SUCCESSFUL RE-ESTABLISHMENT OF NATIVE TREES AND SHRUBS ON HIGH ELEVATION COAL DUMPS AT FORDING RIVER OPERATIONS

Roger J. Berdusco, R.P.F.\textsuperscript{1}, Billie O'Brien, B. Sc.\textsuperscript{1}, and Carol E. Jones, M. Sc., P. Ag.\textsuperscript{2}

\textsuperscript{1} Fording Coal Limited, PO Box 100, Elkford B.C., Canada V0B 1H0
\textsuperscript{2} C.E. Jones and Associates Ltd., 204-26 Bastion Square, Victoria B.C., Canada V8W 1H9

ABSTRACT

The Fording River Mine, operated by Fording Coal Limited is located in the Rocky Mountains of British Columbia at elevations ranging from 1650 to 2300 m. Research has been conducted at the mine site since 1969 to develop technology for restoring the forest resource and the critical wildlife habitat. Experiments have been conducted to determine the effect of seeding two species of legumes with the conifer species. The effect of an interseed delay of up to five years on various growth parameters of the conifers was assessed. The growth of the conifers was compared to height to age curves developed for natural regeneration on forest sites in the valley. Research has also been conducted to determine the optimal method of establishment of deciduous trees and shrubs which are critical for the development of ungulate winter range on steep, south aspect slopes. Innovative techniques utilizing various types of seedling protectors have been tested. A range of native trees and shrubs have been tested on various sites and lists of candidate species developed.

INTRODUCTION

The Fording River Mine, operated by Fording Coal Limited, is located near Elkford in the Rocky Mountains of southeast British Columbia, Canada. The minesite encompasses an area of approximately 3000 hectares of which 430 have been reclaimed. Mining operations commenced production in 1971 with the first coal shipment in early 1972. The initial capacity of Fording River Operations was 2.7 million tonnes. Today, Fording River Operations is the world's largest metallurgical coal producer with an annual production capacity nearing 8 million tonnes of clean coal. The main mining areas are Eagle Mountain to the east of the Fording River, the Greenhills Range to the west of the Fording River and Turnbull Mountain and Henretta Ridge to the north of Eagle Mountain.

The mine operation is within the Engelmann spruce - Subalpine fir biogeoclimatic zone and ranges in elevation from 1650 to 2285 m above sea level. The valley bottom and lower slopes are mainly forested with Englemann spruce and Lodgepole pine with minor occurrences of Subalpine fir and Douglas fir. Occasional stands of Alpine larch occur on north slopes at elevations above 1800 m. Stands of White-bark
pine mixed with grass-shrub communities occur on south and west aspects.

The Canada Land Inventory classed the upper Fording River area into various resource uses. The river valley bottom and lower mountain slopes are classed as Moderate Big Game Range and Moderate Yield Forest. As Moderate Big Game Range, this area has some limitations for the production of ungulates, but is important for year round or seasonal use. Productivity of Moderate Yield Forest ranges from 3.6m³/ha/yr to 4.9m³/ha/yr, making it desirable for harvesting, especially in valley bottoms. The Fording River valley bottom area is also valuable for recreation pursuits such as hunting, fishing and hiking.

The mid-slope to mountain peak are classed as Moderate Big Game Range, Prime Big Game Range, Limited Yield Forest and Highland. The Prime Big Game Range occurs on the southerly slopes of Eagle Mountain, Castle Mountain and Turnbull Mountain. Productivity of the Limited Yield Forest Class ranges from 2.2m³/ha/yr to 3.5m³/ha/yr, making it undesirable for harvesting. The Highland class has capabilities for both Big Game Range and extensive recreation.

Research has been conducted at the mine since 1969 to develop technology for restoring both the forest resource and the critical wildlife habitat. Surface mine reclamation experience specific to developing coal mines in this region was non-existent in 1969. The type of vegetation and cultural practices required to achieve immediate and long term reclamation objectives were unknown. Early research addressed the most immediate concerns related to reclamation including erosion control and provision of forage and browse for wildlife species. Field studies were initiated in 1973 when the first waste dump sites became available for revegetation. These studies were expanded to assess the effects of slope and soil materials on the productivity of vegetation established on spoils at various elevations. It was determined that legume dominated vegetation can be established on waste dumps over the range of elevations which will result from the mining activity. This vegetation was successfully established on slopes up to 37 degrees, and it was concluded that covering dumps with glacial till overburden did not improve productivity of the vegetation cover. Since 1980 the emphasis of the research activities has been on the development of technology for rehabilitating waste dumps to productive forest and ungulate range.

The results from these research programs have been influential in both the operational reclamation practices and in the development of the long range reclamation plan. The long range reclamation plan at Fording River Operations is to re-establish the previously existing land uses on a property average basis. The major end land uses for the post-mining landforms at the Fording River minesite are Moderate Yield Forest and
both summer and winter Big Game Range. The reclamation objectives are to establish a self-sustaining vegetative cover which is commensurate with these pre-determined end land uses.

MINING AND RECLAMATION PLANNING

The mining operations at Fording River Operations, employ both truck/shovel and dragline mining techniques in multiple seam pits. Truck/shovel operations tend to construct spoils in the top down method and can be up to 400m high. Spoils constructed by the dragline are typically conical in shape, up to 50m high and formed from the bottom up. The combination of truck/shovel and dragline equipment produces up to 8 million tons of cleaned coal and 71 million BCM of waste per annum. Both methods of mining create waste material that required various degrees of site preparation for reclamation purposes. The waste material from mining at the Fording River minesite consists mainly of sandstone, carbonaceous mudstone, siltstone and some glacial till. Truck/shovel dump construction results in the more competent sandstone rolling to the bottom of the spoil area providing good drainage at the base of the spoil. This principle allows for the construction of flow-through rock drains. The less competent materials such as shales and mudstones remain at the top portion of the dump and weather rapidly. These are the materials that are spread over the entire dump in the resloping process and provide suitable growth medium for revegetation. Dragline spoils tend to be more homogenous throughout their construction.

The resloping of waste dumps is accomplished using D11 dozers, with reclamation blades having a capacity up to 57m³. The dozers start at the highest level of the waste dump and move downwards using a technique called the horizontal cut method. This minimizes the distance a dozer must back up the resloped face and also provides a relatively flat working surface for the dozer. Reslope designs accomplish either a total resloping of the entire waste dump or a combination of resloped and angle of repose slopes at the bottom of the spoil. On higher waste dumps, terraces of approximately 6 metres in width are constructed at 40 to 60 metre elevation intervals down the face of the spoil to provide access across the spoil face and to aid in drainage control.

Long range mining plans are used to forecast probable reclamation activities and timing of reclamation work. The major considerations in mine planning which relate to reclamation involve spoil configuration and drainage design. Flow-through rock drains, which allow spoiling in drainages, while maintaining stream flows and waste dump stability, are used extensively to effectively manage drainage control and minimize total mining disturbances.
Spoils must be designed to accommodate all the waste generated by mining while leaving a final configuration that can be resloped to a suitable angle, and be amenable to the establishment of vegetation leading to the main end land uses. Spoils are currently constructed using a combination of free-dumping and wrap-around dumping. Free dumping is maximized followed by wrap-around dumping at 80 to 120 metre elevations which provides for spoil stability as well as reducing the resloping volumes for reclamation. As resloping volumes increase significantly with dump height, there is incentive to reduce overall dump height or utilize wrap around dumps to minimize reslope costs.

Current practices for spoil resloping at the Fording River minesite are generally to change the angle of repose, typically 38°, to slope angles of 26° to 34°, depending upon spoil type, moisture regime and end land use. The three most apparent benefits for using steeper reclaimed slopes are a reduction in the area disturbed, a reduction in the amount of material to be moved during resloping, and in high elevation areas with south to south west aspects, the steeper slopes are better suited for wildlife habitat. Shallower slopes have advantages for use as a forestry end land use.

**AFFORESTATION RESEARCH**

The results of early experiments where conifer seedlings were planted into a cover of agronomic grasses and legumes indicated severe losses in seedling survival, most likely due to competition for moisture and nutrients. While seedling survival is important, other considerations such as the contribution of agronomic species to the stabilization of surface erosion on slopes, improvement of soil nitrogen concentrations and contributions to soil organic matter content could not be overlooked. Additional research was undertaken to determine the optimal timing for planting conifers with a legume ground cover.

**Growth of Conifers in Combination with Legumes**

Experiments were initiated to determine the effect of seeding two species of legumes, *Medicago saliva* (alfalfa) and *Lotus corniculatus* (birds-foot trefoil) on two conifer species, *Picea engelmannii* (Engelman spruce) and *Pinus contorta* (Lodgepole pine). These trials were designed to assess the effect of seeding the legumes during the year of planting and one and two years subsequent to planting. Detailed monitoring included: survival and growth characteristics of the conifers; production and cover of the legumes; and nutrient characteristics of the conifers and legumes. The results presented here are from an assessment of *Picea engelmannii* conducted seven years after planting.
Survival of *Picea engelmannii* was negatively affected by the seeding of *Medicago saliva*. This was particularly evident in the year of planting but was evident in the subsequent years (Figure 1). The seeding of *Lotus corniculatus* also had a negative influence on survival when seeded in the year of planting, but had little effect on survival when seeded in subsequent years.

Total height of *Picea engelmannii* was negatively affected by the seeding of *Medicago sativa* in any year but was particularly reduced by seeding in the year of planting (Figure 2). Seeding *Lotus corniculatus* in the year of planting also had a negative effect on total height of *Picea engelmannii* however there was no effect from seeding in subsequent years. Height increment followed a similar pattern to total height.
Picea engelmannii, seven years after planting, had significantly lower growth on trees which were planted into either legume species during the year of seeding (Figure 3). This effect was not noted on trees where the legumes were seeded in subsequent years. Basal diameter of Picea engelmannii was negatively affected by the seeding of both Medicago sativa and Lotus corniculatus, particularly during the year of planting.

The age to height growth relationships observed in this experiment were compared with age to height curves developed for Picea engelmannii and Pinus contorta naturally regenerating on natural forest sites in the Fording River valley. Picea engelmannii grown on the coal spoil consistently achieved greater growth than the natural forest regeneration except when seeded with Medicago sativa during the year of planting. When seeded with Lotus corniculatus, even when planted into an existing cover of the legume, Picea engelmannii growth was always greater than the natural regeneration (Figure 4). Pinus contorta growth on coal spoil was generally less than that achieved by the natural regeneration, except when seeded with Medicago sativa two years subsequent to planting, or when seeded to Lotus corniculatus in the year of planting or in the subsequent year.

Further experiments tested only the response to Lotus corniculatus on the two conifer species. In these experiments the time delay between planting the conifers and seeding the legume ranged from 3 to 5 years.
Results of monitoring programs conducted 8 years after planting indicated that various growth parameters of both *Picea engelmannii* and *Pinus contorta* were positively effected by the accompanying *Lotus corniculatus* cover, and that these differences were statistically significant at the 95 percent confidence level.

Both total height growth and annual height increment of *Picea engelmannii* were significantly greater in all of the delay treatments over the control. Basal diameter was significantly greater for the 4 and 5 year delay periods over the control.

*Pinus contorta* showed a positive significant difference in total growth in the 3 and 4 year delay of interplanting (the 5 year delay was not planted with *Pinus contorta*). Only the 3 year delay showed a significant difference in height increment 8 years after planting. Basal diameter was significantly greater for both the 3 and 4 year delay in interseeding delay over the control.

Mean needle mass was determined for the conifers planted after a 4 year delay and compared to the control. Mean needle mass of *Picea engelmannii* was found to be significantly greater than that of the control. The mean needle mass of *Pinus contorta* was not significantly greater than that of the control.

The mean foliar nitrogen of both *Picea engelmannii* and *Pinus contorta* was found to be significantly greater than that of the control. No significant difference was found between the mean foliar phosphorous or mean foliar potassium between the treatments and the control for either conifer species.

The height to age curves resulting from this experiment were plotted with the curves developed for natural regeneration on forest sites in the valley. As was observed with the previously described experiment, *Picea engelmannii* with the interplanting of *Lotus corniculatus* achieved higher total growth over the first eight years on coal spoil than on natural hillslopes. *Pinus contorta* planted on coal spoil achieved a very similar growth curve to the natural regeneration sites, however total height was slightly reduced.

**UNGULATE WINTER RANGE ESTABLISHMENT**

Ungulates are the major wildlife resource in the vicinity of the Fording River mine. Elk (*Cervus elaphus nelsoni*) are the most abundant, although Big Horn Sheep (*Ovis canadensis canadensis*) are also year-round residents. The availability of winter range is the limiting factor for the elk population. Comparatively,
there is abundant summer range. Therefore, research efforts have focused on providing good quality winter range through reclamation. Experiments began in 1985 to develop the technology necessary to rehabilitate suitable waste dump slopes to elk winter range. The physical conditions which are required to provide this habitat include steep high elevation slopes with south or southeast aspects. These site characteristics result in challenging conditions for establishment of the required vegetation. A major component of elk winter range is the development of areas of woody plant species which provide important browse. Selected species include: Prunus virginiana (choke cherry), Amelanchier alnifolia (saskatoon), Symphoricarpos albus (common snowberry), Ceanothus velutinus (redstem ceanothus), Populus tremuloides (trembling aspen), Elaeagnus commutata (wolf-willow), Comus sericea (red-osier dogwood), Acer glabrum (Douglas maple), Salix scouleriana (Scouler's willow), Shepherdia canadensis (buffalo-berry), Spiraea betulifolia (birch-leaved spirea), and Rosa adularia (prickly rose).

Results of initial experiments indicated that survival of browse species planted on these exposed slopes was very low, ranging from 0 to 58 percent, and that season of planting did not affect survival on these sites. The same seedling stock planted on other less exposed areas of the mine site achieved much higher levels of survival. The greatest loss to survival usually occurs in the first year after planting. These losses are presumed to be due to two factors: the site exposure; and wildlife browsing.

In 1995, a research trial was initiated to determine if plant protectors installed at the time of planting would improve shrub establishment and survival by providing additional shelter for the seedlings from the adverse climatic conditions and wildlife browsing. Trials have been planted in both fall and spring since September 1995. Each seasonal trial included four plot replicates and the plot locations were selected to provide similar southwest exposure, slope position, and uniformity of spoil material. Plant protectors were installed on fifty percent of the seedlings, various types of protectors have been tested. In the fall of 1995, plant protectors of a folded corrugated plastic were installed, and in spring and fall of 1996 a solid corrugated plastic tube was used. In the spring of 1997 a solid plastic tube was tested and in the fall of 1997 an alternate brand of corrugated plastic tube will be employed.
The results to date indicate that the shrubs in the protectors were generally in better condition than the unprotected ones: protected shrubs are larger and leafed out earlier in the spring. The majority of the unprotected deciduous shrubs were heavily browsed and some were uprooted by animals. All deciduous species displayed better growth and survival rates when protected while some coniferous species had slightly lower survival when grown in the protectors. It is suspected that the air temperature inside the protectors during the summer months may result in desiccation of the coniferous species.

Survival results of three deciduous species planted in the fall of 1995 are presented in Figures 5 to 7. *Acer glabrum*, shown in Figure 5 presents a typical survival curve, some minor losses occurring in the protected plants but more significant and continuing losses occurring in the unprotected plants. Figure 6 illustrates a more extreme loss situation in *Rosa acicularis*, where survival of the unprotected plants is less than 50 percent, while the survival of the protected plants is greater than 80 percent. *Prunus virginiana* survival, presented in Figure 7 demonstrates that while the plants within the protectors have higher survival than the unprotected plants, the rate of loss over time is similar. The cause of the mortality in the protected *Prunus* plants may be related to the increased air temperature within the protectors. In these mini-greenhouses, the *Prunus* plants did not lose their leaves.
and become dormant as early in the fall as did the unprotected plants. This may have resulted in plant losses if severe freezing temperatures occurred before the plants had become fully dormant. Many of the dead *Prunus* plants observed in protectors during the spring assessment of 1997 retained leaves from the previous year.

The results of this trial will be used to determine the optimal type of plant protector, season of planting and combination of browse species. To date this trial has illustrated that valuable browse species can be established on these type of exposed sites and that the important native shrub component of the wildlife habitat can be developed.

![Figure 7](image.png)

**SUMMARY**

Research is continuing to assess the most cost-effective methods of achieving the proposed end land uses for the reclaimed mine areas. The experimental results achieved to date have been incorporated into the operational reclamation of areas presently being reclaimed. Those sites which are planned to become coniferous forests are planted with one year seedlings of *Picea engelmannii* and *Pinus contorta* and seeded with *Lotus corniculatus* two years after the date of tree planting. This allows the conifer species to become established without the pressure of competition with the legume and ultimately provides for both surface erosion control and the addition of nitrogen to the site by the legume cover.

The experiments to establish ungulate winter range have not yet provided conclusive results, however it has been demonstrated that the establishment requirements on these sites will be different than that of the forested sites. Preliminary results indicate that some form of protection for the seedlings after planting is necessary to achieve good survival rates. Further monitoring will be required to determine the most suitable type of plant protector for various species and the duration of time for which the protection is required.
The authors would like to gratefully acknowledge the important contribution of Mr. Bob Gardiner who was responsible for the design and assessment of many of the research trials discussed in this paper.