Improving Volume Reconciliation Using Drone Technology in the Open Pit Mining Industry in Ghana - a Case Study

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ABSTRACT

The advent of drone technology in the surveying field has made complex estimation tasks simple, fast and reasonably accurate in the mining industry. Classical surveying methodology has also proven tedious, cumbersome and occasionally unsafe. A contractor was engaged to continue mining a cutback which had been started by another contractor. There was a challenge due to the pushback that was done on the already mined out pit. A huge interface was created that allowed materials to roll down into the bottom of the mined out pit. The new contractor had to mine the loose material generated by the previous contractor at a fee whiles the loose material generated by themselves was to be free of charge. Estimating the extra materials added on by the new contractor was a challenge so the company acquired a Vertical Take-off and Landing (VTOL) drone to assist in that delicate volumetric survey. The estimation was done by comparing the monthly new loose material introduced into the pit and the total volumes of new loose materials mined in the pit on monthly basis. Ideally, the two figures should sum up equally but due to material losses and factors beyond control, there was a marginal difference of **4%**. The total estimated reel material mined in the project was **535,906.04 BCM** whereas total estimated loose material added within the same period was **515,494.51 BCM**. This results could not have been achieved without the use of the drones surveying the walls to pick details of materials perching on the walls. It would also have been impossible with the classical terrestrial survey technology in the form of GPS and Total Station available. The only challenge was the size of the file which was difficult to manage on an ordinary computer.

1.1 Introduction

Surface mining is characterized as a capital intensive mining method with higher productivities and lower costs compared to underground methods. The material extraction is usually carried out in stages called phases or pushbacks. Each pushback contains waste and ore that are extracted from the mine through layers called benches (Artega et al, 2014). This is mostly done for a business case so that portions of the orebody can be extracted in advance to generate cash to fund or run the extraction of the other deposits and reduce the risk associated with the investment in case of any unforeseen eventuality. The initial cuts usually leave behind very deep openings and high interface that create a big room for materials to reel down into the mined out bottom during the subsequent pushbacks. These reels are generated by blasting activities that occur at the interface spilling materials down and clean ups from loading and hauling activities.

Volume estimation in open pit mining is usually based on the solid or in-situ materials moved. There is usually a twist to this during push backs. At the upper elevations during the initial stages of the push backs, reel down material will be accounted for as paid but they would not have been loaded and hauled. When the pushback gradually daylight into the levels where the reel down materials have settled, loose materials that have earlier on been accounted for have to be mined for free or at discounted rates depending on the contract. Whether its paid or not, it should still be estimated to rationalise truck factors if the ratio of loose to in-situ volumes is quite significant. Another reason for estimating is to split reel down volumes between different contractors who contributed to the reel down material if a particular pushback phase involved more than one contractor within the phase just as is the case for this article.

Classical terrestrial survey methodologies that employ the use of GPS and optical instruments like Total Stations have been used over the years to generate 3D Digital Terrain Models (DTM) for volume estimations. However, they have had their safety issues over the years. Additionally, they are laborious and mostly acquire data based on the discretion of the user. If there is a tired operator who intends to hasten and finish work quickly, they may be tempted to pick data at unreasonably wider intervals and overlook some details. Some areas such as the interface slopes of these pushbacks where the loose materials of interest are may be practically impossible to access. Since the arrival of the drone technology, these challenges have been generally overcome and recently, reasonable estimates of periodic reel down

materials are able to be estimated with reliably good accuracy. The drone available on site is a VTOL version which is easily operated in difficult terrains such as is found in the mining environment.

1.2 Objectives

This technical paper seeks to investigate the following:

- Estimate the volume of reel down material introduced into the bottom of the pit by the contractor month-by-month basis.
- Estimate the total monthly reel down material mined.
- Reconcile the reel added and reel mined figures.

1.3 Paper Structure

The paper will explain the various terminologies used in section 2; and section 3 to describe the methodology of calculating monthly reel down volumes introduced into the pit bottom and reel material mined monthly. Reconciliation of the two volumes will be discussed in section 4 conclusions and recommendations made.

2.1 Asbuilt

The term asbuilt is generally used to describe the true representation of the pit as found at any stages of the pit life including backfilled areas of already mined out sections, floor sheeting, rock buttressed areas for geotechnical purposes and generally any loose material sections within the pit. These loose materials are dumped into the pit for the purposes of supporting some weak slope faces, course way construction for water management and floor sheeting. The introduction of material due to blast spillage and excavations at the interfaces of the pit. The interface windrow materials are usually left for safety purposes and when the next blast pattern is to be laid, it gets pushed over the edge sending loose materials down the bottom of the pit contributing to the reel.

During the periodic pit surveys, everything is captured, when it is done with the drone. The surface generated thus gives a wrong impression of the true state of the pit. This could cause serious model depletion issues. In volume estimation, double accounting could also occur especially when these materials coming from upper elevations have already been accounted for. If it is also not quantified, truck factor estimated within a particular month where extensive reel down materials have been mined can be misleading especially in small volume pits. Asbuilt surfaces are important because it gives a good representative surface to aid in physical short term planning design options as these filled out faces create flexibility for ramps and accesses to be created in the pits to optimise the operations. These flexibilities would not have been available during the initial design phase of the pit.

2.2 Asmined

Contrary to asbuilt, an asmined surface describes the pit as it has been mined out without any backfilled reel material captured. This is usually generated through editing after the initial surveys and it can be very complex and cumbersome if it involves drone data. It is very important for metalliferous mines where model depletions and ore reserve estimations are critical for determining the life of mine (LOM). The reel materials are introduced into the asmined surface; it serves as a reference that enables the reel material to be properly quantified. Fig 2.1 is a section of an asbuilt and asmined surface for a particular portion of the pit to explain the terms.

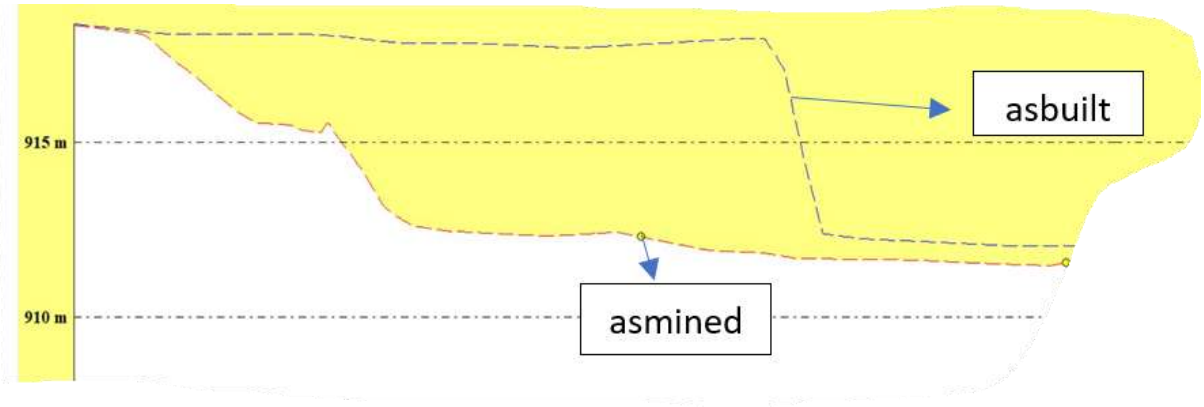


Fig 2.1 Cross section of a pit Asbuilt and Asmined for the same period

2.3 Fill and Reel Material

Both terms are used to describe loose materials in the pit apart from blasted materials. However, a fill material is mostly a planned dumping of a mined out material usually intended for the waste dumps with the permission of the client. Reel materials are those that are spilled down the pit bottom from operational activities such as blasting and loading. Generally fill materials are paid for when rehandled either through volumes or predetermined rates agreed between the client and the business partner. In the events of a contractor change, all reel generated by the previous contractor prior to the start of work by the new contractor is quantified before the new contractor commences work.

3.1 Monthly Reel Estimates

In estimating the reel mined within a particular period, asbuilt surface of the previous month is compared to the asbuilt of the current month. These asbuilts are generated from the contours of drone surveys at the interfaces where conventional survey methodologies are unable to access. The Digital Terrain Model (DTM) of the two surfaces is formed for these purposes. Example is displayed in the figure 3.1 below. The blue DTM of the asbuilt surface for the previous month and the brown colour is the DTM for the current month under consideration.

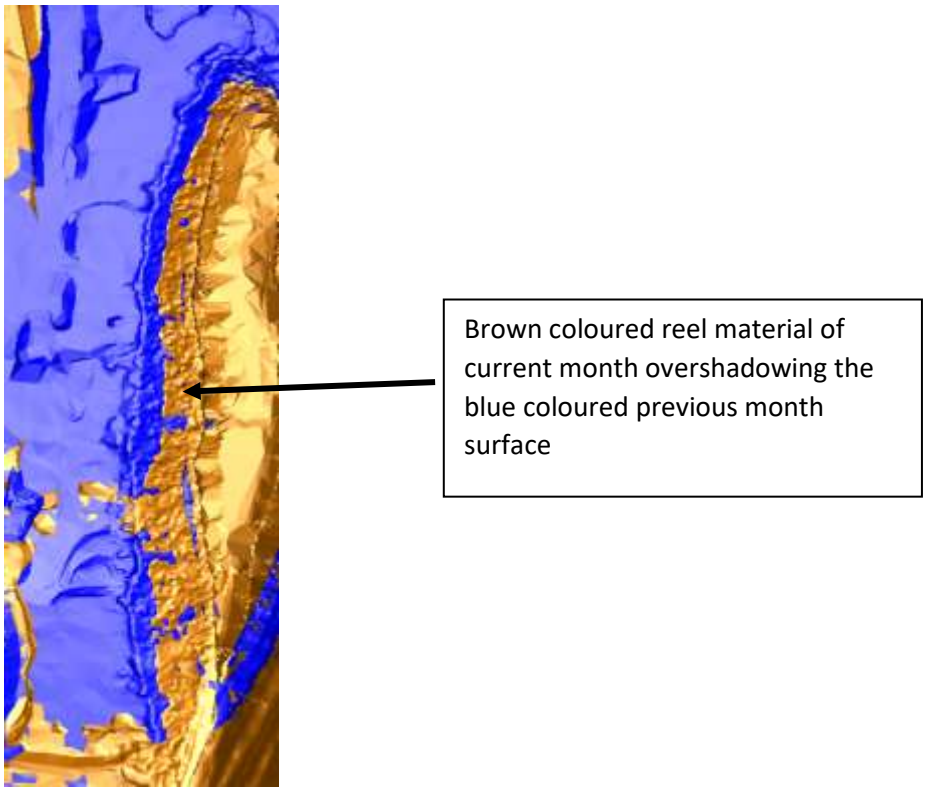
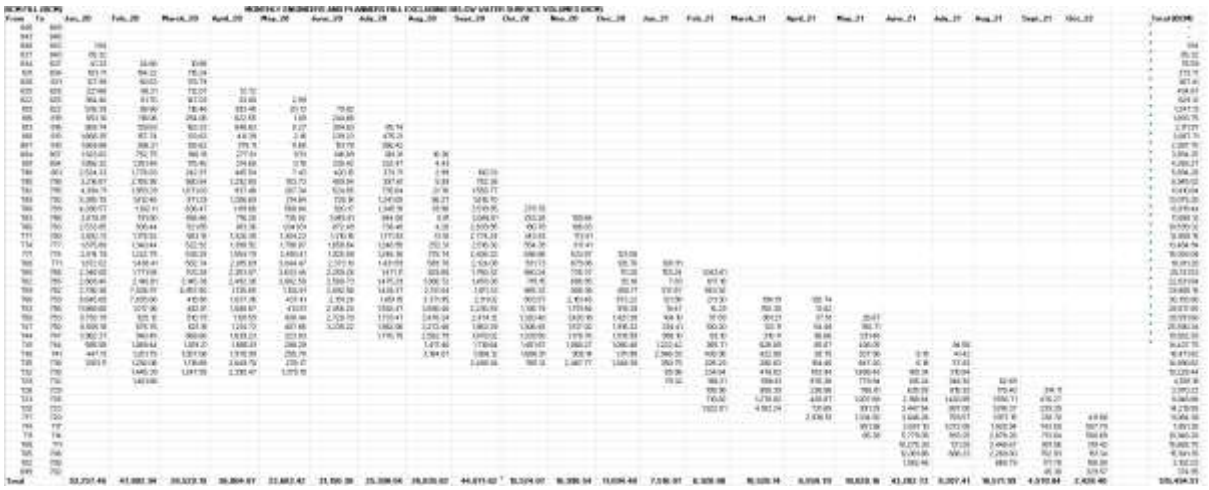


Fig 3.1 Comparison of two Asbuilt surfaces

At the end of the month, after mining the upper elevations, the reel down material increased hence the brown colour overshadowing the blue colour in the direction of the arrow in fig 3.1. It was also clear that some of the reel from the previous month also dislodged from their positions to the bottom thus few pockets of blue patches permeating through the brown. Using the two surfaces, the estimated reel added into the pit is calculated. Table 3.1 indicates the total reel volume from various benches at the upper elevations for the entire project duration.

Table 3.1 Monthly Reel Added by Benches



A total of 515,494.51BCM reel material was estimated to have been added into the pit which was eventually mined out.

3.2 Monthly Reel Mined

These reel materials in the pit was mined at various months included an existing reel material in the pit generated by the previous contractor that complicates the estimation. Three different surfaces has to be kept and edited anytime there is a survey of the pit in order to make that split between a previous contractor's reel (fill) and that of a current contractor. The three surfaces are the asbuilt, asmined and the contractclose asmined (an asmined that has the closing reel material of a previous contractor at contract end). On a periodic basis, boundaries are generated within the zone containing loose material and surface to surface volumes calculated between the two asbuilt surfaces (previous and current month). However, because the volume generated will be for both loose and in-situ volumes, there should be a way of estimating the in-situ volume and deducting them from the total volume generated by the two asbuilt surfaces. This is accomplished by using the same boundary to run the volume between the two asmined surfaces. The in-situ volume generated from the asmined data is used to adjust the volume calculated between the two contract termination asmined surfaces to determine the proportion of that volume that is truly loose. Table 3.2 shows a summary of the above explanation for the month of October 2021.

Table 3.2 Monthly Reel Mined by Benches

FROM ASBUILT			FROM ASMINED	FILL + REEL	FROM FILL ASBUILT	FILL MINED - INSITU			
From	To	Cut Vol	Insitu Cut Vol	Loose Mined	Contractclose Mined	Contract Close Fill Mined	BCM	Reel Mined	BCM
702	705	34485.133	22787.949	11697.184	32398.769	9610.82		2086.364	
705	708	80124.439	38975.186	41149.253	63489.664	24514.478		16634.775	
708	711	40559.056	16718.398	23840.658	31612.322	14893.924		8946.734	
711	714	16575.153	6178.427	10396.726	13304.965	7126.538		3270.188	
714	717	5290.45	0	5290.45	3373.643	3373.643		1916.807	
717	720	2933.612	0	2933.612	1912.478	1912.478		1021.134	
720	723	1808.256	0	1808.256	930.648	930.648		877.608	
723	726	994.528	0	994.528	606.876	606.876		387.652	
726	729	606.711	0	606.711	425.022	425.022		181.689	
						63394.427	46,958.83	35322.951	26,165.15

On a monthly basis, this estimation has been generated for the pit till the total reel is completely exhausted. After collating the month-on-month reel material mined during the project, the total was 535,906.04 BCM.

3.4 Discussion of Results

Finally, the results obtained by the reel mined was about 4% higher than the total estimated reel materials added. Reconciliation of volumes within +/-5% is acceptable within the industry and especially where the variance is expected since the surface used for the reel addition had rocks of different compaction from the surfaces used for the reel mined.

4.1 Conclusion

In mining, no single volume should be overlooked since every cubic of material moved has a cost implication. In this project, not all the volumes discussed here is put up for payment but to make sure the mining physicals are rationalised to prevent any controversies.

4.2 Recommendations

At the end of the project, the recommendation based on the outcome of the results is that tracking the volume of reel materials added into the pit should ideally be on a daily basis but this is virtually impracticable. This is because mining is continuous and dynamic. Daily reel materials are added and when the pit is nearing the bottom, some of these materials added within the month could be mined out without being captured in the reel added and mined volumes in the mining benches.

REFERENCE

Artega, F., et al.: Schemes of Exploitation in Open Pit Mining: Mine Planning and Equipment Selection Conference, DOI:10.1007/978-3-31902678-7 126