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Evaluation of reclamation success in Alberta's oil sands

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Abstract

Suncor Energy Inc.'s Reclamation Area #8 (RA8) is an overburden disposal area containing lean oil sands and an average of 3% hydrocarbons. RA8 was reclaimed to an upland ecosite over several stages starting in 1979 and continuing in 1984, 1987 and 1990. Annual monitoring of the site was conducted from 1979 through to 2008. As a result, RA8 is one of the few sites in the Oil Sands Region that provides an example of long-term reclamation performance. Although each portion of the area was reclaimed according to the standards of the day, valuable information is provided on the long-term performance of reclamation using a variety of different preparation and planting strategies. Reclamation approaches included relieving compaction on berms; a peat-mineral reclamation soil cap; breaking up the surface to improve the seedbed; controlling erosion with the planting of annual barley; applying fertiliser and afforestation. Percent cover by species, vegetation height, litter cover and soil samples were evaluated throughout the reclaimed areas. Meteorological monitoring was added to the program in 2004. The results indicate that advanced reclamation is successful at RA8. Six of eleven dominant species found in the area are comparable to those found in the low-bush cranberry aspen-white spruce (d2) ecosite phase. Tree and shrub cover increased following reclamation, with shrub cover reaching a plateau after nine years. Second generation spruce seedlings have established on the site. Forbs established on the site through the soil seed bank or through natural ingress. Grass and forb cover decreased as tree and shrub cover increased. Moss has also established on the site. Traditional use species are present and those planted during initial reclamation have remained. Moderately high carbon to nitrogen ratios and high cation exchange capacity were observed in the upper 15 cm of soil and were likely a result of the organic matter additions in the peat mineral mix.

1 Introduction

Suncor's Oil Sands Base Mine is located within the Regional Municipality of Wood Buffalo (RMWB) where bitumen is extracted from the Athabasca oil sands deposit. Operations include open pit mining, extraction processes and upgrading to provide a variety of refinery feedstocks and diesel fuels. Reclamation Area #8 (RA8) is an overburden disposal area containing an average of 3% hydrocarbons located adjacent to undisturbed natural riparian areas along the Athabasca River. RA8 was reclaimed to an upland plant community over several stages starting in 1979 and continuing in 1984, 1987 and 1990. Annual monitoring of the site was conducted from 1979 through to 2008. As a result, RA8 is one of the few sites in the Oil Sands Region that provides an example of long-term reclamation performance. Although each portion of the area was reclaimed according to the standards of the day, valuable information is provided on the long-term performance of reclamation using a variety of preparation and planting strategies.

The purpose of this monitoring program was to determine the effectiveness of different reclamation techniques and provide information to adaptively manage reclamation on the site allowing for improvements where required. The purpose of this paper is to explore the long-term trends in vegetation development on an oil sands reclamation area and to assess the feasibility of developing reclaimed ecosystems with composition and structure that is analogous to natural ecosystems in the area.

2 Methods

RA8 is a terraced landform with an average slope of about 3:1. The substrate at the surface of the structure is a sandy loam to sandy clay loam overburden. RA8 was reclaimed in four separate years using a different set of treatments for each area. The basic reclamation techniques, detailed in Table 1, were in compliance with the regulatory approval conditions of the day and were considered best practice at that time.

There are four zones within RA8, including sites 12, 34, 41 and 49. Site 12 was reclaimed in 1979 and is only 0.5 ha in size. Site 34, which was reclaimed in 1984, contains vegetation monitoring transects 1, 2, 3 and 4. Site 41, which was reclaimed in 1987, contains vegetation transects 5, 6, 7 and 8. Site 49, which was reclaimed in 1990, contains transect 9 (Figure 1).

Figure 1 Vegetation monitoring transect locations on Reclamation Area 8

Reclamation strategies included relieving compaction on terraces to aid in root penetration, direct placement of a peat-mineral cap, breaking up and improving the seedbed, applying barley as a nursery crop to control erosion, fertiliser application and afforestation.

Prior to placement of the peat-mineral cap, the terrace was ripped (in 1987 and possibly other years) with a ripper bar attached to a grader or dozer. The peat-mineral cap was placed, which contained about 3% hydrocarbons by weight. Seedbeds were prepared with a klodbuster, harrow and/or chisel plow. Fertiliser was applied by helicopter and incorporated into the seedbed at a rate between 100 to 300 kg/ha annually or twice annually, usually in the late spring, for two to five of the initial revegetation years. Fertiliser levels range from: nitrogen 6 to 46%, phosphorus (P_2O_5) 0 to 30% and potassium (K_2O) 0 to 24% (Table 1).

Table 1 Reclamation techniques applied to Reclamation Area 8

Site	Year Reclaimed	Monitoring Transects	Hectares (ha)	Soil Type[3]	Treatments	Seeding	Fertilisation[2]	Afforestation (species: number of stems)
12	1979	n/a	0.5	15 cm peat-mineral mix	**1979** Hydroseeding	grass/legume mix[1]	**1979** 8-38-15 @ 200 kg/ha 6-24-24 @ 220 kg/ha **1980** 6-24-24 @ 225 kg/ha 6-24-24 @ 225 kg/ha	none
34	1984	1, 2, 3, 4	16.2	17 cm peat-mineral mix	**1984** Klodbuster, land imprinter, hydroseeding	barley (otel) @ 62 kg/ha; aerial application	**1984** 10-30-10 @ 225 kg/ha **1985** 10-30-10 @ 100 kg/ha 34-0-0 @ 100 kg/ha **1987** 34-0-0 @ 100 kg/ha 10-30-10 @ 100 kg/ha **1988** 34-0-0 @ 200 kg/ha 10-30-10 @ 100 kg/ha	**September 1984** white spruce:15,610 pine: 10,266 poplar: 9,052 willow: 4,860 dogwood: 4,310 rose: 3,887 buffaloberry: 2,669 wolf willow: 210 saskatoon: 526
41	1987	5, 6, 7, 8	21.7	21 cm peat-mineral mix	**1987** chisel plow, klodbuster	barley (Jackson) @ 62 kg/ha; aerial application	**1987** 32-16-5 @ 200 kg/ha **1988** 32-16-5 @ 200 kg/ha 23-25-8 @ 300 kg/ha **1989** 6-24-24 @ 100 kg/ha 34-17-0 @ 200 kg/ha	**September 1987** white spruce: 39,666 northwest poplar: 6,811 lodgepole pine: 5,292 rose: 3,850 dogwood: 3,780 buffaloberry: 935 saskatoon: 3,040 sandbar willow: 4,370
49	1990	9	7.2	24 cm peat-mineral mix	**1990** harrowed	barley (Jackson) @ 62 kg/ha	**1990** 25-12-16 @ 280 kg/ha 46-0-0 @ 145 kg/ha **1991** 18-16-16 @ 685 kg/ha **1992** 8-24-24 @ 425 kg/ha **1993** 20-10-10 @ 400 kg/ha	**September 1990** white spruce: 23,713

[1] grass/legume mix consisted of grass @ 60 kg/ha (25% Northern wheatgrass; 15% Red top; 30% Violet wheatgrass; 30% Creeping red fescue) and legumes @ 30 kg/ha (60% Alfalfa; 40% White Dutch Clover). [2] Fertiliser blends shown as % by weight, Nitrogen-Phosphorus (P_2O_5) –Potassium (K_2O). [3] Peat-mineral mix contains moss and sedge peat and about 40% by volume of sandy overburden substrate. Information from Klym and Shopik (1980), Suncor (1985), Suncor (1988) and Suncor (2009).

Afforestation was carried out using a variety of trees and shrubs including white spruce (*Picea glauca*), lodgepole pine (*Pinus contorta*), poplar (*Populus* spp.), Northwest poplar (*Populus deltoides* x *Populus balsamifera*), willow (*Salix* spp.), dogwood (*Cornus stolonifera* (*sericea*)), rose (*Rosa* spp.), buffaloberry (*Shepherdia canadensis*), wolf willow (*Eleagnus angustifolia*) and saskatoon (*Amelanchier alnifolia*) at approximately 3,000 stems/ha. Site 49 (Transect 9) is one exception as the only woody seedlings planted were white spruce. Stock was reared from seed and cuttings collected locally and grown at the Reid Collins nursery in Aldergrove, BC or the nursery in Joffre, AB. All reclamation planting was conducted in September of the initial reclamation year.

A total of nine transects were monitored after reclamation. Each 30 m long transect, is positioned at mid-slope and runs parallel to the contours of the slope. During monitoring ten 0.1 m^2 quadrats were systematically placed along each transect. Average percent living cover (by individual species) and dead plant cover (litter) were estimated within each quadrat. Mean percent cover was observed for each vegetation component (e.g. vascular invaders, shrubs and trees), with mean total cover values calculated from these estimates. On sites where vegetation cover is taller than the monitors, percent cover was estimated using an aerial projection above the tallest species down through the canopy to determine cover within the quadrat. Vegetation height data was also collected. In 2008, moss cover was included in total cover estimates as moss is becoming a greater component of total cover as reclaimed areas age. The presence of moss in the ground cover may be an indication of changing soil acidity, which may result in future change to the vegetation cover (AMEC Earth and Environmental, 2009).

Soil samples were collected in the peat-mineral layer (0 to 20 cm depth) and the underlying substrate (approximately 20 to 50 cm depth) at a minimum of three locations along each transect. The soil samples were combined to obtain one composite sample per transect. In some cases, soils from two or more transects on areas reclaimed the same year were mixed prior to analyses.

A meteorological station (rainfall, snowfall and air temperature) and triplicate arrays of Diviner access tubes (soil temperature and soil moisture at multiple depths) were installed in 2004 and monitored. Total annual precipitation at RA8 in 2008 was 325 mm with 253 mm of that occurring in the growing season (May to August). Annual mean temperature was 1.0 to 1.7°C with a mean growing season temperature of 15.8°C. One long-term Cumulative Environmental Management Association (CEMA) soil and vegetation monitoring plot was established 2005 on Site 34. The CEMA long term monitoring plots were established in reclaimed areas as well as in undisturbed stands to monitor the development of reclaimed areas in the Oil Sands Region and to compare reclamation progress with surrounding natural ecosystems (OSSVWG, 2006).

3 Data

The percent cover by species for the 2008 monitoring season is shown in Table 2. The soil characteristics of samples collected on RA8 are detailed in Tables 3a and 3b.

Table 2 Mean percentage vegetation cover in August 2008 at reclaimed overburden sites on Reclamation Area 8 seeded to barley in 1984, 1987 and 1990 (From AMEC Earth and Environmental, 2009)

Cover Type	Year Reclaimed								
	1984						1987		1990
	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5	Transect 6	Transect 7	Transect 8	Transect 9
Non-seeded Species									
Aster	0.3	0.0	0.0	2.7	0.0	0.0	0.0	2.1	0.6
Bedstraw	1.4	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.2
Dandelion	0.6	1.2	2.3	3.3	2.3	2.1	0.0	0.0	1.3
Fireweed	0.0	2.4	0.3	3.7	8.6	2.4	1.1	0.0	2.0
Goldenrod	1.4	0.0	1.4	4.5	0.0	0.0	0.0	0.0	0.8
Horsetail	0.0	0.0	0.0	0.0	14.4	0.0	0.0	0.3	1.6
Peavine	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0

Cover Type	Year Reclaimed								
	1984						1987		1990
	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5	Transect 6	Transect 7	Transect 8	Transect 9
Petasites	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.1
Sedge	0.3	0.6	0.0	0.0	0.6	0.3	21.8	4.4	3.0
Solomon's Seal	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.3
Sow Thistle	14.8	0.0	0.3	6.2	2.4	2.4	4.0	5.2	3.9
Strawberry	0.0	19.2	0.6	4.7	21.7	6.9	8.2	16.3	8.6
Vetch	2.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3
Wintergreen	1.1	0.0	0.0	0.0	0.0	0.3	5.1	0.3	0.7
Yarrow	0.3	0.6	0.3	0.3	0.6	0.0	1.7	0.6	0.5
Subtotal	*22.2*	*24.0*	*5.7*	*25.3*	*53.8*	*14.3*	*41.7*	*29.2*	*24.0*
Seeded Species									
Marsh Reed Grass	2.0	0.3	0.0	0.3	0.0	1.1	0.0	0.0	0.4
Sweet Clover	0.0	0.6	1.4	0.9	0.0	0.0	4.3	0.0	0.8
Wheatgrass	0.0	1.2	0.6	3.9	0.3	1.4	0.0	4.5	1.3
Subtotal	*2.0*	*2.1*	*2.0*	*5.1*	*0.3*	*2.4*	*4.3*	*4.5*	*2.5*
Shrubs									
Blueberry	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.2
Dogwood	11.2	3.4	16.2	6.6	6.3	0.0	4.4	6.2	6.0
Raspberry	29.2	0.0	0.0	0.0	0.6	14.1	0.0	15.4	6.6
Rose	6.2	7.8	0.3	0.0	13.8	0.0	0.3	0.0	3.1
Saskatoon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.2
Willow	3.1	0.3	1.1	5.8	17.1	36.3	8.2	11.0	9.2
Subtotal	*49.6*	*11.5*	*17.5*	*12.4*	*39.8*	*50.3*	*12.9*	*34.6*	*25.4*
Trees									
Aspen	30.8	33.3	0.0	16.0	6.2	46.1	2.4	27.9	18.1
Aspen seedlings	0.0	0.0	1.1	1.1	0.0	0.0	0.3	0.0	0.3
Balsam poplar seedlings	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.1
Jack pine	10.9	17.9	18.2	13.2	0.0	2.1	0.0	0.0	6.9
Poplar	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5
Willow seedlings	0.0	2.1	0.0	7.2	0.3	0.0	7.7	1.4	2.1
Spruce	28.5	23.9	20.2	11.9	23.3	26.4	32.3	27.5	21.5
White birch	0.0	3.1	0.0	0.0	0.0	3.8	0.0	0.0	0.8
White spruce seedlings	0.0	0.0	10.2	0.0	0.0	0.0	0.0	0.0	1.1
Subtotal	*73.9*	*80.3*	*49.6*	*49.4*	*30.1*	*78.7*	*42.6*	*57.0*	*51.3*
Total Living Vascular Cover	**146.2**	**115.8**	**62.2**	**80.0**	**123.3**	**145.3**	**93.5**	**123.8**	**51.9**
Moss	0.3	11.8	22.0	10.3	9.0	5.3	3.0	4.7	7.4
Litter	88.0	83.0	61.0	75.3	83.0	88.0	85.5	85.5	72.1
Total Cover	**234.5**	**210.6**	**145.2**	**165.5**	**215.3**	**238.6**	**182.0**	**214.0**	**131.4**

Table 3a Soil chemistry of surface and subsoil samples collected in 2008 at Reclamation Area 8 (adapted from AMEC Earth and Environmental, 2009)

Transect	Sample Depth (cm)	pH	EC (mS/cm)	Available Nutrients				Total Nutrients (%)		Bitumen (oil and grease)	
				NO_3-N (ppm)	P (ppm)	K (ppm)	SO_4-S (ppm)	C	N	ppm	%
1,2,3,4	0 to 20	7.22	2.252	0.8	1.7	94.0	299.0	8.3	0.29	21,100	2.11
5,6,7,8	0 to 20	7.37	1.159	0.8	3.2	101.8	147.4	9.4	0.36	10,538	1.05
9	0 to 20	7.42	0.620	0.9	0.9	79.9	15.9	4.2	0.14	10,900	1.09
1,2,3,4	20 to 50	7.28	2.805	-	-	-	-	5.6	-	29,120	2.91
5,6,7,8	20 to 50	7.50	1.719	-	-	-	-	5.2	-	27,550	2.76
9	20 to 50	7.52	0.321	-	-	-	-	4.4	-	10,800	1.08

"-" = not available.

Table 3b Soil chemistry of surface and subsoil samples collected in 2008 at Reclamation Area 8 (adapted from AMEC Earth and Environmental, 2009)

Transect	Soluble Cations								SAR	Saturation (%)
	Ca++		Mg++		K+		Na+			
	meq/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg		
1,2,3,4	9.32	177.82	5.71	67.20	0.60	22.58	15.52	346.40	5.18	96.8
5,6,7,8	5.80	149.80	2.84	43.28	0.40	22.32	15.70	118.35	2.35	140.2
9	5.43	52.20	1.46	8.50	0.25	4.59	0.50	5.53	0.27	48.0
1,2,3,4	13.74	142.78	7.12	44.85	0.61	12.42	17.00	200.75	5.55	52.5
5,6,7,8	5.88	74.68	3.00	23.18	0.44	11.49	12.33	189.15	5.67	65.5
9	2.65	40.50	0.73	6.79	0.07	2.19	0.36	6.25	0.28	76.1

"-" = not available.

4 Results

4.1 Vegetation

RA8 is a good example of advanced reclamation at Suncor. RA8 contains different microsites including small wetlands and shrubland areas. However, the majority of the vegetation composition is characteristic of the low-bush cranberry aspen-white spruce (d2) ecosite phase as described in the Field Guide to Ecosites of Northern Alberta (Beckingham and Archibald, 1996). The boreal mixedwood d2 ecosite phase is characterised by a mesic moisture regime and medium nutrient levels. This ecosite is commonly found on midslope, upper slope, crest and level areas and on all aspects. The dominant tree species are aspen and white spruce, the dominant shrubs are low-bush cranberry and prickly rose and the dominant forb is bunchberry (*Cornus canadensis*) (Beckingham and Archibald, 1996).

Among the dominant species on site (i.e. mean cover greater than 1%), six of eleven species are commonly found on the d2 ecosite phase (aspen, white spruce, rose, saskatoon, raspberry and fireweed). The other five dominant species on RA8 that are not commonly found on the d2 ecosite phase (e.g. strawberry and dandelion) may be reflective of the young succession stage of the site, variability in moisture conditions (e.g. sedge and horsetail), or species that were directly planted at the time of initial reclamation (e.g. dogwood). Common species of the d2 ecosite phase that are not present on RA8 include balsam fir, black spruce, low-bush cranberry, twin-flower, Canada buffaloberry, bunch berry, wild sarsaparilla and dewberry.

Tree cover has increased steadily since the initial years of establishment. Tree cover in 2008 (18 to 24 years after reclamation) ranged between 30 and 80% (mean cover: 57%). The total number of tree species in 2008 ranged between three and seven species (mean number: four species), which is slightly higher than the

number of tree species planted during the initial reclamation years (mean number: three species). White spruce and aspen were found to be the dominant tree species present (mean cover: 24 and 20%, respectively) (AMEC Earth and Environmental, 2009). Second generation spruce seedlings have established on RA8 and balsam fir (*Abies balsamea*) has begun to naturally ingress onto the site.

Shrub cover increased steadily in the first six to nine years following reclamation, levelling off thereafter to percentages observed in 2008, which ranged between 12 and 50% (mean cover: 28%). However, it took over 15 years in Transect 9 before shrub cover reached similar levels. The total number of shrubs 13 to 19 years after reclamation ranged between two and six species (mean number: four species), which is comparable to the number of shrub species planted during the initial reclamation years. Willow, dogwood and raspberry were the dominant shrub species present (AMEC Earth and Environmental, 2009).

Forb cover decreased from establishment to 18 to 24 years after reclamation. The peak in forb cover occurred one to four years following initial reclamation. This downward trend may be related to increases in tree and shrub cover over this same period. Forb cover in 2008 ranged between 6 and 54% (mean cover: 27%). The total number of forbs in 2008 ranged between five and fourteen species (mean number: eight species). The highest numbers of forbs were observed along Transect 9. As RA8 was not seeded with forbs, these species have originated either through natural regeneration from the soil seed bank and propagules, or through natural invasion. Strawberry was the dominant forb species present in a majority of transects (mean cover: 10%). Other forbs with greater than 1% mean cover included sow thistle, sedge, fireweed, horsetail and dandelion (AMEC Earth and Environmental, 2009).

Grass cover decreased over time, although some fluctuations in grass cover have occurred. In 2008, grass cover was considerably lower than forb cover. Grass cover in 2008 ranged between <1 and 5% (mean cover: 3%). The reduction in grass cover can be viewed positively since high grass cover can have a negative impact on the establishment of woody and forb plant species. The use of barley as a cover crop, rather than more aggressive and competitive agronomic grass species and legumes used for revegetation and erosion control purposes during the 1970s, represents a positive change in Suncor's reclamation practices (AMEC Earth and Environmental, 2009).

Moss cover in 2008 ranged between <1 and 12% (mean cover: 8%) (AMEC Earth and Environmental, 2009). Moss species were not planted and have established naturally, suggesting forest succession is occurring.

One noxious weed, Sow thistle (perennial sow thistle (Sonchus arvensis)), was recorded in eight of the nine transects in 2008 and ranged between 0 and 15% cover (mean cover: 4%). Sow thistle has decreased substantially since 1990 when average cover was 16% (AMEC Earth and Environmental, 2009).

Several important traditional use species were documented. A majority of these species including dogwood, raspberry, rose and saskatoon were planted at the time of initial reclamation in 1984 and 1987 and have remained on site since that time. On Transect 9, the same traditional use shrubs are now present, but were not planted (mean cover: 4%). Blueberry was not planted during initial reclamation, but in 2008 it was observed along two transects with low cover ranging between <1% and 2% cover. Strawberry was observed in eight of the nine transects in 2008 with cover ranging between 0 and 21% (mean cover: 10%) (AMEC Earth and Environmental, 2009).

4.2 Soil

Surface soil reaction was strongly acidic (pH 5.4) to mildly alkaline (pH 7.5) and this changed very little over time. Soil salinity, as measured by electrical conductivity (EC), was very low (EC: <2 mS/cm) to low (EC: 2 to 4 mS/cm). One area had moderately high EC values (EC: 4.4 to 4.6 mS/cm). Electrical conductivity values did not change significantly over time. Soil sodicity, as measured by sodium adsorption ratio (SAR) was generally low (SAR: <8) with the exception of two areas that had moderately high SAR values (SAR: >8). One of the areas with a high SAR value also had a moderately high EC value suggesting marine Clearwater Formation content. There was a slight decrease in SAR values for these two areas over time, however, some of the areas with low SAR values fluctuated between years. It is unclear if the change in SAR values is a result of leaching or is a reflection of the variability in sampling (AMEC Earth and Environmental, 2009).

Organic carbon ranged from 9.2 to 15.6 % for the peat-mineral layer (upper 20 cm) and 2.8 to 5.3% for the underlying substrate (20 to 50 cm depth). Total nitrogen ranged between 0.26 and 0.69% for the peat-mineral layer and 0.04 and 0.08% for the underlying substrate. Carbon to nitrogen ratios ranged from 23 to 34 for the peat-mineral layer and 54 to 126 for the underlying substrate. The moderately high carbon to nitrogen ratio in the peat-mineral layer may be due to the organic matter additions in the peat-mineral mix. The high carbon to nitrogen ratios in the underlying substrate may be due to the subsoil bitumen content of 1.7 to 4.0% (mean: 3%). Available nitrogen fluctuates on a yearly basis with no apparent trends over time. This may be due to changes in soil moisture content or fertiliser additions on a year to year basis (AMEC Earth and Environmental, 2009).

Cation exchange capacity (CEC) ranged between 32 and 49 meq/100 g for the peat-mineral layer and 7 and 16 meq/100 g for the underlying substrate. The high CEC values in the peat-mineral layer are likely due to the high organic matter content of the peat-mineral mix (AMEC Earth and Environmental, 2009).

The average cover soil placement depth on RA8 was about 20 cm and the overburden substrate is rated as good or fair on all parameters according to *Soil Quality Criteria Relative to Disturbance and Reclamation* (AAFRD, 1987), except that it contained about 3% lean oil sands. Despite the elevated lean oil sands content, RA8 is able to support a diverse native plant community.

5 Conclusions

RA8 supports a functional, developing upland ecosystem that closely resembles the d2 ecosite phase described in Beckingham and Archibald (1996), which is one of the most common ecosite phases in the boreal mixedwood. The performance of this site indicates that it is possible to establish typical boreal forest ecosystems in the reclaimed environment. This site supports several species typical of natural boreal forest ecosystems as well as traditional use species, which are valued by aboriginal stakeholders in the region. Planted and naturally ingressed traditional use shrub species include dogwood, raspberry, rose and saskatoon. Blueberry was not planted, but has ingressed in low amounts.

Modern reclamation techniques are targeted toward the development of native ecosystems with planted species composition and distribution being more in line with analogous natural ecosites. Species composition is developing to a mixedwood forest ecosystem. It is likely that the composition and structure of this site will continue to develop into a community capable of supporting a diverse, functional population of vascular and non-vascular species, which will provide habitat for a variety of wildlife, insects and microorganisms.

Successful reclamation techniques included the use of direct placement of peat-mineral mix as a surface soil. The peat-mineral reclamation soil has soil characteristics conducive to plant establishment and growth and contributes natural seeds and propagules to the reclaimed landscape. The number of vegetation species that have appeared on the site, but were not planted, is an indicator of the effectiveness of this method. The use of annual barley as a cover crop provides erosion control without causing excessive competition with planted woody species and naturally ingressing forbs and shrubs. Die back material contributes to the organic layer at the surface of the soil and provides some protection from drying of the soil surface.

Soil conditions were less than ideal due to lean oil sands content of about 3% and higher than average salinity and sodicity in the subsoil. However, diverse, native vegetation communities have established with a 20 cm cover of reclamation material despite these shortcomings.

Recommendations for future reclamation projects include the use of native vegetation species comparable with analogous natural ecosites, continued use of peat-mineral mix as a reclamation substrate and direct placement of reclamation substrates where ever possible. Future research topics for this and other similar sites could include studying the relationship between vegetation development success and site characteristics such as aspect, slope position, hydrocarbon content, elevation, temperature and soil moisture.

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