RECLAMATION RESEARCH IN THE FOOTHILLS/MOUNTAINS REGION OF ALBERTA: A CASE STUDY[1]

Terry M. Macyk[2]

Abstract.--The Alberta Research Council has conducted a reclamation research program near Grande Cache, Alberta on behalf of Smoky River Coal Ltd. since 1972. The main objective of this on-going study is to develop effective methods of establishing and maintaining a vegetative cover that is in harmony with adjacent undisturbed areas. Soil handling and management were found to be critical to revegetation success. Characterization studies indicated that unmined soils are generally shallow, moderately to slightly acid, medium textured and contain low levels of available plant nutrients. Reconstructed soils are generally coarser textured, higher in pH and lower in available nutrients than unmined soils. Plot studies to determine the suitability and adaptability of various agronomic and and native grasses and legumes, as well as fertilization trials, were established. Conifer seed and seedlings, and cuttings of deciduous species were planted in the reconstructed soil areas following establishment of a grass and legume cover. Long term results indicate that agronomic species will thrive and reproduce at this elevation and that native species will invade the revegetated areas. The results obtained from the research effort to date have been successfully transferred to the operational scale. The success of reclamation in the area is measured by the productivity achieved and the presence of and utilization by wildlife.

INTRODUCTION

The Terrain Sciences Department of the Alberta Research Council has been conducting a reclamation research program in the Grande Cache area on behalf of Smoky River Coal since May 1972. When the Alberta Research Council (ARC) undertook the project, reclamation research was truly in its infancy in Alberta. Techniques employed elsewhere at the time, primarily in the United States, were not applicable to the Alberta situation. Furthermore, legislation pertinent to reclamation in Alberta was not formally in place until the Land Surface Conservation and Reclamation Act of 1973 and the Coal Policy of 1976. This paper provides a summary of the work undertaken and an assessment of the results obtained. Details pertinent to the various aspects of the study are documented in the progress reports prepared annually (see literature cited).

Setting

The operations of Smoky River Coal Ltd. are located approximately 150 km north of Jasper in the Rocky Mountain Foothills. The two major surface mining operations are the No. 8 and No. 9 Mine areas located adjacent to the Smoky River and Sheep Creek respectively. Elevations range from 1600 to 1800 m and the topography is steeply sloping. Climate can be considered one of the major limiting factors to revegetation success. For example, the frost-free period (>0°C) was 45 days in 1984 whereas the killing frost-free period (>-2.2C) was 94 days. Snow can occur in any month of the year and wind is a common phenomenon.

Objectives

The original objectives of the project were defined as follows. New ones were added as additional needs were identified.

1. characterize unmined and reconstructed soils and evaluate their suitability for reclamation purposes;
2. determine, by field testing, suitable grasses and legumes for establishment of a protective vegetation cover on reclaimed areas to minimize erosion;

---

[1] Paper presented at the 1985 National Meeting of the American Society for Surface Mining and Reclamation, Denver, Colorado, October 8-10, 1985.
[2] Terry M. Macyk is Associate Research Officer, Terrain Sciences Department, Alberta Research Council, Edmonton, Alberta, Canada.

Proceedings America Society of Mining and Reclamation, 1985 pp 13-17
DOI: 10.21000/JASMR85010013

https://doi.org/10.21000/JASMR85010013

3. determine, by field and laboratory testing, the nutrient requirements for maintaining a viable vegetative cover;
4. determine methods of establishing a long-term vegetative cover that is in harmony with adjacent, undisturbed areas.

MATERIALS AND METHODS

Coal production from the No. 8 Mine commenced in June, 1971. The research program that placed emphasis on soils and vegetation concerns began in May, 1972.

Pre-Mining Soils

A soil survey of that portion of the No. 8 Mine area that had not yet been disturbed by mining and the entire No. 9 Mine lease area indicated that the soils were dominantly Luvisolic and Brunisolic (Canada Soil Survey Committee 1978) with the depth of salvageable material overlying bedrock ranging from 10 cm to 1 m. Table 1 provides means and standard deviations for pH, particle size and available nutrients for samples collected at eight sites.

Table 1.--Analytical data for soils in the unmined setting

Depth	pH		Particle size (%)					
			Sand		Silt		Clay	
(cm)	Mean	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.
0-15	5.8	1.2	31	9	50	7	19	5
15-30	5.6	0.5	30	10	52	11	18	6
30-45	6.3	1.0	28	16	55	16	17	9
45-60	6.5	1.2	29	18	52	17	20	4

Depth	Available nutrients (Kg/ha)					
	Nitrogen		Phosphorus		Potassium	
(cm)	Mean	S.D.	Mean	S.D.	Mean	S.D.
0-15	0.8	0.7	32	27	186	134
15-30	0.6	0.7	13	13	18	135
30-45	0.6	0.7	13	12	12	41
45-60	0.5	0.5	8	7	103	28

*S.D. - Standard Deviation

The data indicate that the unmined soils are moderately to slightly acid, medium textured and have low levels of available plant nutrients, especially nitrogen and phosphorus.

Materials Handling Procedures

Soil salvage is an integral part of the materials handling program associated with the overall mining operation. Following the removal of merchantable timber, the soil overlying consolidated bedrock is removed in one lift in a manner such that a minimum amount of coarse fragments are incorporated. The soil materials are stockpiled for future use. Because the surface or organo-mineral horizons are minimal or nonexistent and the sola are quite variable in thickness, segregation or selective handling of soil materials is not considered.

Soil material is replaced on the spoil surface by scrapers or truck/caterpillar operations following the removal of overburden and coal and subsequent backfilling and grading. Scrapers tend to allow for a more uniform depth of soil replacement but they are limited by slope angle and they cause more severe compaction under moist conditions. Caterpillars are not as versatile as scrapers, however their tracks provide excellent seed germination sites.

Reconstructed (Post-Mining) Soils

The reconstructed soils that are developed do not duplicate the soils that existed prior to disturbance. The physical properties of the soils are the ones most drastically altered by the mining process.

Table 2 provides analytical data for the surface (0-15 cm) material of the reconstructed soils at three of the experimental sites established in the first year of the project.

Table 2.--Analytical data for the surface material (0-15 cm) of reconstructed soils

Area	pH		Particle size (%)					
			Sand		Silt		Clay	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
I	6.6	0.8	36	6	44	7	20	6
II	7.0	1.1	40	11	45	8	15	5
III	8.2	0.4	not determined					

Area	Available nutrients (Kg/ha)					
	Nitrogen		Phosphorus		Potassium	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
I	0.8	0.5	13	6	124	71
II	0.8	0.5	6	5	107	42
III	0.5	0.3	3	3	144	12

The data indicate that reconstructed soils are 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 results in a crusting problem which has 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.

These reconstructed soils have some limitations, however, with proper management they are invaluable in achieving reclamation success.

Vegetation Establishment

A specific end land use was not developed at the time the project was initiated, however, the overall goal was and continues to be the establishment of a long-term self sustaining cover that is in harmony with the adjacent undisturbed area. Erosion control was one of the initial considerations relative to establishment of a plant cover. This was to be followed by re-establishment of a forest cover with some capability for wildlife use.

The vegetation work was initiated in May, 1972 with the establishment of three plot areas, the first of many to be utilized during the project term. The three locations included 60 individual 6 x 9 m plots to determine the suitability of 30 different agronomic grasses and legumes (table 3). Slopes ranged from 0 to 40 degrees.

Table 3.--Agronomic grasses and legumes utilized for revegetation

Legumes
Alfalfa - Beaver, Chimo, Drylander, Rambler, Roamer
Alsike Clover
Birdsfoot Trefoil - Leo
Cicer Milk Vetch
Sweet Clover
White Clover
Vetch - Spring, Crown
Grasses
Bromegrass - Carlton, Magna, Polar
Creeping Foxtail
Creeping Red Fescue - Arctared, Boreal, Erica
Crested Wheatgrass - Fairway, Nordan
Durar Hard Fescue
Intermediate Wheatgrass
Kentucky Bluegrass
Meadow Foxtail
Nugget Bluegrass
Perennial Ryegrass
Pubescent Wheatgrass
Redtop
Rough Fescue
Russian Wildrye (Sawki)
Slender Wheatgrass
Streambank Wheatgrass
Tall Wheatgrass
Timothy

Fertilizer trials were included to determine the most appropriate fertilizer types and analyses to be used, as well as timing and rate of application.

A concern relative to utilization of native species was addressed early in the study. It had been suggested that native species be utilized because animals prefer them, that less maintenance is required after establishment and that natives are more aesthetically pleasing. Realistically, however, in 1972 there was very little "native" seed available. Consequently, seed from loco-weed (Oxytropis spp.), Alpine hedysarum (Hedysarum alpinum), lupine (Lupinus spp.) and Hairy wildrye (Elymus innovatus) was collected in the undisturbed portions of the mine area and subsequently cleaned and planted.

The native species issue was also approached from the standpoint of introducing trees and shrubs relative to meeting the objective of establishing a long term cover that is in harmony with the surrounding area. A major problem was encountered in that seedlings suitable for planting above an elevation of 1100 m were unavailable. Consequently, a cone collection program was undertaken and greenhouse space acquired to rear lodgepole pine (Pinus contorta var. latifolia), engelmann spruce (Picea engelmannii) and white spruce (Picea glauca). Different sizes and types of containers were utilized to determine those most suitable for use in reconstructed soils and to get an appreciation of the relative costs associated with seedling production.

Cuttings of willow (Salix spp.), balsam poplar (Populus balsamifera) and root cuttings of aspen (Populus tremuloides) were rooted in the greenhouse. Direct planting methods were also utilized for the cuttings of willow. Most of the materials were planted within areas having an established grass and/or grass/legume cover.

During 1983 a direct seeding program to establish spruce and pine was undertaken to determine whether this procedure might be useful to consider on an operational scale. This program was expanded in 1984 and 1985.

RESULTS AND DISCUSSION

Suitability of Agronomic Grasses and Legumes

Most of the agronomics that were planted initially survived and continue to thrive. Many of the species produced and dropped viable seed. There was some concern at the outset that legumes, and in particular alfalfa, would not adapt or survive at the elevations involved in this study.

Time and annual monitoring of growth resulted in the development of an appreciation of species suitability (desirability), stand composition and fertilizer requirement. For example, 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. A number of recommended seed mixtures and seeding rates appropriate for different slope aspects (moisture regimes) were developed and are documented in the annual reports prepared (Macyk 1975, 1976, 1977). In terms of the most suitable time of year for planting, it was determined that spring seeding is superior to fall seeding. The major reason for spring planting is that legumes, which should be included in the cover established, perform much better when seeded in the spring.

To summarize, one might suggest that legumes such as alfalfa and clover along with the fescues, wheatgrasses, and wildryes are the most appropriate for revegetation use. Bromegrass and timothy provide good initial cover but tend to be highly competitive in mixtures and have relatively high nutrient requirements.

Fertilizer Requirements

As indicated previously, the available nutrient levels of the undisturbed and reconstructed soils was quite low. The grasses and legumes showed a marked response to the application of fertilizers to the extent that fertilized plots produced 10 to 20 times more dry matter than the unfertilized plots.

A number of concerns surfaced relative to the use of fertilizers in reclamation. Firstly, there was the concern that large applications of fertilizer would be required annually to maintain the established cover. Furthermore, the original cover established was relatively dense, which it was suggested, would preclude invasion by natives and resultant dead plant material would create a fire hazard in spring. The dead plant material probably does create a fire hazard but it is also useful from the standpoint of improving the organic matter status of the reconstructed soil.

On the basis of long term observations it can be stated that refertilization is not required annually to maintain a viable vegetative cover. Furthermore, a summary relative to timing of applications was developed and follows:

1. fertilizers should be applied at the time of seeding (year 1) and the following year (year 2);
2. for areas seeded to mixtures comprised of grass only, refertilization should take place in year 3 and every three years thereafter;
3. for areas where legumes such as alfalfa are included in the mixture, the vegetation cover can be left for five years and perhaps longer without refertilization.

Native Species Trials

Results indicated that the seed of some of the native grasses and legumes collected had relatively low germination rates. For example, the germination rate for loco-weed was 70 percent, whereas that of alpine hedysarum was 15 percent. It was observed that establishment of a viable erosion control cover utilizing natives only, took at least two years longer than it did when agronomics were used. Despite some of the limitations associated with utilizing natives, the species used in this study are considered appropriate for large scale use. A major concern relates to the acquisition of an adequate seed supply.

Relatively good success was achieved in terms of tree and shrub establishment. It was demonstrated that trees and shrubs will thrive in areas initially seeded to grasses and legumes. This practice was questioned initially because of an anticipated competition for moisture. It became apparent that the protection afforded the seedlings by the grass and legume cover, especially in holding snow in the winter, far outweighed the negative aspects of moisture competition during the growing season.

Furthermore, it was noted that seedlings growing in association with alfalfa appeared more healthy and vigorous than those growing in association with grasses.

The following summary represents an assessment of results five years after the initial planting of trees and shrubs.

1. engelmann spruce survival rate - 65%
2. lodgepole pine survival rate - 50%
3. rooted willow and balsam cutting survival rate - 65%
4. direct planted willow cutting survival rate - 40%
5. container grown conifer seedlings are superior to bare root stock in terms of survival and growth rate
6. larger size containers promoted higher survival rates.

Direct seeding of spruce and pine seed has shown some promise. Initial results indicate that fall seeding is superior to spring seeding and that pine demonstrates better germination than spruce. It may be premature to suggest that direct seeding is a viable alternative to planting seedlings, however, if the method is successful it would be very cost effective especially in areas where quick re-establishment of merchantable timber is not required.

Emphasis was placed on assessing some of the characteristics of trees planted in the reclaimed area and relating this to trees found in the adjacent forest and in areas reforested after harvesting operations.

Recently, emphasis was placed on assessing some of the characteristics of trees planted in the reclaimed area and relating this to trees found in the adjacent forest and in areas reforested after harvesting operations.

In 1983, an assessment of the characteristics of trees planted in the reclaimed area relative to trees present in the adjacent forest was undertaken. Trees selected for examination or comparison were chosen on the basis of obtaining similar species and sizes from both the natural and reclaimed areas. Trees were excavated to allow for examination of rooting habit and depth. Stem diameter at the base, age and height of each individual tree were determined.

Roots were concentrated in the upper 30 cm of the soil with only minor rooting below 50 cm for both spruce and pine within the reclaimed and undisturbed areas. Rooting habit or pattern was quite similar for trees excavated from the undisturbed and reclaimed areas.

The data obtained indicated that the growth rate for trees in the reclaimed area was considerably greater than than that of trees growing in the natural forest. These results might be explained by the fact that the trees in the reclaimed setting may have benefitted to an extent from the fertilizers applied to the accompanying grass cover. Furthermore, the trees in the reclaimed area likely receive more direct sunlight than the trees in the natural forest setting. However, it should be pointed out that the trees in the reclaimed area are more exposed to climatic extremes such as wind.

An attempt was made to compare the growth of trees in the reclaimed area with those growing in reforested areas that had previously been logged for pulp industry purposes. It was felt that this might provide a more valid comparison of growth since the reforested areas are more open to light. A site was selected approximately 40 km south-east of No. 8 Mine. The elevation of 1500 m is somewhat less than that of the mine but it was the highest or best that could be readily accessed. The data in table 4 provide a comparison of results for the different locations.

Table 4.--Age and growth data for conifers

Treatment/Location	N*	Diameter (cm)	Height (cm)	Age (yrs)
Reclaimed - No. 8 Mine				
Spruce	12	1.4	55	11
Pine	12	2.6	75	11
Reforested				
Spruce	17	1.2	52	14
Pine	18	1.3	59	11
Natural Forest - No. 8 Mine				
Spruce	23	0.9	42	17
Pine	26	3.1	108	28

N* - number of trees

The data presented suggest that the trees growing in the reclaimed area are at least comparable to those in the reforested and the natural forest settings. It should also be noted that climate is more severe at the No. 8 Mine than at the location from which the reforested trees were obtained.

Encroachment by Natives

Field observations indicate that encroachment by natives into the disturbed areas will occur with time. Various lichens, mosses, lupine, loco-weed, alpine hedysarum and Indian paintbrush are naturally invading the areas initially seeded to agronomics. Willow, alder, balsam poplar and the conifers, dominantly spruce, pine and subalpine fir are also found in the area.

The encroachment by natives is the result of seed spreading from adjacent undisturbed areas and/or the result of incorporation of seed and vegetative material during soil salvage operations and the resultant germination of seed or sprouting of vegetative material following soil replacement.

These observations suggest that revegetation can be planned and managed in a manner such that natives can be included in the original seed mix and they can be expected to encroach or invade on their own. In other words, native grasses, legumes, herbs, shrubs or trees will come in naturally if not planted originally. However, the appropriate seeding or planting of natives speeds up the overall process and allows for establishment of preferred species.

Wildlife Utilization of Reclaimed Areas

During the initial stages of the study it was suggested that most wildlife species would not utilize reclaimed areas especially those where agronomic grasses and legumes were utilized. Bighorn sheep initially inhabited the experimental areas only in spring because the plots greened up earlier than their native range. Presently, they stay within the reclaimed area throughout the growing season, selectively grazing particular species such as alpine bluegrass, creeping foxtail, hard fescue and to some extent the tender shoots of alfalfa.

Black and grizzly bear thrive in the vicinity and deer and elk are now common in the area.

CONCLUSIONS

Reclamation efforts in the Foothills/-Mountains Region can be successful provided that appropriate procedures are adopted. Soil management and the selection of suitable agronomic and native species aided by natural processes will result in the establishment of diverse plant communities and allow for different land use options.

LITERATURE CITED

Canada Soil Survey Committee, Subcommittee on Soil Classification. 1978. The Canadian System of Soil Classification, Canada Department of Agriculture Publication 1646. Supply and Services Canada, Ottawa, Ontario, 164 p.

Macyk, T.M., and Z.W. Widtman. 1984. Progress report, surface mine reclamation project, No. 8 and No. 9 Mines, Grande Cache, Alberta. Alberta Research Council, Terrain Sciences Department Report, 41 p.

Macyk, T.M., and Z.W. Widtman. 1983. Progress report, surface mine reclamation project, No. 8 and No. 9 Mines, Grande Cache, Alberta. Alberta Research Council, Soils Department Report, 28 p.

Macyk, T.M. 1972 to 1982 inclusive. Progress report, surface mine reclamation project, No. 8 Mine, Grande Cache, Alberta. Alberta Research Council, Soils Department Report. (Reports prepared annually.)

Macyk, T.M. 1976 to 1982 inclusive. Progress report, surface mine reclamation project, No. 9 Mine, Grande Cache, Alberta. Alberta Research Council, Soils Department Report. (Reports prepared annually.)