ABSTRACT

As a result of a review of rock dump reclamation in 2000, resloping of unreclaimed rock dumps from angle of repose to less than a 2:1 slope was adopted as the preferred method. As a result of the analysis and field trials, resloping was performed using two different methods, horizontal cut and incline cut depending upon waste rock dump height. Resloping profiles were designed using three-dimensional modeling software. Productivity of the dozer fleet was analyzed based on dump height, crest length and area reclaimed.

INTRODUCTION

Bullmoose is an open pit metallurgical coalmine located 50 km from Tumbler Ridge, BC. During 19 years of mining operations, 30 million tonnes of metallurgical coal have been produced from the Bullmoose mine site. The total disturbance of the Bullmoose mine site is 886 ha with 120 ha of waste rock dumps remaining to be reclaimed. With reserves scheduled to be depleted in the first quarter of 2003, emphasis is being placed on completing as much reclamation work as possible prior to mining operations ceasing. Reclamation of waste rock dumps is a major part of Bullmoose's efforts to re-establish wildlife habitat.

Following a review of rock dump reclamation in 2000; resloping of unreclaimed waste rock dumps from angle of repose (37°) to a 2 (horizontal) to 1 (vertical) slope (26.7°) was adopted. Design guidelines were established and finalized using a three-dimensional modeling software package. Productivity of the dozer fleet was analyzed based on dump height, crest length and area reclaimed. All resloping was completed using two different methods; a combination of slope cut method and incline cut method, which has been referred to as hybrid method or incline cut method depending upon waste rock dump height.

This report focuses on the design and productivity of resloping rock waste dumps from June 2001 to August 2002. The intention of this report is to detail what Bullmoose has determined as an effective method for preparing to return waste rock dumps to wildlife habitat.
PREVIOUS WASTE ROCK DUMP RECLAMATION METHOD

Prior to the review of reclamation procedures for waste rock dumps, bulldozers would round the crests of waste rock dumps, as seen in Figure 1, to redistribute finer material in the top third of the waste rock dump down the slope to fill in spaces between larger boulders. Salvaged growth medium was free dumped along the crest. These piles were then pushed over the crest of the waste rock dump to achieve a 0.5 meter thickness over the slope. As fine material has a tendency to hang on the crest, a spiked chain was pulled along the face of the waste rock dumps to distribute the material and create micro sites for improved seed germination. Soil was also transported to the toe of the waste rock dump and then pushed up the slope to cover any large boulders at the toe of the dump. Finally the waste rock dump was seeded and fertilized. With this method, haul track access was mandatory to the crest and toe of the dump, Some of the waste rock dumps that required reclaiming could not be accessed by haul trucks without building haul roads to these areas.

Figure 1, Rounded Crest.

As a result of an alteration in waste rock dump configuration, this reclamation method was reviewed and the alternative of resloping was investigated. It was determined that re-sloping waste rock dumps to a slope less than 2:1 would result in an equivalent effective result as past reclamation techniques.
RESLOPING METHODS

Two methods of resloping were considered; horizontal cut method and slope cut method. Both methods took into consideration the operational limitations of the equipment used which consisted of an existing fleet of D10N bulldozers.

The waste rock is a typical sedimentary sequence, with shale, siltstone, mudstone and sandstone. The majority of the rock breaks down into fines as the bulldozers move over it as well as the natural segregation of courser fraction and natural degradation of weaker rock types. These mechanisms produce excellent fines suitable as a growth medium therefore the waste rock dump faces did not require the application of a growth medium. The waste rock has been found to form a natural slope of 1.3:1 (37°).

Horizontal Cut Method

The horizontal cut method, Figure 2, works by making an initial cut at the design back line. Then the material is pushed over the crest on a nearly horizontal platform where the material is deposited at the angle of repose. Successive parallel cuts are made until the entire waste rock dump has been resloped. The maximum slope that a D10N bulldozer can reverse was found to be a 2:1 slope, which is dependant on the type of material. Reversing more than one dozer length was found to be impractical and non-productive. This was the limiting factor for the maximum angle of resloping with the horizontal cut method.

Figure 2, Horizontal Cut Method.
The horizontal cut method was determined to be the most efficient. The major problem with the horizontal cut method is as the resloping progresses down slope the flat working platform decreased to a point at which there is no room to maneuver. The minimum operating width of the platform for a D10N bulldozer was found, from operational experience, to be 10m. This width was calculated to occur 18m above the toe, irrespective of waste rock dump height.

**Slope Cut Method**

Slope cut method, Figure 3, establishes a working face parallel to the design slope and then takes successive cuts parallel to the design slope until this slope is met. This method has two major limitations; the maximum design slope and the push distance. The slope cut method final angle is limited to 2.5:1 (22°) in waste rock dumps, due to the limitation of bulldozers reversing up slopes greater than one bulldozer length. Maximum slope in very fine saturated waste rock dumps can be as shallow as 18° (S. Bonham Carter, Quintette Operating Corporation).

![Figure 3, Slope Cut Method.](image)

**BULLMOOSE DESIGN**

The horizontal cut method and the slope cut method each have limitations. For waste rock dumps under 40 m in height, the slope cut method was adopted. For waste rock dumps over 40m in height, a hybrid method, Figure 4, was developed from the two methods. Horizontal cut method would start the resloping
at a design slope of 2:1 (26.7°). At 18m above the toe, the slope cut method was implemented to allow sufficient room for the D10N to maneuver.

Figure 4, Cross-Section for the Hybrid Resloping Design.

For waste rock dumps less than 40m in height, the slope cut method was chosen to simplify implementing design. The amount of bulldozed material that would be reduced by using the hybrid method of resloping is less than 10%. Table 1 shows the comparison between the three design slopes considered and the corresponding cut volumes and backlines.

<table>
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<th>Dump Height (m)</th>
<th>Backline (m)</th>
<th>Cut Volume (m³)</th>
<th>Backline (m)</th>
<th>Cut Volume (m³)</th>
<th>Backline (m)</th>
<th>Cut Volume (m³)</th>
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Cut volume is per meter of crest length.

Table 1, Design Guidelines for Resloping.
Figure 5 shows the transition from a $25^\circ$ slope to a $20^\circ$ of a resloped waste rock dump using the hybrid method. This dump was the trial waste rock dump for this method. Another consideration with the resloping of this waste rock dump was the blending of the resloped face with the previously reclaimed face.

Figure 5, Resloped 1580 Dump.

SPECIAL CONSIDERATIONS

Table 1 outlines the basic cut design for a 1m straight crest length. At Bullmoose, the majority of the waste rock dumps reclaimed did not have straight crest lengths, but rather curved crest length. This would either increase or decrease the cut volume depending on the orientation of the curve. For these waste rock dumps, a three-dimensional computer model was built to determine the optimum backline distance.

Toe and crest surveys of the waste rock dump were imported into Bullmoose's three-dimensional modeling software and two surfaces were built; one representing the unresloped surface and the other surface representing the designed surface. Cut and fill volumes were calculated and representative cross sections were cut. If the cut and fill volumes were not within 10% of each other, the backline was
adjusted in the area where the cross section appeared not to balance. It was important to cut sections for the following circumstances:

1) Change in waste rock dump height  
2) Where resloped toes would meet  
3) Crest lengths that curve in either a concave or convex manner

With crest lengths that have either convex or concave curves, the change in the backline offset was between 10% and 15% of design offset. Because the volume cut increases exponentially with the offset from the crest, the backline location does not have to change a considerable amount to adjust for the difference of the necessary material. The adjustments were more dependant on the relative sharpness of the curve.

**PRODUCTIVITY**

All resloping is completed with the production fleet of bulldozers that consist of seven DION. The entire fleet is fitted with 30.6 m$^3$ (40 yd$^3$) reclamation blades.

For planning purposes, Quintette's experience in resloping waste rock dumps was used for determining initial correction factors for bulldozer productivity. From the corrected productivity, the operating hours per meter of crest length were calculated. Based on this information, a plan was developed for resloping.

Operating hours, for the bulldozer productivity, included traveling to the dump, taking lunch breaks, refueling the bulldozer and repairing minor mechanical problems as well as the actual time resloping. Given that all bulldozers used are part of a production fleet, utilized for reclamation on down shifts and when spare bulldozers were available on operating shifts, it was difficult to determine the mechanical availability for the bulldozers working on resloping projects. There were no weather delays as all resloping to date has been conducted in the late spring to early autumn months.

This corrected productivity matched measured productivity of resloping accomplished to date at Bullmoose. Figure 6 shows productivity in operating hours per meter of crest length versus the waste rock dump height. Given that the two operations mined the same geologic formation, dozer fleets were the same in age and type and similar designs were used, the corrected productivity was an accurate value to use in planning.
FACTORS AFFECTING BULLDOZER PRODUCTIVITY

The major factors affecting productivity are:

1) Maintaining the slope design. If the designed slope is not maintained, either too shallow or too steep, unnecessary material is pushed or not enough material is cut. Given the geometry of resloping, this can greatly impact productivity. It is much more efficient to cut some additional material. If it is necessary to cut additional material, this is difficult and unproductive. Maintaining the slope design starts with properly implemented design and establishing the initial slope. The slope is then checked with an inclinometer periodically to ensure the slope design is maintained.

2) Resloping of frozen material. Frozen material needs ripping, this adds additional hours to resloping therefore waste rock dumps will not be resloped while frozen.

4) Employing experienced operators. As the reclamation season progresses bulldozer productivity increases with operators' experience. Assigning a crew to a given project also increase
productivity. With two reclamation crews and additional manpower on operating shifts assigned to reclamation projects, this can be impractical. Because of this, it is important to have a well communicated plan so that time is not wasted when new personnel start on resloping projects.

CONCLUSION

Resloping of waste rock dumps provides enough fines that application of a suitable growth medium to the waste rock dump face is not necessary and therefore a cheaper alternative. A combination of the hybrid method and slope cut method has been used to efficiently reslope waste rock dumps to create wildlife habitat. These methods will continue to be used to reslope all unreclaimed waste rock dumps at Bullmoose Operating Corporation.

REFERENCES