VALUE IMPACTS OF TRUCK LIMITED SCHEDULING

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Abstract

Recent falls in commodity prices and economic uncertainty have seen many businesses re-evaluate their operational expenditure to ensure mine profitability. Due to the high capital and operational costs of truck and digger fleets, the loading and hauling of material is a significant proportion of a mine's expenses (Nel, Kizil and Knights, 2011). It is often one of the first areas considered for cost reduction, so if an operation needs more trucks to maintain or improve productivity, a robust justification for the expenditure is crucial.

Mining schedules form the basis of productivity and cost estimates for mining operations and there must be a significant level of confidence regarding achievable quantities and rates. Traditionally, a mining schedule is produced without detailed consideration of the trucking capacity or requirements. Although some mine planning software incorporates haulage predictions into schedules, most cannot model the dynamic nature of dumping and haulage. Studies have shown that detailed haulage analysis is essential for more realistic mining schedules and cost estimation, instead of the traditional mining block centroid to dump block centroid methods (Doig and Kizil, 2013).

Recent developments in software allow the dynamic integration of haulage analysis with mining schedules. Engineers can now create mining schedules in conjunction with dumping schedules, allowing mining schedules to reflect the restrictions created by the number of available trucks, combined with the dynamic consideration of available in-pit and out-of-pit dumping locations.

A study was completed of mining schedules produced in conjunction with a dumping schedule and various haulage strategies. These schedules were studied to determine their impacts on coal production and revenue. For each schedule scenario, a financial analysis of the Net Present Value (NPV) was calculated.

The study showed that trucking shortfalls can significantly impact mining schedules and cost estimations, both in terms of cost and revenue lost when trucks cannot maintain forecast production rates. The impacts of trucking on mine production, risk closure, and profitability, make a strong case for the completion of mining schedules in conjunction with dumping schedules and haulage analysis.

NB: This paper was first presented at the Life-of-Mine 2014 Conference.

1. Introduction

Economic uncertainty and cyclical commodity prices are a feature of the mining industry. To remain competitive during downturns in the mining industry, many ompanies periodically look to minimize the cost of operations while maximizing productivity.

In economic downturns, capital expenditure is usually one of the first items to be cut from new and existing budgets. Approximately 50 to 60 percent (Nel, Kizil and Knights, 2011) of the total operational cost of a mine is attributed to loading and transportation of material, thus it is often one of the first areas where cuts are made. Therefore, it is imperative for an operation to fully understand its trucking requirements and the effects of a deficit or surplus of trucks on the mining schedule.

Software packages for estimating and simulating truck cycle times and requirements have been available for many years. They require intense manual input for estimating cycle times on multiple hauls, which leads to user reluctance to increase detail, to run multiple scenarios, and to include a destination schedule. However, recent advances n software development allows detailed analysis to be conducted and incorporates a full destination schedule with the cycle time calculations.

For a typical strip mine, a variation in cycle time for one strip can vary up to 15 % when comparing various sampling densities for haulage cycle time calculations (Doig and Kizil, 2013).

The study showed that if truck requirements are determined from a mean cycle time without considering variations within that strip, the mining rate can be significantly impacted. This is because a certain number of trucks may be allocated to an excavator based on the average cycle time calculated. If the cycle time is increased above the calculated average, trucks spend more time travelling, reducing the number of loads and thus the amount of material they can move in a given period. This results in an increase in the idle or wait time for the excavator, reducing the amount of productive time for that resource.

Table 1 shows an example of the typical variations in mining rate that a loading unit can see across a single strip.

Table 1 - Excavation rate variations (Doig and Kizil, 2013)

Parameter	Average	Max	Min
Cycle Time (min)	22.68	25.9	19.92
bcm/load	80	80	80
Cycles/h	2.6	2.3	2.8
bcm/h	212	185	241
No Trucks	6	6	6
Mining Rate	1270	1112	1445
Difference		12%	14%

The strip used in this analysis is shown in Figure 1 with the relevant excavator mining rates calculated on individual block cycle times with a destination schedule.

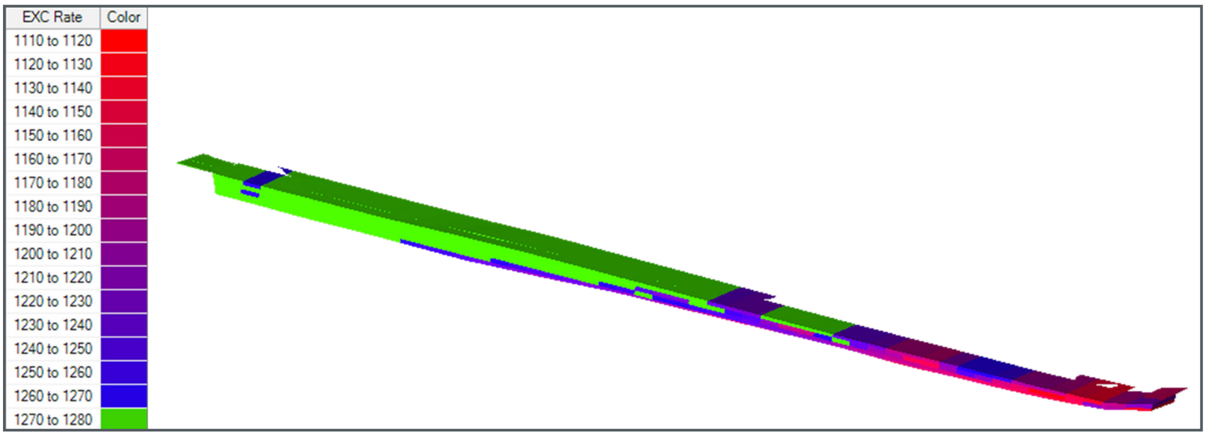

Figure 1 - Excavation rate variations within a single strip (Doig and Kizil, 2013)

The variation from the mean cycle time can influence truck productivity. When the block cycle time is below the mean cycle time for the strip, the fleet may then become excavator-constrained. This results in longer queuing times for trucks and reduces truck productivity. If, however, the cycle time increases above the mean, the fleet is then truck-constrained, which in turn decreases the excavator mining rate. Considering these factors, it is apparent that trucks are the lifeline to an operation. Inadequate trucks, therefore, can result in significant shortfalls in mining targets.

Considering trucking is so critical to a mining schedule, this paper shows that it is necessary to incorporate a dynamic haulage destination schedule with the mining schedule. That is, incorporating truck limited haulage modeling, to get more definitive and precise cost and productivity estimations. If truck limited haulage modeling is completed, more realistic schedules can be generated, which leads to greater confidence in cost and revenue estimations, improved profitability, and reduced risk for the business.

Recent developments in computer processing and software, allows truck limited haulage analysis to be conducted with relative ease. This enables the user to incorporate detailed haulage analysis with the mining schedule and allows multiple and complex scenarios to be run.
This study determines the value impacts of truck limited haulage, which requires considering production quantities, costs and resultant NPVs, compared with various truck numbers. This paper shows how combining a dump destination schedule with a mining schedule can reduce the mining quantities dependent on the trucking capacity.

2. Case study

2.1. GEOLOGICAL MODEL

Due to confidentiality agreements, no company data was available for the study conducted. A model was created using the Deswik training dataset which comprises of a fictional geological model analogous to Central Queensland open cut dragline operations. The model has eight coal seams dipping north-east between 6 % and 8 %. The interburden thickness varies between 30 m to 60 m with a parting band in the K seam between 2.0 to 0.5 m thick within the K seam as shown in Figure 2.

2.2. PIT DESIGNS

Medium term pit designs were created for ten strips. This included ramp designs, prestrip passes and maximum dragline spoil designs with the relevant lowwall ramps, as shown in Figure 3. In conjunction with this, five ramps or bridges were designed, with hard ramps on either end and in the centre and two soft ramps that require rolling with the dragline as each strip progresses. Figure 4 illustrates the final pit shell in conjunction with the dragline spoil pile designs and maximum progressive dump shells.

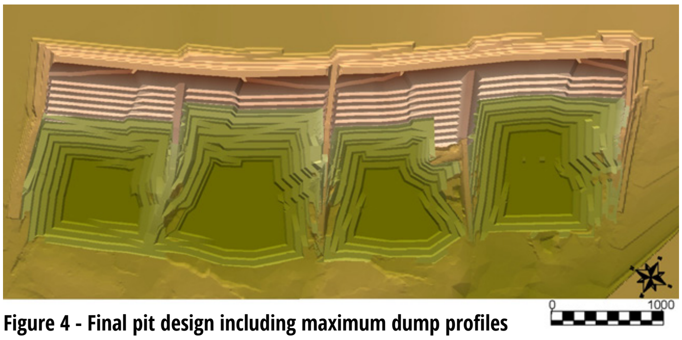

Figure 4 - Final pit design including maximum dump profiles

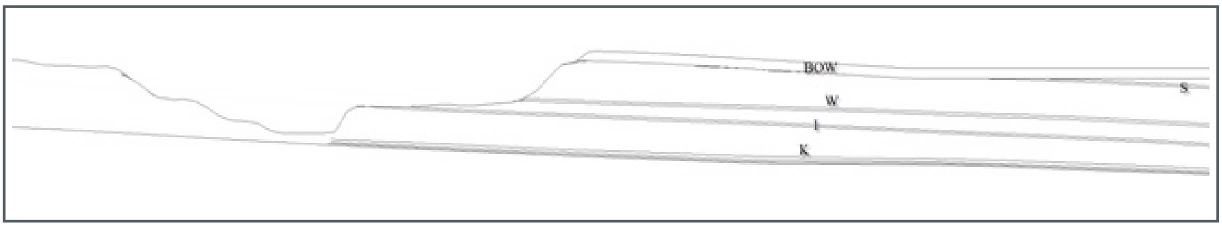

Figure 2 - Geological model cross section

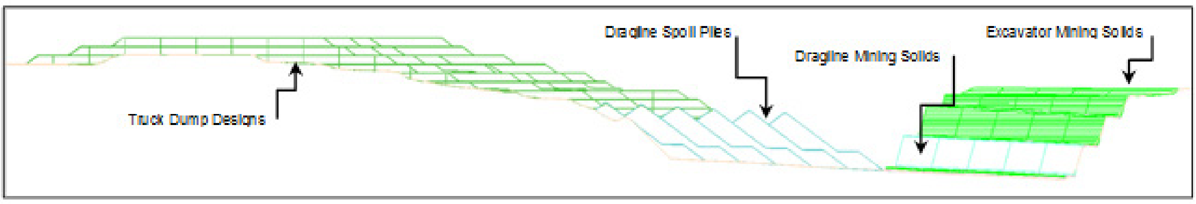

Figure 3 - Design Cross Section

2.3. MINING SCHEDULE

An initial mining schedule was generated along with the maximum potential effective mining rates for the relevant machines as shown in Table 2. In order for these rates to be fully achievable, the excavators must be fully trucked. Therefore, if these resources are waiting on trucks at any time, the rate will be reduced. This will result in the original mining targets not being met.

The resources were allocated to the north and south pits, with the coaling excavators being given the freedom to move on either side of the central hard bridge. The excavators were assigned into pools and then the resource leveling algorithm was run in Deswik Sched to determine the actual resource allocation. In Figure 5, the resource levelling produced the Base Case mining schedule where mining rates were not constrained by the available trucks.

2.4. LANDFORM AND HAULAGE SCHEDULE

The landform and haulage schedule was set up to include a relatively high level of detail including haul roads along the main ramps and dump access. A series of mining connectors and dump connectors were then generated to connect each individual mining block and dump block to the relevant haul roads. Additionally, haul roads were generated for the haul paths to the Run-of-Mine (ROM) location. Many coal operations have multiple truck types for a number of reasons, and to reflect this, multiple truck fleets were used in the case study. Three different truck classes and their number presumed to be available for use on the site included:

- Caterpillar 785D – Coal Body (8 trucks)
- Caterpillar 797F (8 trucks)
- Caterpillar 793D (unlimited trucks)

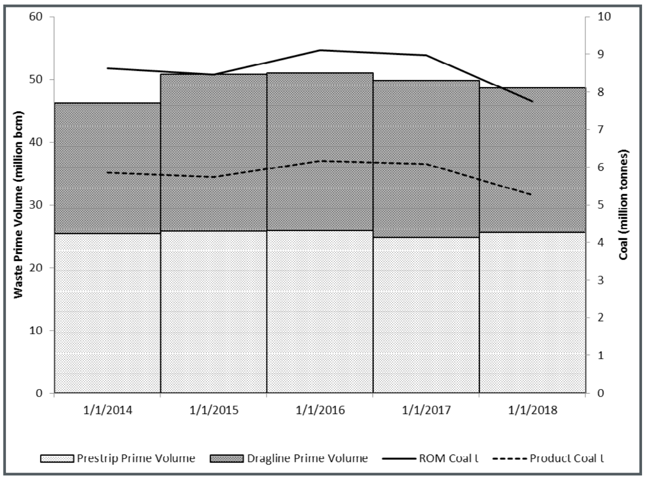

Figure 5 - Base mining schedule physicals

2.5. TRUCK LIMITED HAULAGE

The truck limited haulage functionality was set up in Deswik's Landform and Haulage Scheduler (Deswik. LHS). Material mappings were set up to preference the varying truck classes as shown in Table 3. The phases represent the order that trucks will be allocated to tasks. When the allocated trucks hours have been consumed in the first phase, the truck type from the second phase is used. If there are not enough truck hours for the time slice in all of the phases, the mining task is then pushed out to the next time slice due to inadequate trucks maintaining the mining rate.

Table 3 - Truck priorities

Material	Phase 1	Phase 2
Coal	785D	793D
Prestrip	797F	793D

Table 2 - Equipment Rates

Machine	Driving Property	Rate/h	AV	UT	Effective Rate/h	Movement / year
Dragline 1	m^3	2,600	90%	85%	2,000	17,520,000
Dragline 2	m^3	2,400	88%	85%	1,800	15,768,000
Excavator 1	m^3	1,350	83%	80%	900	7,884,000
Excavator 2	m^3	700	80%	80%	450	3,942,000
Excavator 3	m^3	1,500	83%	80%	1,000	8,760,000
Excavator 4	m^3	900	83%	80%	600	5,256,000
CO Excavator 1	t	800	85%	76%	520	4,555,200
CO Excavator 2	t	800	85%	76%	520	4,555,200

The availability of the trucks was dependent on both mechanical availability and utilization which included down days due to wet weather. The predicted wet weather down days is seen in Figure 6, which resulted in a variable overall utilization of trucks being available at any given period.

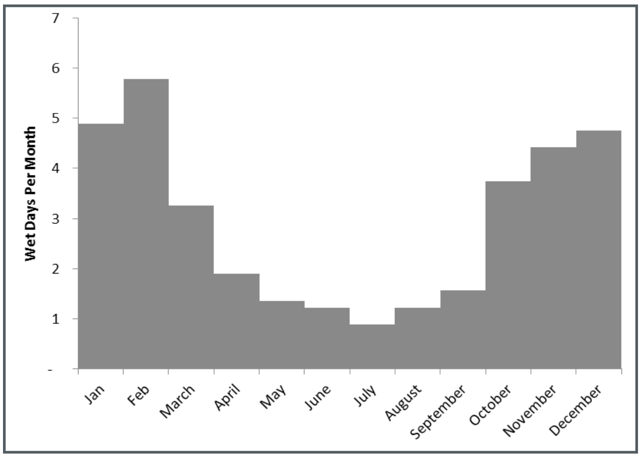

Figure 6 - Wet days affecting truck utilisation

The haulage scenario was then run with the truck limited functionality using monthly time increments. Multiple scenarios were run with increasing truck numbers in order to determine the highest value number of trucks for the operation. Where there were inadequate trucks for a given time period, the schedule pushed out the tasks to the next period and the resource leveling priorities re-determined the sequence of tasks.

2.6. COST MODEL

A cost model was constructed for the operation with costs obtained from generic industry values. Due to the variations in the material movements and processed coal tonnes, it was necessary to create a model to include both variable and fixed costs for the operation. The model was generated to include both the capital and operational expenses for individual primary and ancillary equipment. The calendar and operational hours were then used from each haulage scenario and mining schedule scenario to calculate the costs and the NPV. The major equipment costs and other related expenses are shown in Table 4 and Table 5 respectively.

Table 4 - Equipment costs

Equipment	CAPEX $/Cal h	OPEX $/Cal h	OPEX $/Cal h
CAT 797	94	128	324
CAT 793	81	128	171
CAT 785	54	128	97
Large EXC	201	137	459
Small EXC	132	133	311
Draglines	1190	180	2164
Drills	151	133	117
Dozers	60	133	139
16H Grader	22	128	53
24H Grader	51	128	107
Water Truck	30	128	93

Table 5 - Other operational financials

Other costs	Unit	Variable	Fixed
Blasting	AUD$/bcm	$0.50	-
CHPP	AUD$/ feed t	$4.00	$32 000 000
CHPP Other	AUD$/ feed t	$2.00	$8 000 000
Train Load	AUD$/ product t	$0.25	-
Offsite Rail	AUD$/ product t	$6.00	$5 442 176
Offsite Port	AUD$/ product t	$0.70	$5 44 217
Offsite Stockpile	AUD$/ product t	$2.50	$5 442 176
Other TS	AUD$/bcm	$0.30	-
Exploration	AUD$/yr	-	$4 000 000
Land ($/yr)	AUD$/yr	-	$2 000 000
Corporate office	AUD$/yr	-	$36 000 000
Management and Staff	AUD$/yr	-	$62 000 000
Royalty	% Revenue	-	7.3%
Disturbance	AUD$/ha	-	$30 000
Revenue	$AUD/ product t	-	$125

3. Results

3.1. PHYSICAL RESULTS

The physical quantities from the five year planning period were collated for comparison of the different scenarios, as shown in Figure 7. Initially, as the number of trucks increased, so did the material moved and thus the mined coal tonnes. As illustrated in the diagram, at first, the introduction of additional trucks (14th through to the 20th) contributed significantly to mining additional coal. The value added of this first lot of additional trucks was inflated because these trucks were moving mainly coal already uncovered by the draglines. The 21st to 29th trucks contributed to both the coal and overburden movements resulting in around 200,000 ROM coal tonnes per year per truck.

A point was reached where the schedule was no longer truck-constrained but was, rather, restricted by the loading units. This point is indicated on the graph (Figure 7) where the material moved, plateaus at 34 trucks. This demonstrated that there is a point where a surplus of trucks fails to add value in terms of material moved.

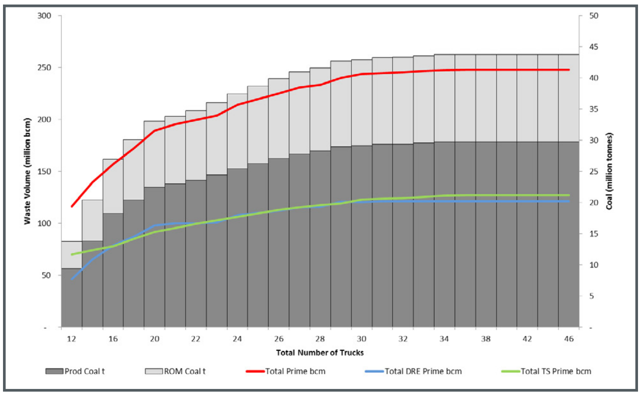

Figure 7 - Total equipment physicals over five year planning period

3.2. FINANCIAL RESULTS

Costs and revenues were estimated for each individual scenario to determine the costs and the resultant NPV. Costs were estimated using a combination of fixed costs for the operation, variable costs for the increased equipment and costs of processing additional coal, traded off against the increased revenue. Figure 8 shows the cost per product tonne of coal estimated. Results show that when the operation is under-trucked, the cost per tonne is increased due to the high operational cost and capital investment.

This drops quickly as the truck numbers increase, until the 29th truck is added. After the 29th truck, the costs remain fairly consistent due to the payoff of the additional truck. After the 34th truck, however, additional trucks without an increase in loading capacity, provide no additional value and thus increase the cost of the operation.

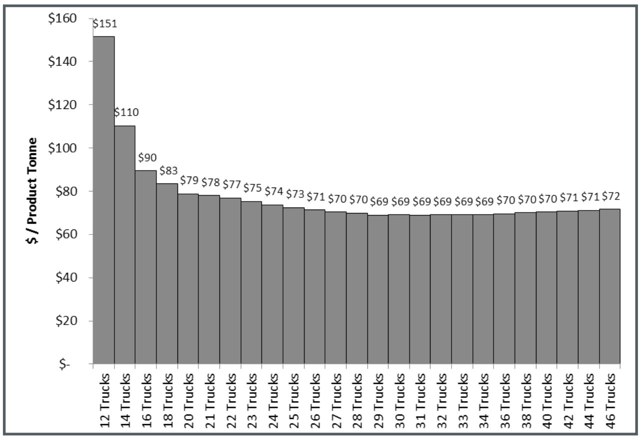

Figure 8 - Total cost per product tonne

Although cost is a relatively good indicator for determining truck numbers for an operation, a decision cannot be made without considering the time value of money. In order to capture this, an NPV was calculated over the five year mining schedule. The calculated NPV and ROM coal tonnes per year for the various scenarios are illustrated in Figure 9.

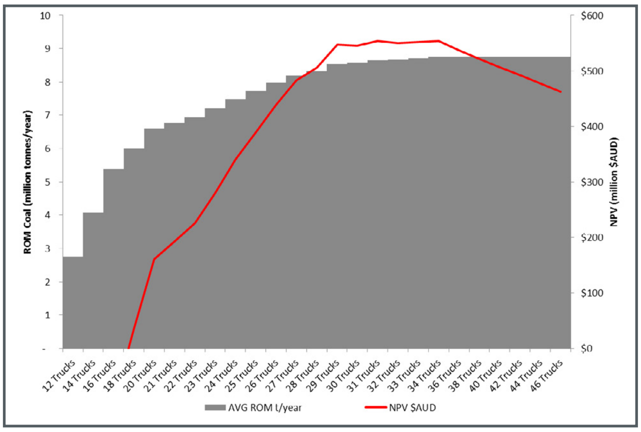

Figure 9 - NPV Comparison

As can be seen in the graph, additional trucks increase the NPV on a relatively straight line basis. However, after the 29th truck, the NPV flattens off with a decrease in the NPV after the 34th truck is added. This shows that the costs of the 30th to the 34th trucks are offset by their benefit.

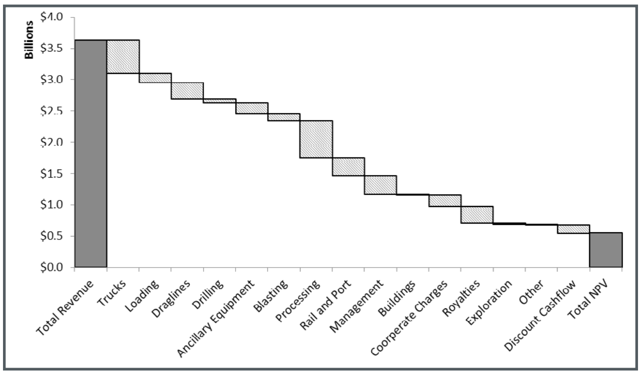

Figure 10 - Revenue and cost waterfall for 29 truck scenario

Figure 10 shows the cost breakup for the 29 truck case. Figure 11 shows the value each truck adds to the operation. The NPV calculations showed that, each additional truck adds a significant value over the five year planning period until the 29th truck. After this, additional trucks up to 34 trucks, manage to pay for themselves. From the 35th truck, the additional trucks start costing more than they return. The chosen number of trucks then could be between 29 and 34 trucks. However, it was found that having more than 29 trucks made very little difference to profit and actually increased the financial risk and liability of the operation.

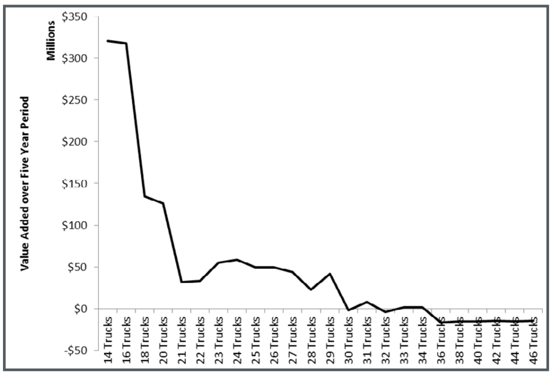

Figure 11 - Value added through purchase of additional trucks over five year period

3.3. DISCUSSION OF RESULTS

The analysis shows that varying the available trucks for the operation has significant financial impacts and risks. In the case study, the original mining schedule, that is the Base Case, represented an 8.75M t/y operation. This correlated with a requirement of 34 trucks as shown in Figure 9. However, the analysis also showed that this was an excess of five trucks to the most cost effective scenario. In terms of capital and operational costs, this is a significant investment.

The truck limited case showed that the optimal production for the operation is 8.54M t/y over the five year planning period correlating with a requirement of 29 trucks. This results in a loss of 210 000 ROM t/y compared to the base case mining schedule where the schedule was not truck limited. Figure 12 and Figure 13 show a comparison of the original schedule volumes to the most cost effective scenario where 29 trucks are used for the ROM coal tonnes and prestrip volumes respectively.

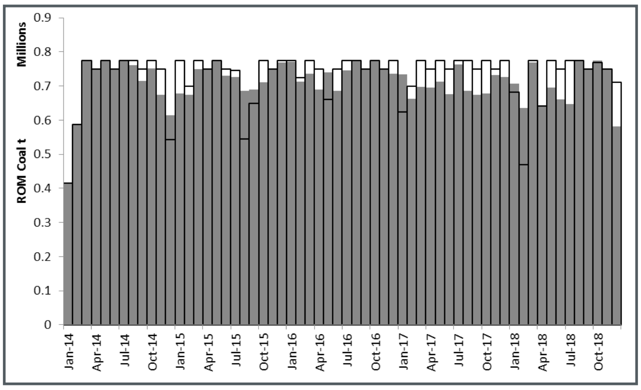

Figure 12 - ROM coal tonne comparison

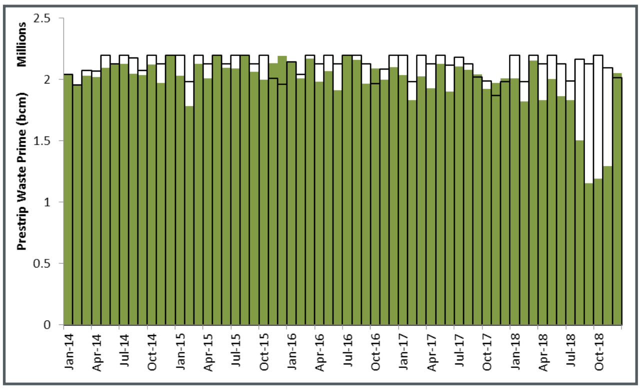

Figure 13 - Prestrip movement comparison

4. Conclusions

The case study shows that to achieve accurate and reliable mine plans, a thorough understanding of trucking requirements is essential. It is evident that, to a point, a single truck can significantly influence mine production. In this case study, although a total of 34 trucks were required to meet the original mining schedule, it was more cost effective to reduce the operation plan by 210 000 ROM tonnes a year, requiring a total of 29 trucks.

Truck limited haulage analysis is currently a non-mandatory component of many business mine plans. The study demonstrates though, that both a deficit and a surplus of trucks can significantly impact cost and NPV. Truck limited haulage modeling, whereby a dynamic haulage analysis is conducted, is therefore valuable especially in regards to cost efficiency, NPV, and in reducing financial risk.

With the recent advances in software technology (such as that developed by Deswik, truck limited studies can now be completed with relative ease. The question should be posed whether truck limited scheduling should become a mandatory component of business planning for a mining operation.

Please contact your local Deswik office for further information about the above case study or about any of the tools used.

www.deswik.com

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