Soil salvage and placement: Breaking new ground at Teck's Cheviot open pit coal mine

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Abstract

Soil management is an integral component of land reclamation at Teck, Cardinal River Operations' (CRO) Cheviot open pit coal mine in the subalpine subregion of Alberta's east slopes. Reclamation objectives at the mine include forest establishment, watershed protection, wildlife habitat, biodiversity and recreational use, and soil management practices determine in large part the success in achieving these objectives. We employ a unique combination of soil salvage and placement techniques. The salvage process incorporates all organic matter, including tree slash, trunks and roots - no burning disposal of tree slash occurs beforehand. This maximises the volume of organic matter incorporated during the soil salvage process and improves soil quality, while promoting the natural recovery of native plant species. Soil placement utilises a "rough-mounding" technique in which the dozer keeps the soil in front of the blade during the push. This practice results in a very rough, mounded surface that avoids soil compaction and provides a range of micro-sites, essential in this extremely windy, exposed environment. The resulting irregular soil thickness provides a suitable range in conditions for native plant re-establishment and encourages the redevelopment of soil and vegetation processes.

1 Introduction

Teck Resources Ltd. (Teck) is Canada's largest producer of metallurgical coal, operating 6 coal mining operations in Western Canada: 5 in the Elk River Valley of southeast British Columbia and Cardinal River Operations (CRO) in west-central Alberta. Over 3,000 employees operate these mines, and the total annual production capacity exceeds 25 million clean tonnes of high-quality metallurgical coal. CRO's Cheviot mine began production in late 2004 and has an annual productive capacity of 1.8 to 2.5 million clean tonnes of medium-volatile metallurgical coal sought in global markets in the production of steel.

There are two distinct operating areas of CRO: Luscar mine and Cheviot mine. Luscar mine is approximately 40 km south of Hinton and operated from 1969 – 2004, in that time developing over 25 distinct mining pits within a cumulative disturbance footprint of approximately 2,338 hectares (ha). Just over half of this area has been reclaimed in that time. The Cheviot mine is approximately 20 km south of the Luscar mine. The current disturbance footprint is approximately 750 ha of which approximately 34 ha has been reclaimed.

Soil conservation is a fundamental component of the mine's reclamation programme. Soils handling has evolved over CRO's 40+-year history of mining operations to the current state that is somewhat unique in western Canadian industrial mining operations. CRO's soil conservation programme is the focus of this paper.

1.1 Environmental Background

General Overview: CRO's operations are located primarily in the Subalpine Natural Subregion (Beckingham et al, 1996) in the eastern slopes of Alberta. The area is characterised by an inclined, steep and rolling topography, with vegetation forest communities dominated by Lodgepole Pine and Engelmann-White Spruce coniferous stands. The region is described as having a continental, subhumid climate with long, cold winters modified by short periods of Chinook conditions and short, cool summers (Neufeld et al, 2010). The area provides locally important habitat for ungulates such as bighorn sheep, elk and mule deer and large carnivores such as grizzly bear, wolf and cougar. Elevations range from 1,480 to 1,900 MASL. Public recreational activities in the area include hiking, equestrian use, camping, fishing, hunting and Off Highway Vehicle (OHV) use.

Climate: Climate conditions in the area are generally limiting to plant re-establishment and growth. The most limiting conditions include an extremely short growing season (<60 days), occurrence of frost throughout the growing season, low average air and soil temperatures during the growing season and the presence of strong drying winds in winter and early spring. Wind speeds of 100 – 150 km/hr are recorded frequently but typically occur during winter months. Wind is a major climatic factor in determining the distribution and growth of many plant communities in alpine and upper subalpine zones. Protected sites, north/east aspects and valley bottoms tend to have more diverse and productive vegetation, while southerly/westerly sites and crest positions are exposed to wind and tend to be low-growing. Precipitation averages 650 mm annually, most of which falls as rain from May through July.

Soils: The soil landscapes represent the transition from Boreal to Subalpine and Alpine. They are strongly affected by the extremely variable, ridged topography which results in wide ranges in slope steepness, aspect and drainage. Brunisolic and Regosolic soils are common on the upper ridges and on the shallow soil ridges on both calcareous and non-calcareous materials. Luvisols and Gleysols are found on lacustrine clays at lower elevations and in valley bottoms (Neufeld et al, 2010). The effects of the mine-site elevation are apparent in the Subalpine soils which have less leaching and more organic accumulation than the Boreal soils (Knapik and Chernipeski, 1996).

Soil climate of the area is typical of the Front Ranges of the Rocky Mountains - cold cryoboreal to very cold subarctic. Some soils are frozen for part of the growing season and there are some localised areas of permafrost.

The soil moisture regime of the Mountain-Foothills region is classified as humid to subhumid though there are severe moisture deficits in some years. Soil moisture in the area is affected mainly by exposure to the warm dry winds in winter and early spring. The other key factor affecting local soil moisture is the location on the landscape and whether the soil sheds or receives runoff (Knapik and Chernipeski, 1996).

1.2 Mining History

CRO's operations are located within the historic Coal Branch along the front range and foothills of the northern Rocky Mountains in western Alberta, and has an extensive coal mining history. The area includes abandoned underground and open pit mines and the former town sites of Luscar and Mountain Park, where mining first started in 1911. In the early decades, most of the coal was extracted using conventional underground methods. Surface mining was introduced in the late 1940's, a time when production peaked. The Luscar mine was opened in 1969 and the Cheviot mine in 2004. All coal is processed at the Luscar mine's plant. The mines are operating on a 25-year mine plan.

2 Reclamation Objectives

In 1969 when the Luscar mine opened, reclamation objectives focussed on erosion control and wildlife habitat (Cardinal River Coals Ltd, 1976). These objectives were consistent with the regulatory requirements and technologies of the day. Soil conservation did not become an operational practice at the Luscar mine until the mid-1980's, when the reclamation goals were expanded to include the establishment of forest cover.

In 2004, the Cheviot mine was opened after 10 years of environmental assessment and regulatory/stakeholder review. The conditions on which the Cheviot mine was approved were substantially different from those of the Luscar mine, and presented challenges that were addressed through the identification of a broader range of objectives. Six resource values were identified for Cheviot's reclaimed landscapes – watershed protection, wildlife habitat, fisheries habitat, recreational uses and ecological processes. These are described in Table 1. An ecosystem management approach is used as the basis for reclamation planning, recognizing the following factors:

Ecologically attainable and sustainable;

Economically viable;

Socially accepted;

Regulatory conditions are satisfied.

Table 1: Reclamation values and objectives

Objective	Operational Plan
Watershed protection	Design post-mining landforms and revegetated disturbances to control soil erosion and to protect streams from siltation and changes in water quality
Wildlife habitat	Establish a range of habitats that will support ungulate populations including bighorn sheep, elk and mule deer Establish a range of habitats that will support other wildlife species locally common to the area Retain tree islands wherever possible to enhance wildlife habitat and encourage native plant ingress
Fisheries habitat	Minimise impacts to riparian habitat and fish-bearing streams. Where disturbance is necessary, replace lost habitat
Forest re-establishment	Create a diversity of soil and landscape types to facilitate development of forested areas that meet watershed, wildlife and other objectives
Recreational uses	Re-establish trails and recreational uses as per the outcomes of the local land planning initiatives Management Plan Avoid development of high-use trails in ecologically sensitive areas Emphasise scenic values in recontouring plans
Ecological processes	Initiate the development of ecologically functioning reclaimed landscapes Construct post-mining soils and landforms to encourage a range of plant species including locally native plants Avoid using invasive plant species that may encroach on undisturbed areas

3 Soil Management Practices

In the early stages of mine development and reclamation at the Luscar mine, “soil management” involved the resloping of waste rock materials to a stable angle, followed by establishing vegetation quickly to minimise erosion, stabilise slopes and provide forage for wildlife, commonly referred to as the “green up” approach. This typically translated into the seeding of persistent and aggressive agronomic mixes and legumes at heavy rates, combined with application of initial and prolonged maintenance fertilizing.

When soil conservation became an operational practice in the 1980’s, salvage operations were conducted with first piling and burning all of the vegetation (and much of the surface soil layer), followed by stripping the remaining horizons and stockpiling for later replacement. The soil was usually pulled from stockpile and placed with the standard “dump and level” method with either dozers or motor scrapers, and in either case resulted in a fairly uniform and smooth surface layer, often compacted and requiring ripping or other modifications. This soil profile accommodated the re-establishment of agronomic grasses and legumes but presented challenges in establishing trees, shrubs and other native plant species.

The Cheviot mine presented CRO with an opportunity for a spatial/methodological change to reclamation practices and specifically with soils handling practices, to meet objectives consistent with native species re-establishment.

3.1 Pre-disturbance soil characteristics

Detailed soil surveys are conducted on all mine areas during the environmental assessment phase to establish baseline soil parameter characterization. In the Cheviot area, six different parent material groups have been identified, and a summary of typical soil profiles for each of these groups is provided in Table 2. The depths and presence/absence of individual horizons is so variable in this area that the selection of representative soil profiles is a challenge. These soil groups typically fall into the Regosolic, Brunisolic and Mesisolic Great Groups.

Table 2: Typical soil profile descriptions

Soil Type	Site Location[1]	Horizon	Depth (cm)	Texture[2]	pH	EC dS/m	TOC %	SAR	SAT %	Stoniness (% vol)
Colluvial	Site 71 Ca	LF	7-0							**0**
		Bm	0-22	Ch Loam	6.5	0.10	0.47	0.4	29	10
		C	22-100	Ch Loam	6.2	0.17	0.69	0.2	35	20
	Site 86 Ca	LF	3-0							0
		Bm	0-12	Loam	5.7	0.08	1.27	0.2	46	<10
		C1	12-43	Sandy Loam	5.9	0.06	0.5	0.5	27	20
		C2	43-100	Sandy Loam	6.1	0.05	0.78	0.9	24	50
	Site 84 Cb	moss	7-0							0
		C	0-60	Ch clay Loam	6.3	0.04	0.58	0.6	31	50
Bedrock	Site 22 Bc	C	0-10	Ch loam						50+
		bedrock	10+	na						100
Fluvial	Site RO72 Fa	Om	25-0		6.4	0.30		0.1	265	
		Cg	0-75	Loam	7.6	0.35		0.1	61	na
Morainal	Site 67 Ma	LFH	3-0							
		C1	0-29	Loam	5.8	0.06	<0.05	0.2	38	10
		C2	29-100	Ch Loam	6.7	0.04	<0.05	0.3	53	40-50
	Site LW2 Mb	LFH	3-0							
		Ahj	0-3	loam	na	na	na	na	na	<5
		Bm	3-12	Loam	5.8	0.16		0.3	56	<5
		BC	12-37	Silty Clay	6.2	0.20		0.1	48	<5
		C	37+							50+
Organic	Site LW65 Oaw	Om	0-40	Mesic peat	6.6	0.31		0.6		
		Cg	40-100	Clay Loam	6.5	0.16		0.9		27
Residual	Site 104 Rb	LF	3-0							
		Bm	0-20	Loam	5.8	0.07	1.1	0.3	35	10
		C	20-81	Ch Loam	6.2	0.10	8	0.2	44	20

1 – "a" indicates deeper soils with salvage depth of >75 cm; "b" indicates moderate salvage depth averaging 50 cm; "c" indicates shallow soils less than 20 cm.

2 – Ch – cherty

Overburden in the Cheviot area was also assessed in situ (from cores) for its potential use as a rootzone material. The Alberta Soils Advisory Committee (1987) guidelines were used to rank the quality of overburden as a subsoil. Salinity, lime (as calcium carbonate equivalent) content, water content at saturation, and reaction (pH) were the parameters that were measured and rated. Since these materials are known to be non-sodic, sodicity was not measured. Texture, rock and coarse fragment content, and moist consistence were not measured since these parameters cannot be extrapolated to eventual field conditions from lab measurements (Knapik et al. 1995).

Table 3 illustrates the quality rating and the results of the key quality parameters for three representative overburden samples (Knapik et al, 1995). Lime content, salinity, and water content at saturation rated good or fair quality for all samples analysed. The most limiting parameter was reaction (pH) as it rated as poor to unsuitable throughout all the samples measured. Over time, the exposure of rain and carbon dioxide results in a reduction of the pH in the overburden (Knapik et al, 1995).

Table 3: Ratings of crushed & ground overburden samples for quality as root zone material

Location/ Depth (m)	Material	Sat. Water (%)	Sat. Rating	pHp[1]	pHp Rating	ECe[2] (dS/m)	ECe Rating	CaCO (%)	CaCO Rating	Most Limiting
63+01 R3901										
0-10	till/ss/sh	31	Good	7.4	Fair-good	0.6	Good	2.4	Fair	F(pH,CaCO)
13-27	si/ss	36	Good	8.4	Poor-fair	0.5	Good	5.4	Fair	P(pH)
27-41	ss	30	Good	8.7	Poor	0.4	Good	7.3	Fair	P(pH)
41-54	ss	24	Fair	8.7	Poor	0.4	Good	11.3	Fair	P(pH)
71-76	ss	24	Fair	8.7	Poor	0.5	Good	5.8	Fair	P(pH)
146+96 R615										
0-6	till/ss	29	Fair	8	Poor-fair	0.3	Good	1.2	Good	P(pH)
20-29	sh/ss	28	Fair	8.4	Poor-fair	0.4	Good	5.5	Fair	P(pH)
43-55	ss	33	Good	8.6	Poor	0.7	Good	6.7	Fair	P(pH)
70-85	ss	24	Fair	9.2	Unsuitable	1.3	Good	4.4	Fair	U(pH)
110-125	ss	26	Fair	9.2	Unsuitable	1.3	Good	7.7	Fair	U(pH)
183+02 L1422										
0-9	till/ss	31	Good	7.6	Poor-fair	0.4	Good	0.6	Good	P(pH)
25-40	ss	36	Good	8.5	Poor	0.6	Good	12.5	Fair	P(pH)
55-70	si	26	Fair	9.1	Unsuitable	1.6	Good	10.2	Fair	U(pH)
85-100	ss/sh/c	31	Good	8	Poor-fair	3.2	Fair	7.1	Fair	P(pH)
130-139	ss	30	Good	8.5	Poor	0.8	Good	7.7	Fair	P(pH)

Sh – shale, ss – sandstone, si – siltstone, till – glacial till, c – coal

3.2 Coversoil salvage

Coversoil salvage is conducted as a single-lift operation to recover all salvageable suitable soil materials prior to mining disturbance. Suitable material for reclamation purposes includes the organic layer, A and B horizons found in colluvial, morainal, organic and fluvial landscapes. In the upper subalpine region that we operate in, trees are usually too short to be salvaged commercially, so they are felled, cut into smaller sections and salvaged with the soil. The resulting soil has large woody debris including stumps, stems and branches that form a significant component of the reclaimed soil surface. The surficial organic layer (LFH, LF or organic Om), if present, is also incorporated into the mix. The mixing of these soil layers during salvage and stockpiling/placement initially changes some characteristics of the soils (Taylor and Knapik, 1995; Neufeld et al, 2010) – pH tends to increase by 1-2 units, and texture tends to moderate towards loam, particularly soils with high water content soils. Firm consistence also tends to decrease through this mixing process.

Depth of salvage is determined by pre-disturbance soil mapping. The soil survey identifies the soil types as well as providing recommendations for salvage. Suitability of soil material is rated as Good, Fair, Poor or Unsuitable based on criteria of depth, stoniness, reaction (pH) and organic matter content. (ASAC, 1987). Salvage depth generally varies from 25 to 50 cm but is occasionally as much as 80 to 90 cm in areas of accumulated organic materials. Similarly, it may occur in a thin veneer over consolidated rock.

Soil is salvaged to the recommended depth with dozers that push the soil into windrows. The equipment operator is given an expectation of the type of soil material to be salvaged and a general understanding of the salvage depth based on the visual qualities of the soil during the activity. Steep slopes (i.e. greater than 23 degrees), wet conditions, coarse fragment content and previous disturbances limit soil salvage feasibility. The soil is loaded into trucks and either hauled to a stockpiling site or directly placed. Direct placement of soil is the preferred option but can only be completed if pit sequencing can permit reclamation to proceed prior to the completion of soil salvage operations.

3.3 Soil placement

Our regulatory approval under the Environmental Protection Enhancement Act (EPEA) requires that all re-contoured lands receive a minimum average of 30 cm of coversoil, either from stockpile or from direct placement operations. Sufficient "regolith" must also be available to ensure a minimum of 10 cm of suitable subsoil, exists on reclaimed surface prior to the placement of coversoil. "Suitable" is defined as Good, Fair or Poor as per ASAC, 1987. The resloped surface generally consists of weathered fines that meet these criteria, so selective salvage and storage of regolith has not been conducted at the Cheviot mine. At the Luscar mine, where sufficient soil volumes may not be available and where subsoil conditions are not suitable, CRO selectively handles better-quality regolith to ensure sufficient capping.

CRO has developed and implemented a soil placement technique referred to as rough mounding. With this method, soil is hauled to the reclamation site with trucks and dumped along the edge of the site (on flat, accessible ground, the soil is dumped throughout the site). A dozer then pushes a bladeful of soil to the far edge of the site, leaving the bladeful as a mound. The dozer then retreats to retrieve another bladeful, pushing that up to the last bladeful. The dozer continues this process until the entire site is covered with small piles of soil. The dozer never drives on top of any placed soil. The result of this operation is a rough, mounded surface with minimal soil compaction. Coversoil thickness over a distance of 3 m varies from 5 to 60 cm with a median thickness of at least 30 cm. This practice provides abundant micro-relief (30-60 cm from top of mound to bottom of depression), offering shelter and moisture retention for re-establishing vegetation. The rough mounding method has also proven to be an effective means for controlling erosion and increasing biodiversity.

CRO is currently discussing potential refinement of soil salvage and placement with provincial regulatory agencies. "Shallow salvage" emphasises the salvage of organic, A and upper B horizons and results in higher quality soil than deeper salvage, but results in a thinner available replacement cap than the current 30 cm condition. Selective conservation of regolith is an option but based on data from our subsoil monitoring programmes, the difference between weathered overburden and regolith does not warrant selective handing of regolith in most situations. The segregation of organic and upland soils during salvage is an option but in CRO's area there are few organic soils (less than 5% of the disturbance footprint) and the reclaimed landscape is typically well drained and lacks opportunities for organic soil development. CRO is unsure of the benefit and practicality of this technique in our site-specific conditions for the following reasons:

The placement of soil in two thinner lifts would increase the likelihood of soil compaction, particularly in the lower lift;

The placement of soil in two thinner lifts would prevent the implementation of rough-mounding, which we believe is extremely important in providing micro-site diversity and in avoiding soil compaction;

If rough mounding cannot be practiced, we will have to use fast-establishing grasses for wind/water erosion control, and these would tend to interfere with natural recovery objectives;

If the upper lift is primarily organic, it will more likely either dry out or, through poor carbon/nitrogen balance, otherwise limit the establishment of vegetation. We would expect that much of the organic matter would simply blow off of any placement sites that are exposed to wind and deposited in adjacent areas.

Rough-mounding ensures a range in soil placement depths which is more similar to native soil conditions than the placement of soil in two lifts.

The salvage of thin layers in the relatively extreme terrain of the upper foothills presents limitations to consistency in soil salvage quality.

It is expected that further study will be conducted to support this review process.

4 Outcomes of soil conservation practices

Reclamation monitoring programmes have been conducted at the Luscar and Cheviot mines over the past 40 years, including the past 10 years when rough-mounding has been practiced consistently. Side-by side comparisons of rough-mounding and standard soil placement have not yet been conducted where all variables have been controlled, but the monitoring conducted to date provides support for CRO's soils handling practices.

4.1 Soil assessment results

In the most recent soils assessment conducted on reclaimed lands at the Cheviot and Luscar mines (Boorman and Leskiw, 2011), results indicate that CRO's soil conservation practices are achieving satisfactory results. In this latest assessment, conducted on sites that had been reclaimed in the past 3 years, all sites had been rough-mounded and the results are summarised in Table 5 and 6.

The study area is defined by three main types of reclamation materials. The "surface soil" is the uppermost layer which contains salvaged soil from the upper soil profile (surface to 60 cm), the "regolith" is the unconsolidated mantle of weathered rock and material that is above the solid rock, and the "spoil" is the material below the regolith and above the coal deposits.

Table 5: Ranges of soil quality parameters for surface soil, regolith and spoil

	Surface Soil	Average	Regolith	Average	Spoil	Average
pH	Fair to poor	7.33	Fair to poor	7.55	Fair to poor	7.46
EC	Good	0.33 dS/m	Good	0.28 dS/m	Good	0.35 dS/m
SAR	Good	0.5	Good	1.6	Good	1.4
SAT%	Good	42.3%	Good to fair	33.6%	Good to fair	38.1%
Coarse Frag. (%Vol.)	Good	8%	Good to fair	10%	Good to fair	18%
Texture	Good	L-SCL	Good	SL	Good to poor	SCL-CL
Moist Consistence	Good	FR	Good	FR	Good	F
CaCO	Good to fair	1.4	Good	1.2	Good to fair	1.1
TOC	Good	4.1%	Good to fair	3.2%	n/a	n/a
TKN	fair	1361 mg/kg	Fair to poor	874 mg/kg	n/a	n/a

A collection of comments on the combination of woody material incorporation and rough-mounding technique from soils and vegetation assessments conducted over the past 15 years (Boorman and Leskiw, 2011, Knapik et al 1995) are provided below:

The topsoil is not compacted but rather is allowed to settle, producing an ideal soil bulk density for rooting, with rapid water entry and almost no run-off or erosion;

The relief provides shelter form wind, collects and holds snow during Chinook wind episodes, and utilises more snowmelt moisture than does "dump and level" soil placement;

The slash and debris tends to remain on the surface, providing additional cover and vegetative structure. Potential concerns with carbon/nitrogen balance are not being observed, perhaps due to the large piece size of the woody material and/or the slow decomposition rate;

The median thickness of 30 cm provides sufficient water-holding capacity to withstand all but the most prolonged (and exceptional) drought episodes in this area;

Near-surface soil temperatures in newly seeded minesoils are lower on hot summer days due to roughness and debris cover. This may be critical for woody species seedling survival until plant cover is established.

4.2 Vegetation assessment results

Monitoring and research assessments made at the Luscar and Cheviot mines are indicating that rough mounding is a preferred reclamation practice for native species establishment but the results are very preliminary in developing a vegetative trajectory. There have not been a sufficient number of side-by-side comparison tests to be able to draw direct comparisons between rough-mounding and "dump and level" methods. But many observations have been made and a summary of these is provided below:

Rough mounding provides better plant establishment and growth and more native plant diversity than traditional "dump and level" placement (Walker, 2005);

This technique provides numerous microsites for planting tree seedlings and encourages invasion which provides diversity and opportunities for native species ingress (Knapik et al 1995);

The inherent erosion control offered by this technique means that there is less need for a fast-establishing grass-legume mix, resulting in even greater opportunities for native species ingress (C. Brinker, pers.comm.. 2008);

The amelioration in surface soil temperatures offered by this method may be critical for seedling survival until a fuller plant cover has become established (Knapik et al, 1995);

Floristic diversity was considered to be relatively high on the Luscar reclaimed sites (96 different species in 32 transects) compared to other mines, and the primary difference in reclamation approaches between these mines was the use of rough mounding (Strong, 1999).

Rough mounded soils had greater densities of woody stems than those with a smooth surface (Strong, 1999).

As noted above, the use of the rough mounding technique provides a greater degree of freedom in choosing vegetation mixes, as erosion control does not have to be a prime concern. Despite an approved revegetation plan prescribing seeding species, through in-field practice, observation, dialogue and early research, we have continued to modify our seed mix, application rates, and timing. Our two seed mixes used at the Cheviot mine emphasise native species to improve the native ingress and maximise tree establishment. Seed mixes continue to be carefully reviewed as new research becomes available.

The "natural recovery" mix is designed to be seeded at a rate that allows the establishment of woody species while permitting the longer term establishment of higher-value forage cover. A nurse crop of annual ryegrass addresses minor short-term erosion control and surface protection and a low initial composition of native and agronomic forage species will permit the establishment of woody plants and native forbs, while also establishing a lower-density forage cover. The sites where this mix would be used include mid-slope and lower slope positions where an open forest community is desired.

The "grasslands" mix is designed to provide short-term erosion control as well as longer-term forage for wildlife. This mix is used on sites that are most exposed to wind and sun (westerly and southerly aspects), primarily in upper slope and crest positions, as well as on the steepest parts of the landscape (terraced cliffs, talus slopes and escarpments). Annual ryegrass and sweet clover serve as short-term cover and a mix of legumes and native/agronomic grasses provide a longer term forage cover. None of these species are aggressive or invasive, and the seed rate and species composition is designed such that openings in the ground cover will be available for native species ingress and colonization. Given the extreme winds that are experienced on west-facing upper slope positions in the project area, it is expected that a quickly establishing mix such as this one is necessary to protect the soil resource.

Incidentally, in 2007 through CRO's research initiative, a newly reclaimed rough-mounded site was tree planted but otherwise left without any application of seed in an attempt to encourage native re-establishment. The rationale for this trial was to reduce competition with tree plantings, while at the same time avoiding attracting ungulates to the area which can result in heavy losses to the planted trees. Preliminary findings in the monitoring programme indicate the following: a notable difference in tree establishment between north and south facing slopes, with greater success on north facing slopes. Further observations include: total vegetation cover ranges from 15 – 23% (after year 2); species composition ranges from a count of 20 – 24 species (mainly in the form of native herbaceous and graminoid cover); and only minor surficial soil erosion. It is premature at this stage to make any long-term predictions, goals or targets but with further trials, these revegetation results are encouraging and support values of re-establishing natural ecological processes.

5 Conclusions

Rough mounding of the topsoil, together with an emphasis on the incorporation of coarse woody slash, stumps, roots and seeds, provides and encourages significant surface cover, roughness and sources of native seed required for natural revegetation of the reclaimed areas. This "kick-starting" of key soil development functions (structural development, building of organic pools, establishing biotic populations, and adequate porosity) is essential to achieving our reclamation objectives. There are still a number of external factors that will need to be taken into consideration over the next few years in order to determine the overall success of rough mounding as a practical reclamation procedure. Factors such as:

- Harsh seasonal weather conditions and slow growing seasons continue to make tree seedling establishment difficult
- Wildlife browse
- The presence of agricultural (planted) species may limit the success of native species establishment. This applies in particular to the Luscar mine, where agronomic species have been used since reclamation started in 1970.
- Demand for increased reclamation performance towards end land use goals, especially temporal
- How to measure reclamation success at various stages (i.e. 5, 10 and +20 year intervals)

Although we are in the preliminary stages of researching the benefits of rough mounding, the results look promising. Further assessments will be undertaken to monitor the factors beyond reclamation prescriptions, such as climate and wildlife use.

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