and rills. Revegetation using grass/legume mixtures began in 1988 (Table 4.13). A cover crop of Grizzly oats was seeded at 38 kg/ha. Fertilizer was applied as elsewhere at Whitewood.

In 1989 trees and shrubs were planted in the area. Species included Northwest poplar, acute-leaf and laurel-leaf willow, chokecherry, dogwood, green ash, white spruce, and lodgepole pine. Approximately 30,000 stems were planted over a total of 23.5 ha (TransAlta 1990).

Table 4.13. Seed mixes used for the East Pit lake Replacement area.

Shoreline Zone[1]	Riparian Zone[2]
40% Orchard grass	20% White clover
25% Brome grass	40% Crested wheatgrass
25% Meadow fescue	40% Creeping red fescue
10% White clover	

[1] seed applied at 56 kg/ha
[2] seed applied at 56 kg/ha

The grass/legume mixture seeded was successfully established by 1989 and no additional seeding or fertilizing was required. Survival of tree and shrub species was variable, with willow and green ash survival high and aspen poplar, chokecherry, dogwood and coniferous species survival low. Heavy competition from seeded grasses and legumes was considered to be the primary cause of poor survival.

Water quality monitoring was carried out during 1990 to 1992. Results indicated no characteristics detrimental to aquatic life, although mercury, zinc and copper were sometimes higher than the Alberta Surface Water Quality Objectives or Canadian Water Quality Guidelines Criteria. During 1992 a caged trout study indicated that water quality parameters such as dissolved oxygen and water temperature were favourable for fish growth, and that food sources were abundant. **In September, 1994 a Reclamation Certificate was issued for the East Pit Lake and surrounding lands.**

4.4 ANCILLARY MATERIALS

4.4.1 Ash

4.4.1.1 Highvale Coal Mine

The ash content of Highvale coal averages approximately 15.5%. Ash produced from the generating plants is approximately 70% fly ash and 30% bottom ash.

The disposal method at Sundance in 1977 was to dry haul ash to the mine spoil pile area, the bottom of the mine pits, or to a separate ash disposal dump. Ash from the Keephills generating plant was pumped in a slurry via pipeline to an ash lagoon. A testing program in 1977 (Montreal Engineering Company 1977) was conducted to evaluate the properties and behaviour of fly ash and bottom ash and its potential effects on percolating water under field conditions. Results from the leaching study using distilled water showed that the ash produced alkaline leachates characterized by high pH (11 to 12), significant values of specific conductance and hydroxyl alkalinity. The cations leached to the greatest extent included calcium, sodium, potassium, barium, and strontium. When combined with typical clayey materials from the study area the metals were sorbed by the clays. It was concluded that the net effects of percolation of water were not a major concern.

Ash disposed of in the mine was required to be covered by 1.5 m of potential growth material in 1978. Ash disposal methods remained the same until 1989 when a minimum of 1.6 m of combined suitable spoil and soil were used to cover the disposal areas prior to revegetation and some ash was sold for commercial use through TransAlta Fly Ash Ltd. In 1993 the minimum depth of suitable subsoil and topsoil required to cover ash disposal areas was decreased to 1.2 m.

Beginning in 1997 the ash dumping practices were changed. In some areas within the ash dump “footprint”, ash had previously been disposed below the anticipated future water table elevation. In such areas, ash continued to be disposed such that the dump was built up but did not increase spatially beyond the established disposal limit. Afterwards, ash was disposed above the anticipated water table elevation. In some locations this practice required low-lying areas to be backfilled with spoil prior to ash disposal.

4.4.1.2 Whitewood Mine

Approximately half of the fly ash produced at the Wabamun Generating Plant is dry hauled to the ash disposal sites located at the Whitewood mine. The remaining ash is either sold for industrial use or pumped in a slurry with bottom ash to lagoons located west of the generating plant. Dry ash disposal areas were required to be covered with 1.6 m of suitable spoil prior to topsoiling and seeding in 1987.

Various trials were conducted on the Wabamum Generating Plant ash lagoons in an effort to determine effective methods of stabilizing the ash surface and of establishing a self-sustaining vegetation cover. The major conclusion of the project was that the best results were obtained from capping the ash surface with at least 8 cm of soil or spoil (TransAlta 1988).

4.4.1.3 Vesta Mine

Bottom ash was used as an amendment at Vesta for the bentonitic spoil and glacial till areas that were disturbed from mining in the 1960's and 1970's when no reclamation material was required to be salvaged. A research program was initiated in 1991 to collect data for evaluation of the long term effects of reclaiming areas with bottom ash and to assess the suitability of ash for reclamation of soil deficient areas (Manalta Coal Ltd. 1991). The objectives of the study were to investigate and map plant growth and soil fertility and conditions on the ash amended sites to determine if further revegetation efforts were required and to assess the quality of the forages and surface water for livestock consumption. Amended lands had 0.20 to 0.30 m of bottom ash incorporated into the spoil surface prior to fertilizing and seeding with forages.

Ash dumps that were full in 1995 were reclaimed by capping with 1.2 to 1.6 m of suitable material (mine spoil) depending on the area.

The Phase 1 Ash Dump located within the Vesta Mine Permit Area occupies 23.2 ha of lands, the majority of which were mined prior to 1963. The mined areas were reclaimed in 1980, without the availability of topsoil or subsoil under the Vesta Ash Reclamation Research Project (VARP). The spoils were leveled and contoured and a surface treatment of bottom ash was ripped in to provide a growth medium. The area eventually became characterized by washouts and erosion and was therefore considered to be suitable for ash disposal. Ash dumping began in May 1990. Once ash was delivered to the Dump it was levelled and contoured with dozers. Spoil material from within the ash dump area was continually applied over the top of the ash as the dump was developed to control dust from fly ash and to establish a growth medium for reclamation. Twenty centimetres of bottom ash was incorporated into the spoil cap to provide a growth medium.

In 1992, a small portion of the dump was capped with 0.60 m of spoil material (approved capping depth at that time). This area was maintained to compare the 0.60 m depth with that of a 1.2 m depth (1993 approved capping depth) in terms of a vegetative cover. The objective of the revegetation program for the Ash Dump was to establish a pasture cover suitable for wildlife and compatible in landscape appearance to the unmined habitats above the Battle River. The entire Ash Dump surface was revegetated with a cover crop of oats and then seeded with upland and lowland grass-legume mixes (Table 4.14) in the second or third year. The lowland slopes were seeded with grasses which showed good erosion control abilities and were palatable to wildlife. Upland areas were seeded with species more suitable to dryland conditions. Shrubs were planted at select locations where moisture conditions were favorable.

Table 4.14. Seed mixes used for revegetation of the Phase I Ash Dump.

Upland Seed Mix	**Lowland Seed Mix**	**Shrubs**
Alfalfa	Orchardgrass	Willow
Crested wheatgrass	Tall fescue	Saskatoon berry
Intermediate wheatgrass	Timothy	Silverberry
Orchardgrass	Perennial ryegrass	Snowberry
Creeping red fescue	Alsike clover	Wild rose
Tall fescue	Annual ryegrass	
or:	Red clover	
Crested wheatgrass		
Meadow foxtail	**or:**	
Perennial ryegrass	Tall fescue	
Timothy	Orchargrass	
Orchardgrass	Timothy	
Annual ryegrass	Alsike clover	
Tall fescue	Reed canary grass	
Creeping red fescue	Annual ryegrass	
Alfalfa		
Alsike clover		

In 1994 a small area of the Ash Dump was capped with approximately 0.15 m to 0.30 m of organic material. The remaining area of the dump was either reclaimed with a spoil cap and surface treatment of 0.20 m of bottom ash or an end pond for waterfowl habitat through the planting of cattails, sedges and rushes on the shorelines and grasses and shrubs on the slopes above the pond. The entire pond area and edges were seeded initially with oats and then underseeded with the lowland grass-legume mix. Starter clumps of cattails, rushes and sedges were transplanted in pockets around the margin of the end pond. Just above this willows were transplanted in clumps.

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APPENDIX 1: GLOSSARY OF TERMS

Afforestation	The process of establishing a forest by planting trees or their seeds on land that is not a forest, or has not been a forest for an extended period.
Alberta Environment	Provincial ministry that looks after the following: establishes polices, legislation, plans, guidelines and standards for environmental management and protection; allocates resources through approvals, dispositions and licences, and enforces those decisions; ensure water infrastructure and equipment are maintained and operated effectively; and prevents, reduces and mitigates floods, droughts, emergency spills and other pollution-related incidents.
Agronomic Species	Plant species typically grown as agricultural crops.
Biodiversity	A measure of the relative diversity among organisms present in different ecosystems.
Boreal Forest	The northern hemisphere, circumpolar, tundra forest type consisting primarily of black spruce and white spruce with balsam fir, birch and aspen.
Coke	A high-carbon material resembling fine ground up asphalt material. It is a by-product produced by delayed or fluid coking.
Commercial Forest	Land Characterized by: (i) forest stands with trees to meet the standards of a commercial forest as defined in the Alberta Timber Harvest Planning and Operating Groundrules, 2000 as amended; (ii) forest stands stocked with native tree species as defined by the Timber Management Regulations AR 60-73 (144.2), 2000 as amended that may include white spruce, black spruce, jack pine, aspen poplar, balsam poplar, balsam fir, white birch and larch; (iii) forest stands no limited by operating restrictions such as slopes steeper than 45%, with the exception of tailing sand structures with slopes over 20%; stream buffers; potential recreational lakes; stand size; arrangement or accessibility as identified in the Alberta Al-Pac Timber Harvest Planning and Operation Groundrules, 2000 as amended; and

(iv) other characteristics specified in writing by the Director.

Composite Tailings/ Consolidated Tailings (CT)	Composite tailings (Syncrude) or Consolidated tailings (Suncor) are prepared by combining mature fine tailings with cycloned fresh sand tailings to form a deposit that consolidates relatively quickly in tailings deposits. This mixture is chemically stabilized (to prevent segregation of fine and coarse mineral solids) using gypsum ($CaSO_4$).
Coversoil (Mountain Mines)	The uppermost layer of soil that sustains the majority of the soil nutrients and is a suitable environment to establish a good root zone for vegetation and soil biological activity. This is salvaged from the upper soil profile, usually loam, sandy loam or clay loam in texture with <25% coarse fragments. It usually includes the LFH, Ae, Bm or Bt horizons and may include BC and C horizons of deeper profiles. Natural soil material sources include mainly Brunisols, Luvisols and Gleysols.
Coversoil (Oil Sands)	Any peat-mineral mix, organic horizon or upland surface soil.
CEMA	Cumulative Environmental Management Association. An association of oil sands industry, other industry, regional community representatives, regulatory agencies and other stakeholders designed to develop systems to manage cumulative effects association with developments in the Oil Sands Region.
CONRAD	Canadian Oil Sands Network for Research and Development.
Dibble	A small, hand-held, pointed implement for making holes in soil for planting seedlings, bulbs, etc.
Direct seeding	A method of establishing a stand of vegetation by sowing seed on the ground surface. A technique that can be used for tree and shrub establishment rather than planting pre-rooted stock.
Disturbed land (Suncor 1985)	Any land on which the Operator conducts or causes or permits to be conducted any operation or activity consisting of or resulting in any disturbance, exposure, covering, erosion, degradation or deterioration in any manner of the surface of the land.

Ecosite	Ecological units that develop under similar environmental influences (climate, moisture and nutrient regimes). Ecosites are groups of one or more ecosite phases that occur within the same portion of the moisture/nutrient grid. Ecosite is a functional unit defined by the moisture and nutrient regime. It is not tied to specific landforms or plant communities, but is based on the combined interaction of biophysical factors that together dictate the availability of moisture and nutrients for plant growth.
Ecosite phase	A subdivision of the ecosite based on the dominant tree species in the canopy. On sites where a tree canopy is lacking, the tallest structural vegetation layer determines the ecosite phase.
End Pit Lake	A man-made lake, used to fill a mine pit area into which the remaining fine tailings at the end of the mine may be discharged and stored under a water cap.
Eutrophic	The nutrient rich status (amount of nitrogen, phosphorus and potassium) of an ecosystem.
Evapotranspiration	A measure of the ability of the atmosphere to remove water from a location through the processes of evapotranspiration and water loss from plants (transpiration).
Fen	Sedge peat materials derived primarily from sedges with inclusions of partially decayed stems of shrubs formed in a eutrophic environment due to the close association of the material with mineral rich waters. Minerotrophic peat-forming wetlands that receive surface moisture from precipitation and groundwater. Fens are less acidic than bogs, deriving most of their water from groundwater rich in calcium and magnesium.
Fine Tailings	Fine particles in the oil sands tailings stream that segregates from the main sand deposit and forms a fluid deposit. Also known as fine tails (Syncrude).
Forb	A broad-leaved herb that is not a grass.
Forest Ecosystem	The sum of the plants, animals environmental influences, and their interactions within a plant community predominantly of trees and other woody vegetation, growing more or less closely together.

Groundwater	That part of the subsurface water that occurs beneath the water table, in soils and geologic formations that are fully saturated.
Grubbing	The operation of removing stumps and roots.
Herbivory	A mode of feeding in which an organism known as a herbivore, consumes only autotrophs such as plants, algae and photosynthesizing bacteria.
Highwall	The unexcavated face of exposed overburden and coal (or other mineral) in a surface mine or the face or bank on the hill side of a contour strip mining excavation.
Hotlift stock	Stock removed directly from greenhouse and planted in the field.
Hydroseeding	Dissemination of seed hydraulically in a water medium. Mulch, fertilizer and other amendments can be incorporated into the sprayed mixture.
In-situ	Also known as "in place". Refers to methods of extracting deep deposits of oil sands without removing the groundcover. The in-situ technology in oil sands uses underground wells to recover the resources with less impact to the land, air and water than for oil sands mining.
Invertebrate	An animal, such as an insect or mollusc, that lacks a backbone or spinal column.
Land Capability (Suncor 1984)	The intrinsic ability (i.e. ability unaltered by any level of future management inputs, activities, or alterations) of land resources to support a given use type, intensity, and quality on a sustained basis.
Land Capability Class	A land capability class assigned to an area according to the criteria outlined in the Land Capability Classification System for Forest Ecosystems in the Oil Sands, 3rd Ed, as amended.
Lean Oil Sands	Oil bearing sands that do not have a high enough saturation of oil to make extraction of them economically feasible.

Litter, Fibric and Humic (LFH)	The forest floor that accumulates on the mineral soil surface under forest vegetation, and which insulates dead vegetation and organic matter, including litter and unincorporated humus.
Littoral Zone	The zone in a lake that is closest to the shore. It includes thepart of the lake bottom, and its overlying water, between the highest water level and the depth where there is enough light (about 1% of the surface light) for rooted aquatic plants and algae to colonize the bottom sediments.
Mature Fine Tailings (MFT)	Fine tailings that have dewatered to a level of about 30% solids over a period of about three years after deposition. The rate of consolidation beyond this point is substantially reduced. Mature fine tailings behave like a viscous fluid.
Merchantable Forest	A forest area with potential to be harvested for production of lumber/timber or wood pulp. Forests with a timber productivity rating of moderate to good.
Mineral Soil	The A, B and C horizons and underlying parent material
Muskeg	A soil type comprised primarily of organic matter. Also known as bog peat.
Non-commercial Forest	Any area of forested land that does not meet the criteria of commercial forest.
Non-Segregating Tailings	Tailings mixture in which the fines and sand particles settle simultaneously to form a uniform deposit.
Organic Horizon	The surface soil horizon in organic soils containing more than 17% organic carbon by weight.
Overburden	Material below that soil profile and above the bituminous sand.
Overstorey	Those trees that form the upper canopy in a multi-layered forest.
Peat	A material composed almost entirely of organic matter from the partial decomposition of plants growing in wet conditions.
Peat-Mineral Mix	A mixture of an organic horizon and the underlying mineral soil, or an organic horizon and mineral soil from another

source, where the mineral soil in both cases is rated good, fair or poor according to Table 8, Page 27 of the Soil Quality Criteria Relative to Disturbance and Reclamation, 1987, as amended.

pH	The degree of acidity (or alkalinity) of soil or solution. The pH scale is generally presented from 1 (most acidic) to 14 (most alkaline). A difference of one pH unit represents a ten-fold change in hydrogen ion concentration.
Phytoremediation	A process that uses plants to remove, transfer, stabilize, or destroy contaminants in soil, sediment and groundwater.
Phytotoxic	Toxic or poisonous to plants or plant tissue.
Pit Lake	A man-made lake used to fill a mine pit area into which tailings may be discharged. Pit lakes are typically filled with waters pumped from adjacent rivers.
Regolith	The unconsolidated mantle of weathered rock and geological material overlying solid rock. It includes glacial drift, residual, colluvial and fluvial deposits that occur below the pre-mine soil profile, but does not include competent bedrock, either fractured or massive.
Riprap	Large rocks used for erosion control.
Rough mounding	Method where soil is pushed with a dozer to the place of final deposit and left as a rough, mounded surface. The next bladefull of soil is pushed up to but not over the last bladefull, again leaving it as a rough mound. The final surface has a rough mounded surface that provides microsite diversity, inherent erosion control, and minimized compaction.
Scarification (soil)	To loosen or stir the surface soil without turning it over.
Sedge	Any plant of the genus *Carex*, perennial herbs, often growing in dense tufts in marshy places. They have triangular jointless stms, a spiked inflorescence and long grass-like leaves which are usually rough on the margins and midrib. There are several hundred species.
Sodium Adsorption Ratio (SAR)	The comparative concentrations of sodium, calcium and magnesium in the soil solution, where $[Na^+]$, $[Ca^+]$ and $[Mg^{2+}]$ are the concentrations in mmol of charge per litre of

solution. The SAR of a soil extract takes into consideration that the adverse effect of sodium is moderated by the presence of calcium and magnesium ions. SAR values of 7 and higher cause dispersion of soils.

Soil The naturally occurring, unconsolidated mineral or organic material at least 10 cm thick that occurs at the earth's surface and is capable of supporting plant growth.

Spoil The material below regolith that is removed to gain access to the ore or mineral material in surface mining. Debris or waste material from a mine.

Subsoil The soil material found beneath the subsoil but above the bedrock. Technically, the B horizon: broadly, the part of the profile below plough depth.

Tailings A by-product of oil sands extraction typically comprised of water, sands and clays, with minor amounts of residual bitumen.

Topsoil Ae, Ah, Ahe, Ahj and gleyed and weakly gleyed versions of these horizons are typically considered to be part of the topsoil.

Topsoil Island Topsoil placed in strategically located islands at substantial depths as opposed to laying a thin veneer of topsoil over the entire surface.

Upland areas Areas that have typical round slopes of 1 to 3% and are better drained.

Upland Soil Mineral soils developed under forest in locations with imperfect drainage or drier, typically including LFH and A, B and C horizons.

Vascular Plant Plants possessing conductive tissues (e.g., veins) for the transport of water and food.

Weeds Plants that are defined as controlled weeds, nuisance weeds, or noxious weeds by the Weed Control Act, as amended.

Wetlands Areas where the land is saturated with water for long enough periods to support wet-adapted processes and plants.

APPENDIX 2: LIST OF ABBREVIATIONS/ACRONYMS

AENV	Alberta Environment
Albian	Albian Sands Energy Inc.
AOSTRA	Alberta Oil Sands Technology Research Authority
ARC	Alberta Research Council
ASAC	Alberta Soils Advisory Committee
ASB	Aurora Settling Basin
ASRD	Alberta Sustainable Resource Development
ATV	All Terrain Vehicle
bbl/day	barrels per day
BCM	Bank Cubic Meters
BML	Base Mine Lake
C	Carbon
CANMET	Canada Center for Mineral and Energy Technology
CanSIS	Canadian Soil Information System
C:N Ratio	Carbon:Nitrogen Ratio
Cardinal River	Cardinal River Coals Ltd.
CLI	Canadian Land Inventory
C&R	Conservation and Reclamation
CCME	Canadian Council of Ministers of the Environment
CEATAG	CONRAD Aquatic Technology Advisory Group
CFRAW	Carbon Dynamics, Foodweb Structure and Reclamation Strategies in Athabasca Oil Sands Wetlands
cm	centimetre
CNRL	Canadian Natural Resources Ltd.
CO_2	Carbon dioxide
CONRAD	Canadian Oil Sands Network for Research and Development
CSSS	Canadian System of Soil Classification
CT	Consolidated Tailings
dS/m	deciSiemens per meter
EC	Electrical conductivity
e.g.	For example
EIA	Environmental Impact Assessment
EIP	East In-Pit (Syncrude Canada Ltd. tailings facility)
ELC	Ecological Land Classification
EPEA	Alberta *Environmental Protection and Enhancement Act*
EPL	End Pit Lake
et al.	Group of authors
EUB	Alberta Energy and Utilities Board

FT	Fine Tailings
FTFC	Fine Tailings Fundamentals Consortium
GCC	Grande Cache Coal Corporation Inc.
GCOS	Great Canadian Oil Sands
ha	hectares
HEAD	Hydrology, Ecology, and Disturbance of Boreal Wetlands
HSI	Habitat Suitability Index
i.e.	that is
k	potassium
kg/ha	kilograms per hectare
km	kilometres
L/min	litres per minute
LCCS	Land Capability Classification System
LFH	Litter-Fibric-Humic
LOEC	Lowest Observed Effect Concentration
LSCRA	Land Surface Conservation and Reclamation Act
m	meters
m3	cubic meters
MFT	Mature Fine Tailings or Manufactured Fine Tailings
Mg/L	milligrams per litre
MLSB	Mildred Lake Settling Basin (Syncrude Canada Ltd.)
Mn	manganese
N	nitrogen
NAs	Napthenic Acids
No.	Number
NST	Non-Segregating Tailings
OC	Organic carbon
OSLO	Other Six Lease Owners
OSTRF	Oil Sands Tailings Research Facility
OSVRC	Oil Sands Vegetation Reclamation Group
OSWWG	Oil Sands Wetlands Working Group
P	phosphorus
PCOSI	Petro-Canada Oil Sands Inc.
RAMP	Regional Aquatics Monitoring Program
RRTAC	Reclamation Research Technical Advisory Committee
RWG	Reclamation Working Group

SAGD	Steam Assisted Gravity Drainage
SAR	Sodium Adsorption Ratio
SRCL	Smoky River Coal Ltd.
stems/ha	stems per hectare
Suncor	Suncor Energy Inc.
SVSG	Soil and Vegetation Subgroup
SWSS	Southwest Sand Storage Facility (Syncrude Canada Ltd.)
Syncrude	Syncrude Canada Ltd.
TEEM	Terrestrial Environmental Effects Monitoring Program of WBEA
TID	Tar Island Dyke (Suncor Energy Inc.)
TIRLD	Terrestrial Integrated Reclaimed Landscape Design (CT Demo Site – Suncor Energy Inc.)
TOC	Total Organic Carbon
TT	Thickened Tailings
UTS	UTS Energy Corporation
v/v	volume/volume
WASG	Wetlands and Aquatics Subgroup
WBEA	Wood Buffalo Environmental Association
WBSG	Wildlife and Biodiversity subgroup of CEMA
WIP	West In-Pit (Syncrude Canada Ltd. Tailings Facility)
WIRLD	Wetlands Integrated Reclaimed Landscape Design (CT Demo Site – Suncor Energy Inc.)