UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

INVESTIGATION OF THE FACTORS THAT INFLUENCE THE MINE CALL FACTOR WITH PARTICULAR REFERENCE TO ILLEGAL MINING AT DRIEFONTEIN YA RONA SHAFT

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ABSTRACT

The Mine Call Factor (MCF) will be 100% in a perfect mining environment. This is when no gold loss occurs throughout the mining process from the in situ gold blasted on the stope face through to the processing plant and the estimation of the gold produced (called for) is perfect. Ya Rona shaft, part of the Driefontein Operation, showed a downward trend in the MCF from 75% to 70% over the last five years. This study was conducted to determine the possible causes behind the regression in the MCF over this period.

The loss of gold at Ya Rona shaft currently amounts to a 30% loss, assuming an MCF of 100% is achievable. Over the monitored period, Ya Rona shaft has lost approximately 109 kg per month, which amounts to R86,9 million losses in revenue at an assumed gold price of R800,000/kg. Detailed investigations were done on the MCF to determine the possible causes and quantify the losses and gains. Data were analysed on the ore flow, and the variances were investigated. The increase in illegal activities from “Zama Zama” was also of special interest. The investigation has shown that the illegal miners contribute to a 1% loss on the MCF (in the current working areas.) The gold loss in the old mined-out areas and those not in the mine plan is unknown. The mine survey accuracy, sampling and assay methods were also investigated for any anomalies.

Quantitative and qualitative methods were used to determine the possible cause of the low MCF at Ya Rona shaft. The Ore flow data and the Technical Statement were obtained for 2021. The data received includes tonne broken on the face, sweeping percentage, hoisted, face grade, belt grade and yield. The data was analysed to identify variances, and these variances were subsequently investigated. Planned task observations were done on the underground mine surveyor and underground sampler. The accuracy of the mine survey measuring results and sampling methods was checked and analysed (quantitative data).

It was found that the real gold loss can be attributed to poor drilling and blasting practices that lead to poor fragmentation and gold loss through water use.

The underestimation of the widths and height in the gully and the underestimation of accumulations led to apparent gains in tonnes. Accumulation of broken ore and mud is left behind when the mining personnel do not clean out properly or timeously.

The MCF can improve significantly once all these factors have been addressed. Explosives have been changed to an emulsion product to improve fragmentation and water control measures have been implemented (deeper sumps and better pumps). Steps are taken to keep illegal miners out of the underground environment and improvements have been made to the quality of sweepings. The use of blasting barricades on the face is monitored and mud and accumulations are cleaned out regularly.

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1 INTRODUCTION

1.1 Background

A significant amount of gold-bearing ore that has been mined is lost or left underground and not removed. This research report looks at the factors influencing the mine call factor (MCF) on a gold mining operation and the actual losses or gains on the final product. Not all the gold is accounted for in the plant, which was called for by the mine survey measuring methods.

The MCF is a well-known and essential topic in gold mining. Storrar (1981) defined it as a "ratio expressed as a percentage, which the specific product accounted for in recovery plus residue bears to the corresponding product called for by the mine's measuring method". MCF is calculated using the formula (Storrar 1981):

$$\text{MCF} = \frac{\text{Mineral content accounted for from ore worked (recovery + residue)}}{\text{Mineral content of ore worked based on current sampling}} \quad \text{X} \quad 100\%$$

The measured product is the mining area that has been blasted in a 23-shift period and valuated from sampling methods. Ore accounting reconciliation measures at Ya Rona shaft indicate 30 per cent of unaccounted gold loss, or approximately 1 304 kg for the year 2021, as per the technical statement in Appendix 5, which amounts to approximately R1 billion per year. The losses and the impact of illegal miners have never been investigated at the Driefontein Operation, a part of Sibanye-Stillwater, and are not well understood due to the difficulty in estimating gold loss due to illegal mining (qualifiable information) (Sibanye-Stillwater, 2021).

Different cleaning methods of the broken ore in stopes can affect the MCF; for example, excessive water use can wash fine free-gold particles into the cracks and drains before the ore can be trammed. Due to safety concerns related to silica dust produced from the quartzite rock while blasting, dry cleaning of stoping areas is not feasible, water is used to prevent the dust from becoming airborne, and silica dust exposure is known to cause disease and lung cancer. There are different cleaning methods, for instance, water jets or cleaning with a scraper and winch.

Facilities for sample preparation and chemical analysis (fire assay and instrumental techniques) and is equipped with Laboratory Information Management System(“LIMS”) software. This software assists in effectively and efficiently managing sampling data. It handles data from underground sampling, geological drilling and samples from the concentrators and smelter. Underground samples are analysed at the assay laboratory that is Sibanye-Stillwater owned and is situated on the Driefontein operations.

The quality control procedures for the assay process include the following:

- Regular Internal audits;
- Submission of blanks and standards: and
- Round-robin bench marking.

The Driefontein Assay Laboratory is certified by the South African Accreditation System (SANAS). External audit forms part of the accreditation process. The following audits are conducted:

- Four internal audits by Sibanye-Stillwater;
- One external audit; and
- One SANAS audit.

The research also investigated the sampling procedure for grade determination of the stope face (gold content) and the methods to minimise product loss concerning alternative cleaning methods, that is, the sweepings of mined-out areas without water.

Illegal miners, also known as “Zama Zamas”, threaten the gold mine and affect mine employees' revenue and safety. Illegal miners also intimidate mine employees with threats to their person and families to get assistance.

Considering the following issues as possible reasons for the increase in illegal mining underground:

- The decline in available surface sources, which include tailing dams, waste rock dumps, surface dumps;
- Shallow mines allow for easy access for illegal miners;
- The increase in living costs; and
- Lack of job positions (employment) in the mines.

Figure 1-1 demonstrates the Mineral Resources and Mineral Reserves for Driefontein, the Mineral Resources shown with the gold line and the Mineral Reserves shown with the grey line have decreased from 2018 to 2019.

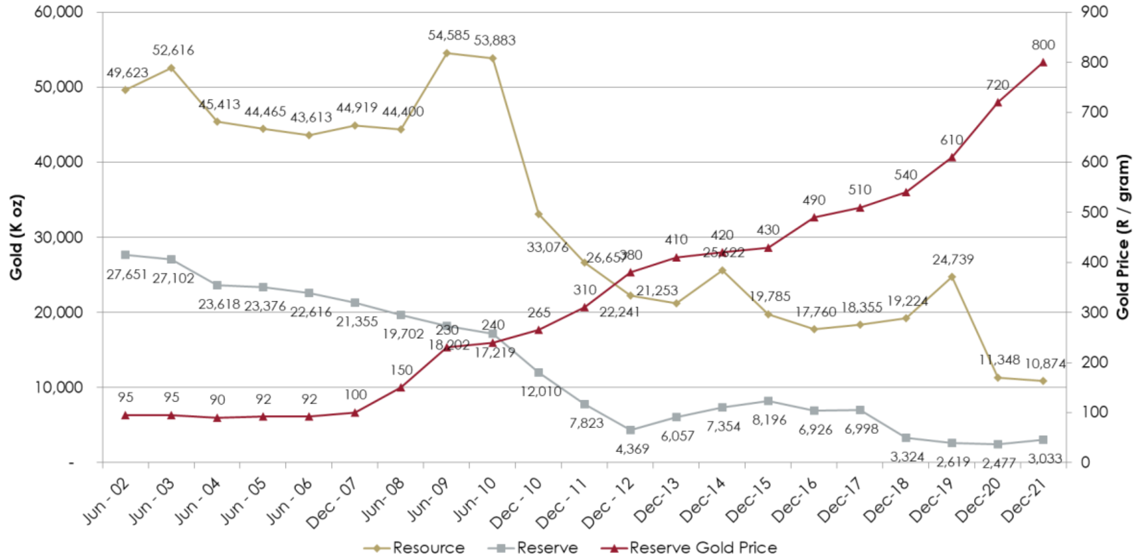


Figure 1-1: Mining gold price and gold content (Wild, 2021b)

The decrease can be attributed to the increase in cost and higher pay limits required to realise a profit; Table 1-1 shows the rise in pay limits per shaft from 2017 to 2020.

The gold content is measured in grams and the gold value is expressed in g/t (grams per tonne), the content of gold (grams) in one metric tonne of rock. Centimetres-grams per tonne (cmg/t) is the product of the width in cm and the value in g/t. This is used when tonnages and content for several mining stope areas have to be calculated (Gold Fields Training Service, 2000).

Table 1-1: Driefontein pay limits from 2017 to 2020 (Wild, 2021b)

Summary							
Shaft		**D1**	**D2**	**D4**	**D5**	**D8**	**Underground**
Total Pay Limit	cm.g/t or g/t	1870	1790	2570	1510	1110	1740
Direct Pay Limit	cm.g/t or g/t	1600	1470	2150	1280	940	1470
C2020 Pay Limit	cm.g/t or g/t	1870	1790	2570	1510	1110	1740
C2019 Pay Limit	cm.g/t or g/t	2200	0	2820	1530	1050	1750
C2018 Pay Limit	cm.g/t or g/t	1670	2240	2520	1410	900	1480
C2017 Pay Limit	cm.g/t or g/t	1360	2100	1970	1210	780	1230
Unit working cost	R/ton	4 243	2 018	4 283	3 387	2 664	3 593

A pay limit is a calculation to determine if a stope can mine, realising a profit or will incur a loss. The pay limits increased by 23,3% from 2017 to 2020 (2570 cmg/t -1970 cmg/t)= 600 cmg/t, 600 cmg/t/2570 cmg/t = 23.3%), which has a domino effect leading to fewer areas to mine, resulting in fewer mine employees being employed, leading to a potential increase in illegal mining.

Table 1-2 is an example of a pay limit calculation used on the mine to determine the pay limit and can be used to calculate the cut-offs further. The actual cost is used with the planned tonnes to get to the unit working cost. The pay limit and grammes per ton are calculated from the gold price and the cost per ton.

Table 1-2: Driefontein Pay limits 2020 (Coetzee, 2020)

Driefontein Ya Rona Shaft

C2020 BP PAY LIMIT CALCULATION.

PARAMETERS

Working cost	Rands	120,029,222
Capital	Rands	
Total NCE	Rands	120,029,222
Tons milled	Tons	28,024
Unit working cost	R/t	4,283
Gold price per kilogram	Rands	610,000
NCE Margin	%	0%
NCE Gold Price		610,000
Gold required to break even	kg	196.769
Required recovery grade	g/t	7.022
Stoping width excluding. gullies	cm	148
Density	t/m3	2.75
Mill Width Factor		1.78

	%	m²	Width (cm)	Tons	Grade (g/t)	Content (kg)
Recovery	97%	3861	264	28,024	7.022	196.769
Residue	3%			28,024	0.217	6.086
Milled				28,024	7.2	202.855
Mine call factor	72.7%			28,024	10.0	278.928
Total ore tons hoisted				28,024	10.0	278.928
Less Reef dev. to mill	0.1%			36	19.2	0.692
Less Waste dev. to mill	21.5%			6,022		0.000
Stope ore hoisted				21,966	12.7	278.236
Less Discrepancy "Shortfall"	11.8%			3,318		
Total stope ore measured				18,648	14.9	278.236
Dilution Other Sources Stoping	10.5%			2,945	1.9	5.610
Total measured stope ore		3861	148	15,703	17.4	272.626

	Total Pay Limit		
	VALUE (cmg/t)	**GRADE g/t**	**STOPE WIDTH (cm)**
C2020	**2570**	**17.4**	**148**

1.1.1 Background of Ya Rona shaft

This research was conducted at Sibanye-Stillwater Driefontein Operations, Ya Rona shaft (Driefontein Shaft – D4), located on the West Wits Line of the Witwatersrand Basin near Carletonville, South Africa, approximately 70km south-west of Johannesburg as shown in Figure 1-2.

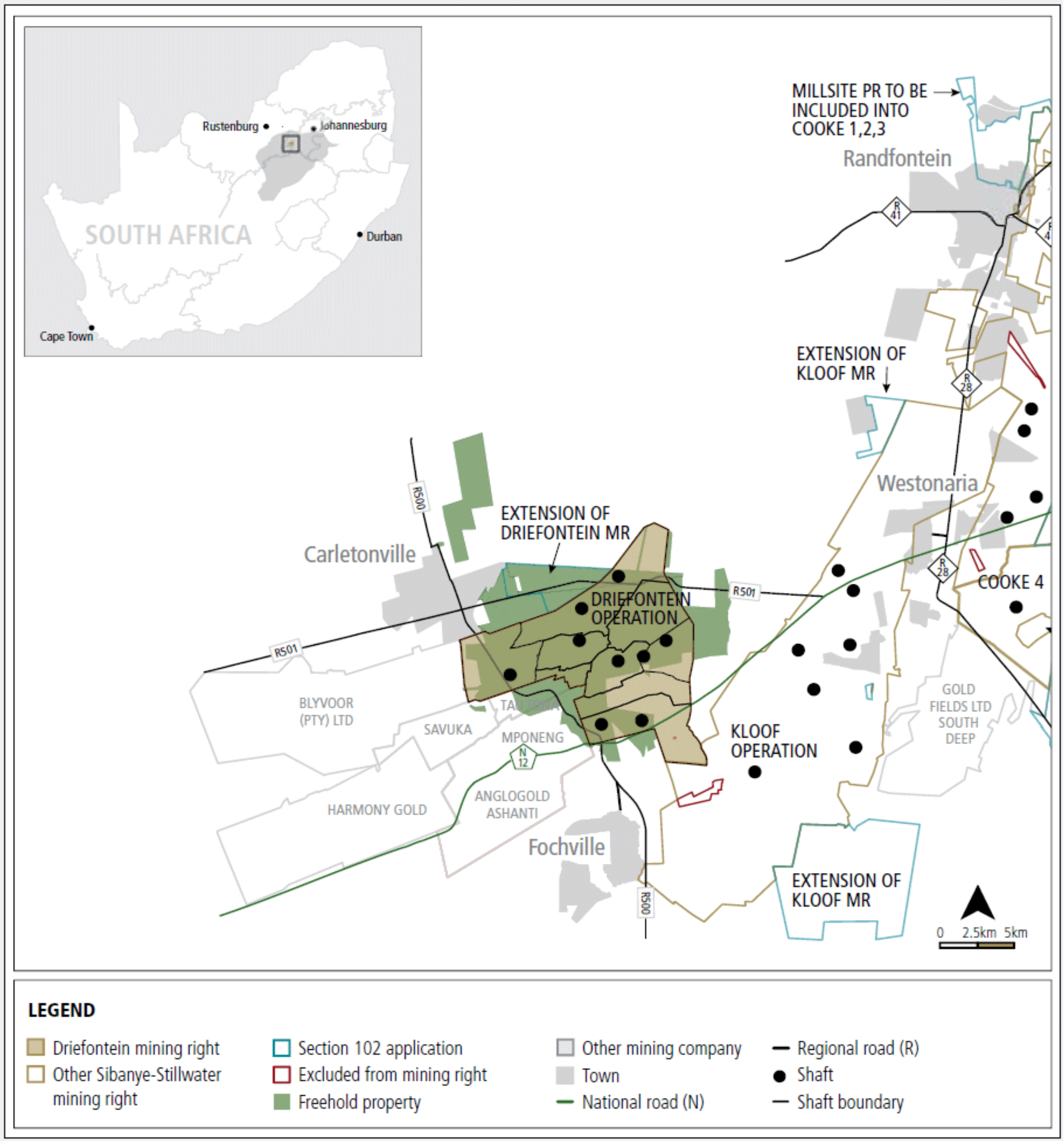


Figure 1-2: Locality Plan of the Driefontein Operation (Gold Fields 2011)

The Witwatersrand Basin is a 6 000 m thick sequence known as the Witwatersrand Super Group (Gold Fields, 2011). Figure 1-3 shows a 3-dimensional schematic view of the Driefontein orebody, illustrating the sediments and the minerals deposited from a fluvial system.

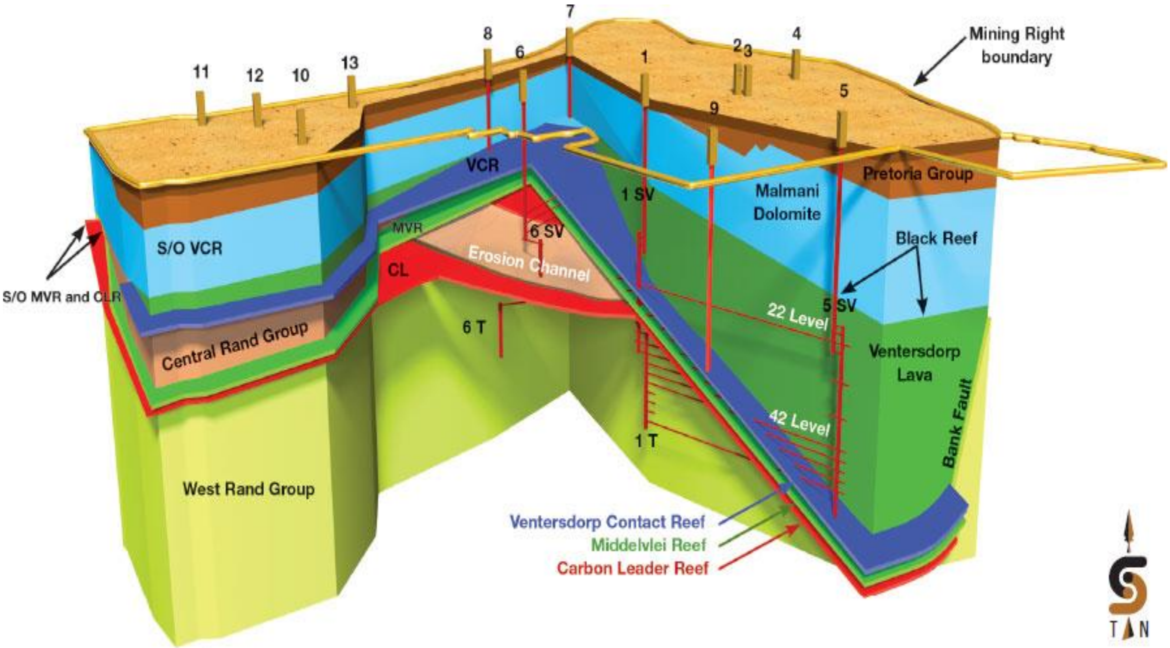


Figure 1-3: Schematic 3D view through the Driefontein ore body looking north (Sibanye-Stillwater, 2013)

In March 1945, the West Driefontein Gold Mine was registered and began sinking the No.1 and No. 2 shafts. The extent of the mine was 12.5 km on strike and 8.5 km on the dip. In May 1968, East Driefontein registered and merged into Driefontein Limited in 1981. The Driefontein Operation is a conventional underground mine consisting opening of 13 Shafts, with only four currently operational shafts and one carbon–in–pulp processing plant. Three primary reefs are being exploited at Driefontein: the VCR, the CLR and the MVR. The research was carried out on the Ventersdorp Contact Reef (VCR), which has a regional dip of 21° south-south-east. The variation in dip is due to the terrace -and -slope topographic development during the original deposit. The VCR strikes east-northeast at a depth of 800 m to 3200 m (Gold Fields 2011).

The primary mining method at Ya Rona shaft is narrow reef stoping with wide raises, with breast panels, as shown in Figure 1-4.

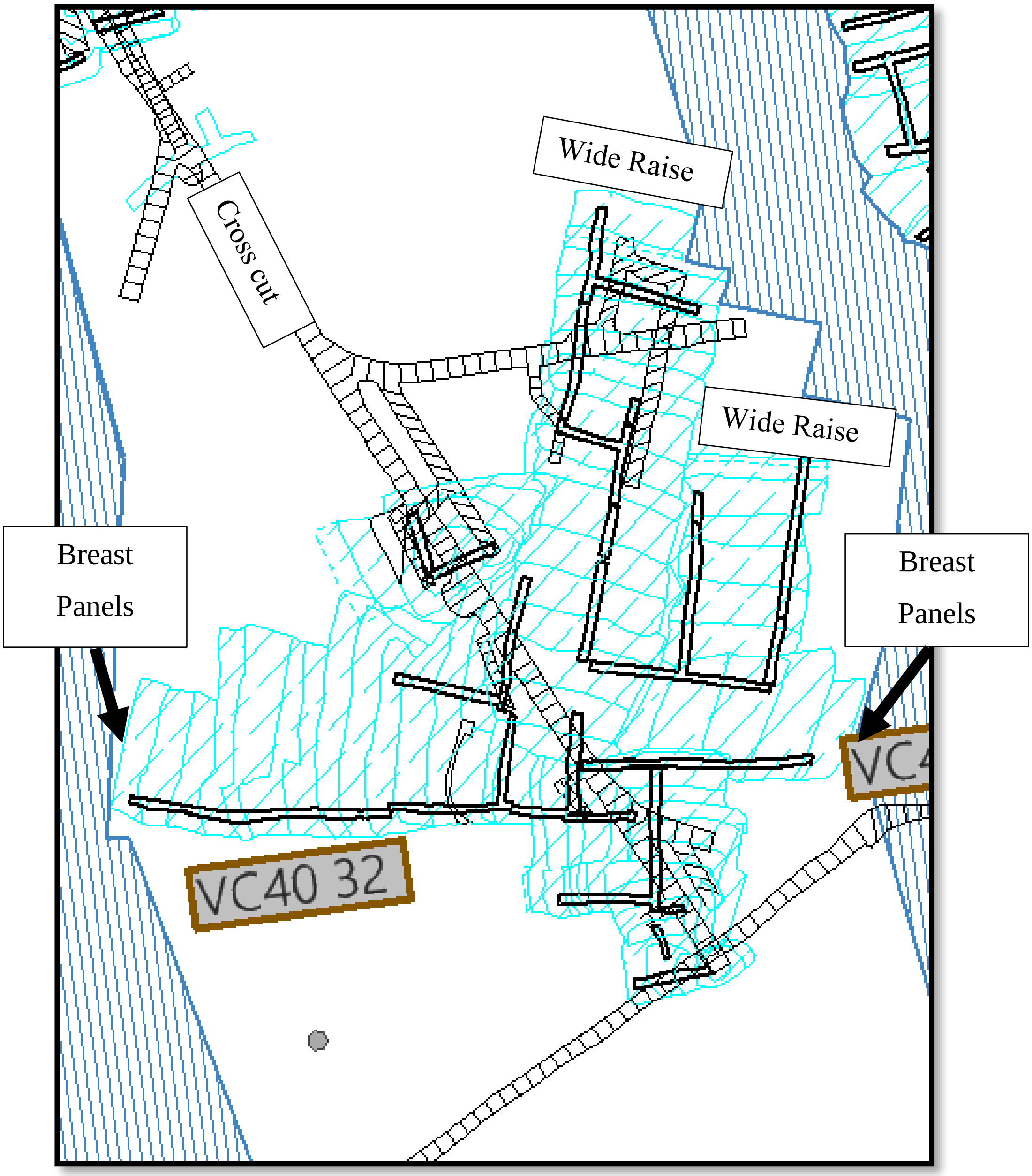


Figure 1-4: Different mining methods (Sibanye-Stillwater, 2021)

Mining methods that are used at the Ya Rona shaft are:

- Wide raise: 15 m wide and 1.8 m high;
- Breast panel: maximum 30 m long and 1.1 m to 2.2 m high depending on reef package; and
- Stoping: depends typically on the reef package with a limitation of 1.2 m stoping width, which is the lowest and 2.2 m stoping width, the highest. The stoping width includes the footwall waste with the reef width, internal waste width and the hanging wall width. This stoping width limitation is for the mining personnel who must travel in and out safely and the different types of support being used (Gold Fields 2011).

Ya Rona shaft contributes 29 per cent of the Driefontein Operation's gold production, with an MCF at 69.3 per cent, meaning a 30 per cent unaccounted gold loss. The unaccounted gold loss at Ya Rona (D4) is higher than the other shafts in the Driefontein Operation, as shown in Figure 1-5.

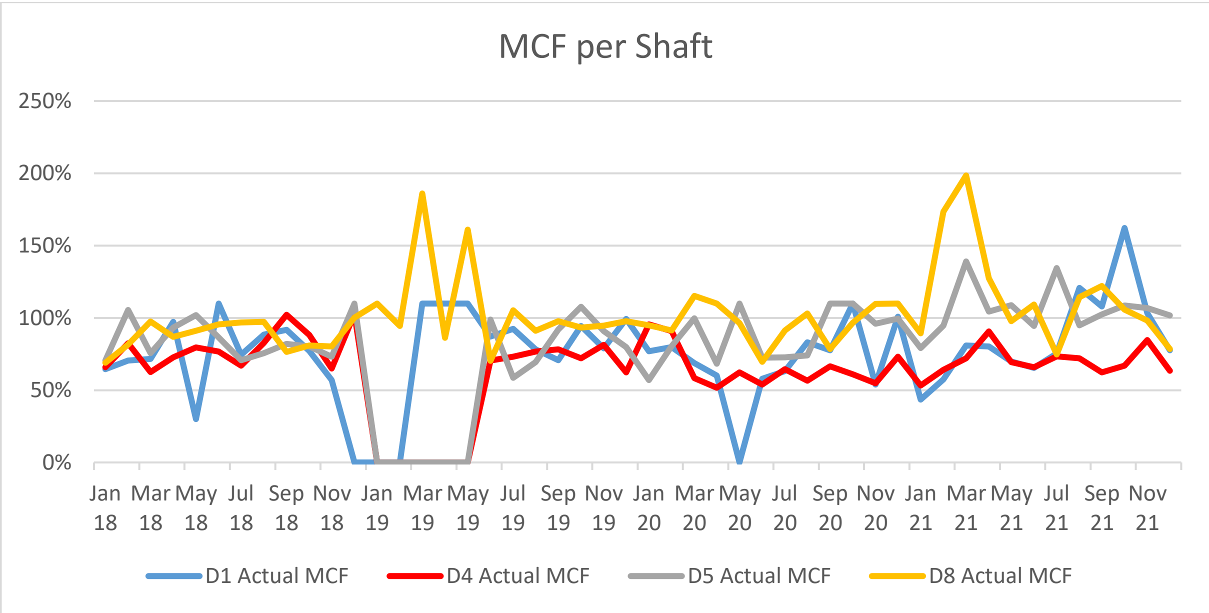


Figure 1-5: MCF per shaft from January 2018 to December 2021 (Gouws, 2021)

1.2 Problem Statement

There is a difference between the monthly estimation of gold by valuation methods and the final gold accounted for by the recovery process. The question to be addressed is, what are the variables contributing to the poor MCF?

There has been a downward trend in the MCF at Driefontein Ya Rona shaft (D4) from 75 percent to 69 percent over the past five years, as shown in Figure 1-6.

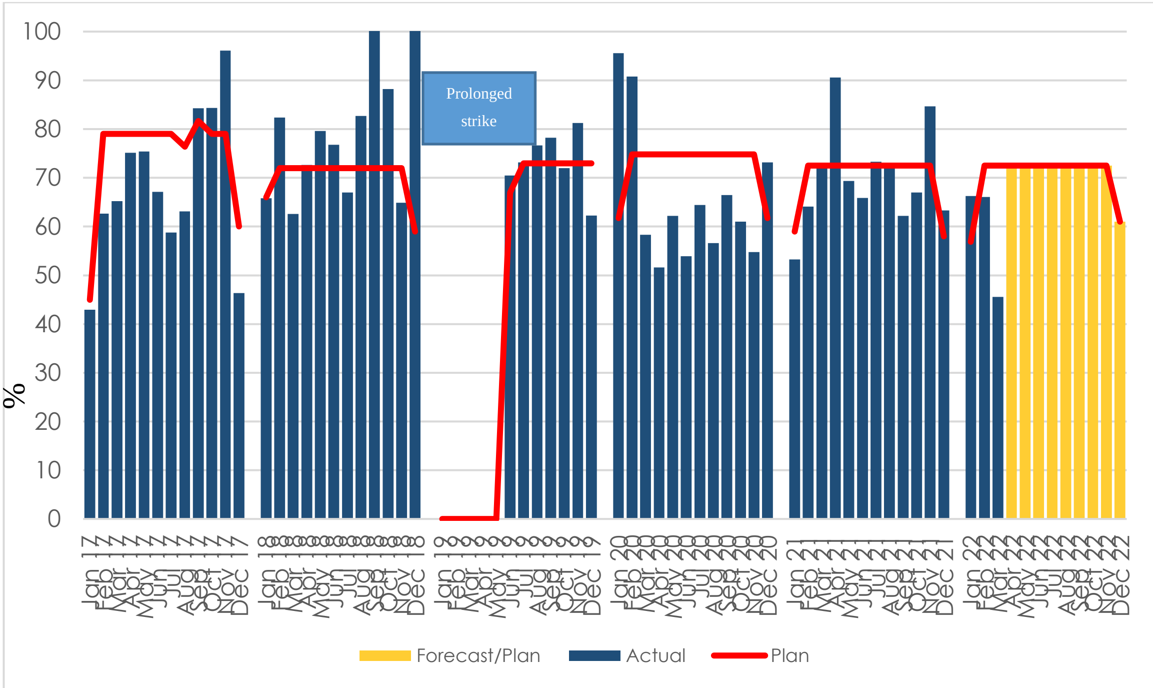


Figure 1-6: MCF graph D4 for the last six years from 2017 – 2022 (Sibanye-Stillwater, 2022)

The average MCF for the Ya Rona shaft at the end of December 2021 was 69.3%. The gold called for by the mine survey measuring methods amounted to 4 250 kg, but the gold accounted for by the plant was only 2 946 kg. This unaccounted gold is 1 304 kg, which amounts to approximately R1 Billion lost in revenue.

Using the historical MCF as a guide for the new plan would result in higher cut-off grades for the business plan and the life of mine in this marginal operation. The areas that were classified as pay will become unpay, which translates into fewer areas to mine, with less face length, which will impact the flexibility of the operating shaft. Therefore, a slightly higher stretch target was proposed, which had to be supported by a rigorous action plan to ensure a higher cleaning percentage.

The research carried out was to determine what is causing this downward trend in the MCF and the causes of the gold loss. At the operation, a two-year average MCF is used as the benchmark in the business plan for the next year as guidance from the executive team, shown in Table 1-3 (Wild, 2019).

Table 1-3: Top-down goals of Ya Rona shaft for the MCF and the recovery factor (Wild, 2019)

		D4			
		Previous Ops C18	12MTH	LOM 2018	Mining Unit
Mine Call Factor - gold	%	70.6%	70.1%	70.3%	71.2%
Plant Recovery Factor - gold	%	96.6%	97.7%	96.6%	97.0%

Guidance is given through a set of suggested modifying factors that can be used as a benchmark for the monthly reconciliation and are reviewed annually by the technical consultants to guide the shaft to a profitable state.

Various factors can affect the actual or apparent loss of gold at an operation, including, but not limited to, the sampling method to determine the grade on the mine may have procedural issues that affect the MCF calculations. Similarly, partial sweeping of mined-out areas may have an effect, or the actual cleaning method and activity may cause gold loss, affecting the MCF calculation. Different cleaning methods are used in underground mining, for example, cleaning with a scraper, water jets and washing the broken ore with water.

The actual number of illegal miners in the underground workings at the operations is not known. The capture and arrest of illegal miners is increasing, so presumably, there is an increase of illegal miners underground. There is no exact measure of how much gold is lost due to the activity of illegal mining and how many mine employees are assisting them by giving or selling food and supplies.

The historical MCF, as shown in Figure 1- 6, has an average for 2021 of 69.3%, indicating that Ya Rona shaft has a serious MCF problem that needs to be resolved.

1.3 Justification for Research

The motivation of this research report was to determine the factors influencing the MCF at Ya Rona shaft with emphasis on the impact illegal miners have on the MCF. This investigation will give an overview of the negative influence that illegal mining may have on the mining industry and the potential cost incurred, and the loss of revenue to the mining industry.

The report will also investigate the sampling procedure used to determine the working place grades (gold content). The report will also examine methods of minimising gold loss, emphasising alternative cleaning methods, that is, the sweepings of mined-out areas without water. Audits are done regularly on blasting barricades to ensure quality sweeping is achieved at the measuring period's end.

The objectives of this research report are to:

- Investigate and determine the impact on the MCF and the final product attributed to illegal mining to better understand going forward to perform gold-loss estimations;
- Investigate the real and apparent losses to the analysis of data from sampling and mine survey; and
- Investigate alternative cleaning methods in the working places to reduce gold loss.

This research report will make the following assumptions in investigating illegal miners and the MCF.

- The estimation of gold theft;
- The impact on the MCF; and
- The findings of the research will be estimations.

1.4 Previous Work

An audit team carried out audits on the MCF at Ya Rona shaft in 2021 over four months. Table 1-4 highlights all the areas that were monitored (Sibanye-Stillwater, 2021).

Table 1-4: MCF dashboard

MCF Dashboard D4#					
1ITEM	Description	Jan-21	Feb-21	Mar-21	Apr-21
MCF Compliance	YTD MCF Compliance - Month Current	81%	75%	85%	86%
MCF	Current (Actual/Planned)	53%/59%	64%/73%	72%/73%	91%/73%
	YTD (Actual/Planned)	53%/59%	59%/67%	64%/69%	69%/70%
Fragmentation	U/G	125	125	129	127
	Belt	86	90	88	84
Drilling	Socket Length	3	3	4	4
	Stope Width (Actual/Ideal Planned)	172/162	172/166	161/186	165/182
	% Reef fully exposed	92%	88%	100%	100%
Cleaning	Total Sweepings % (Current)	96%	97%	101%	85%
	Total sweepings % (YTD)	96%	97%	98%	95%
	X/cut cleaned to standard (Actual/Planned)	7/11	7/10	8/10	8/10
Containment in Gully's	Gully to standard (correct Depth and/or gum planks)	94%	85%	100%	80%
	Gully with spillage	0%	10%	0%	5%
Water Control	X/cut Pumps (Actual/Planned)	8/8	9/10	8/9	10/10
	In-stope Water Control (Actual/Planned)	15/17	18/18	16/17	17/17
	Excessive water from Box	1/2	2/4	1/5	2/6
Barricades	Barricade installed (Actual/Planned)	16/16	15/15	29/29	11/11
Panels above 4000 cm/gt	Concreted X/cut (Actual/Planned)	22/22	22/22	22/22	22/22
	Vacuum Cleaning (Actual/Planned)	3/3	3/3	4/4	4/4
	Gates (Actual/Planned)	9/9	9/9	10/10	10/10

The audit team investigated the following per panel at Ya Rona shaft over the four months:

- Fragmentation;
- Drilling;
- Cleaning;
- Gully standards;
- Water control;
- Barricades; and
- High-grade panels above 4000 cmg/t.

The current MCF improved from 53% to 91% when the audit team was on the shaft. The key findings were:

- Stoping width control improved to 165 cm from 172 cm with good marking and drilling practices;
- More focus was put on cross-cut cleaning;
- Reef exposure increased with the correct marking and drilling; and
- Gullies were blasted to the correct depth, and water control was improved.

There were still areas to address, namely the fragmentation, but this has been resolved by blasting ore passes closer to the stope face. Cleaning and contamination are continuously monitored for improvement.

1.5 Structure of the Research Report

This section lists the outline of the chapters in this research report.

Chapter 1 introduces this research report, including a problem statement, motivation and the previous work on the MCF.

Chapter 2 explains the MCF and the real and apparent losses or gains, sampling methods, best blasting practices and illegal mining activities that can be expected in the mining environment.

Chapter 3 investigates and analyses the ore flow of the Ya Rona shaft and will also analyse and investigate the sources of losses and gains in the tonnage and grade.

Chapter 4 will investigate the difference between real and apparent losses in tonnage and grade.

Chapter 5 summarises the previous two chapters' findings, whether grade or tonnage gains or losses or real or apparent gains or losses.

Chapter 6 gives the conclusion of the research.

Chapter 7 is the recommendations for the research.

2 LITERATURE REVIEW

2.1 Section Overview

Different case studies from mine with MCF issues were investigated to find possible causes and solutions to assist with the issue of the low MCF. This chapter will review the MCF in detail, explaining what real and apparent losses are and where the losses can occur. Drilling and blasting practices will be investigated, and illegal mining will be discussed.

2.2 What is Mine Call Factor?

According to Tetteh and Cawood (2014.p1), *“this means that if sampling, assaying and tonnage measurements in a mine and plant are perfect and there is no mineral loss at any stage during handling and processing, the MCF should theoretically be 100%”*. The MCF at many shafts in the Driefontein Operation is below their planned MCF average; increasing the MCF will improve the revenue at these shafts.

Xingwana (2016) stated that the MCF has a dual purpose:

- Comparing the gold lost during the beneficiation process, from the blasted face gold to the gold received in the plant and accounted for in recovery plus residue; and
- Comparing the tonnage received in the plant to the tonnes called for by the mine’s mine survey department.

All the mine's MCF accounting methods are different, but it is still the only accounting method that determines the mining quality. Some of the mines adapted it to not call for and account for previously mined-out area’s tonnage (De Jager, 1997).

The MCF equation can be split into “gold called for” and “gold accounted for”. “Gold called for” is the metal content estimated during the measuring process over a measuring month that lasts approximately 24 shifts. “Gold accounted for” is the final product plus residue calculated from the plant's accounting methods. When confronted with a poor MCF, the mining personnel's default response is to claim that the plant is losing the gold somewhere during the processing stage. However, plant efficiency does not affect the MCF (De Jager, 1997).

The MCF issues vary from mine to mine due to different mining activities, methodologies, and practices. Any MCF-related problem must be investigated by analysing its various components (Tetteh & Cawood, 2014). These components may include:

- Mine survey measuring methods have recently changed from tape measures and manual field books to sophisticated electronic survey instruments and specialised software. A total station is used underground, and the instrument is set up below a peg with a unique number that has been mine surveyed to locate it spatially. The instrument measures with a laser from the known mine survey peg to several points on the rock-face to determine the area and, eventually, the volume of the excavation;
- Accumulations of ore and gold-bearing mud not removed from underground workings (vamping not done);
- Sampling and valuation methods;
- Theft of ore (gold-bearing) underground by illegal miners;
- Incorrect hopper factors (capacity); and
- The weightometers (on the underground and surface belts) are not correctly calibrated.

The causes of a low MCF must be investigated through a systematic approach. (Macfarlane, 2013)(Storrar, 1977); nine components must be investigated:

- The sampling of ore that is sent to the processing plant;
- Measuring results and calculations performed by the mine survey department;
- Waste rock packed underground;
- Rocks sorted on surface;
- Ore picked from waste;
- Hopper factors and the tramming and tipping of ore;
- Underground accumulations and sweepings;
- Losses due to theft in the processing plant; and
- Assay bias and the silver content in assaying.

No study has been done on illegal mining and the impact of gold theft on the MCF. It is challenging to estimate the gold lost through theft of illegal mining activities and the effects on the MCF due to a large number of unknowns. If the illegal miners were stealing gold in the current mining areas, which is expected to report to the plant, it could contribute to a lower MCF.

Figure 2-1 shows the ore movement and the difference between shaft call factor (SCF), plant call factor (PCF) and MCF.

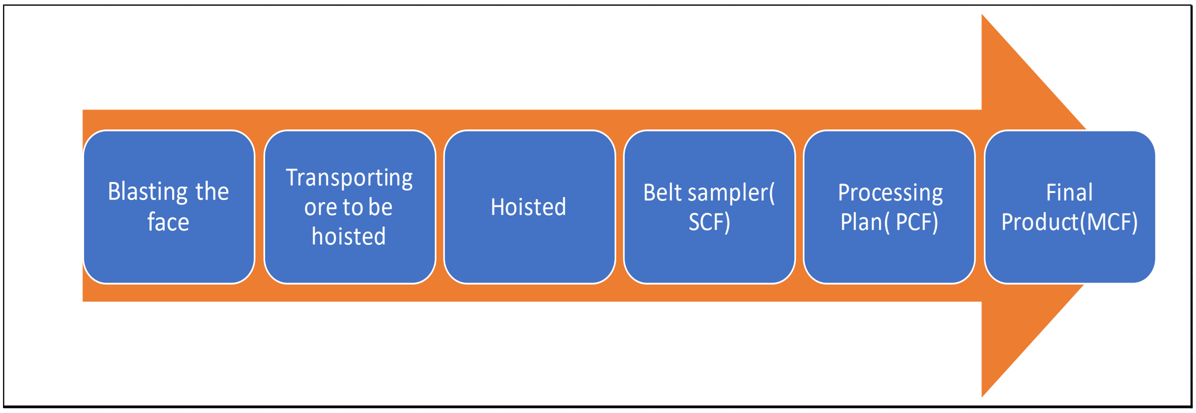


Figure 2-1: Ore movement

The SCF compares the actual tonnage over the belt(hoisted) tonnes and sampled grade versus the product called for by the mine measuring methods as expressed as a percentage (Xingwana, 2016).

The PCF is a ratio expressed as n percentage of the actual product in the processing plant versus the recovered product plus residue (Xingwana, 2016).

Fragmentation, ore loss and dilution must be investigated jointly to get the real impact on the profit margins and the MCF; if these three components are investigated separately, they will not show a significant effect on the MCF (Xingwana, 2016).

2.2.1 Positive tonnage discrepancy

Tonnage discrepancy is the difference in tonnages between what has been blasted and accounted for by the mine survey department and what has been received in the plant. The discrepancy can be classified as either a mine survey shortfall or an excess. A mine survey shortfall is when the plant receives more tonne than the mine survey department measured and is sometimes referred to as a positive tonnage discrepancy or a gain. A mine survey excess is when the plant receives fewer tonnes than the mine survey department measured (Tetteh & Cawood, 2014).

The positive tonnage gain can be attributed to falls of ground (FOG) or broken ore that was not cleaned, brought to the surface, and not called for in that measuring period (De Jager, 1997). In addition to seismicity, sources of tonnage gain are; under-measuring of stoping widths, under-measuring of square metres, scaling of sidewalls in stoping and development areas and scaling of ore passes.

2.2.2 Negative tonnage discrepancy

An excess tonnage discrepancy is when the plant is getting fewer tonnes than what was measured by the mine surveyor. The fewer tonnes show that there are losses from the underground source (Tetteh & Cawood, 2014). Negative tonnage losses can be attributed to broken ore not being cleaned and brought out to the surface, but it was called for by the mine survey department (Xingwana, 2016). Tonnage losses can also be caused by accumulations not being cleaned out, mud being left to collect in the drains, and sweepings not done to standard, over-measuring stoping widths, over-measuring stope and development areas and advances (De Jager, 1997). These errors in estimating mined tonnages will all result in fewer tonnes received by the plant than what was called for by the mine survey department.

2.2.3 Grade losses

A grade loss is a lower grade measured over the belt sampler and in the plant underflow than what was called for by the mine sampling methods. Unaccounted gold is the variance between the gold called for and the gold accounted for. This gold loss can be split into real and apparent losses. Real or actual gold loss occurs within the ore flow process and recovery cycle and can be prevented. The ore flow is the route that blasted ore travels from the working place underground (in-situ ore) to the plant on the surface for gold extraction. The apparent gold loss is gold that has been called for, which was not there in the first place (De Jager, 1997). In the case of illegal mining, the gold loss caused by theft can be categorised as real gold loss.

Examples of apparent and real gold loss are listed in Table 2-1.

Table 2-1: Gold loss explained (De Jager, 1997)

Apparent Gold Loss	**Real Gold Loss**
Underground chip sampling	Dictated by mining method and layout
Different densities of rock	Sweepings are not done properly
Over/under measuring, that is, stoping width, m^2 mined	Reef remaining in the hanging and footwall
	Vamping tonnage and mud not taken to the surface for treatment
	Theft from surface areas (Plant) from mine personnel
	Losses while tramming and hoisting (Spillage)
	Reef tipping into waste tips
	Metallurgical plant process
	Gold theft by illegal miners

Figure 2-2 shows a different format and a more systematic approach to categorising and investigating real and apparent gold loss, as compiled by De Jager (2018). The investigation of real losses should include determining: the use of waterjets, vacuum cleaners in-stope, sealing of the footwall to prevent loss of fines, accumulations of mud, abandoned ore in old areas and inefficiencies in the metallurgical plant. The investigation of apparent loss should include checks on sampling quality, how different reef types affect expected losses, valuation methods used, and the study of relative density.

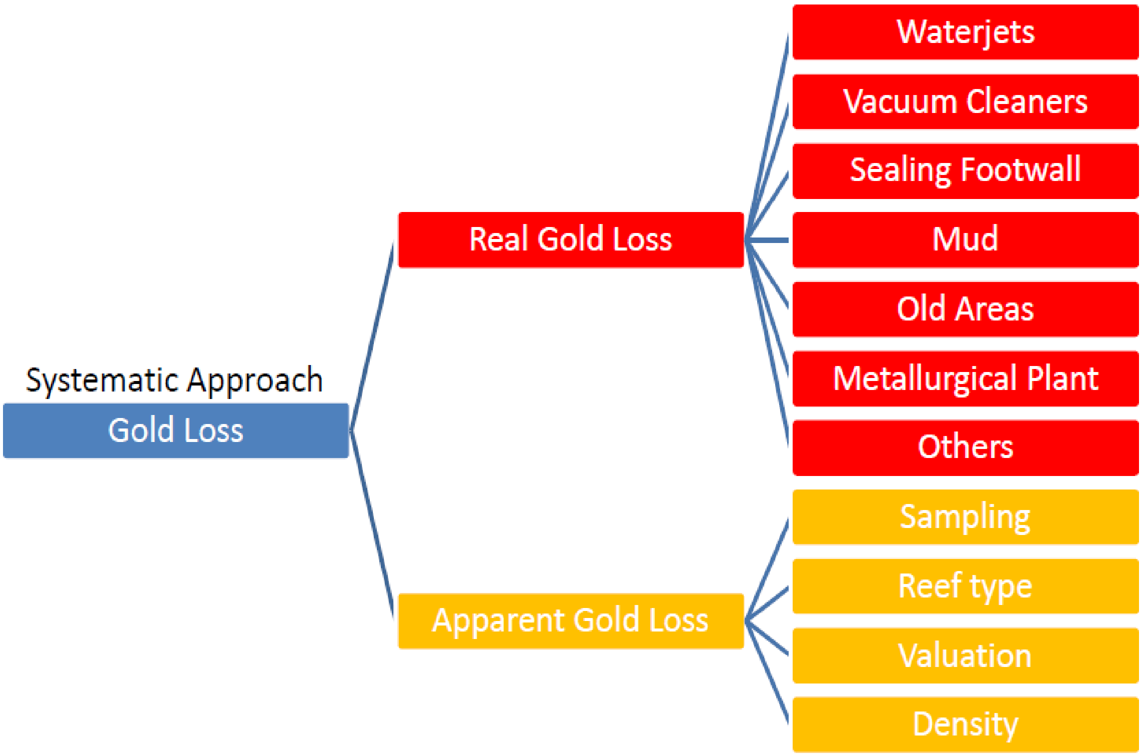


Figure 2-2: Gold loss systematic approach (De Jager, 2018)

Full metal accounting is essential for control and governance along the value chain. A systematic approach must be adopted along the value chain (Macfarlane, 2013). MacFarlane (2013) has a different view on real and apparent losses and has used the items shown in Figure 2-3 to do further analysis to find the losses**.**

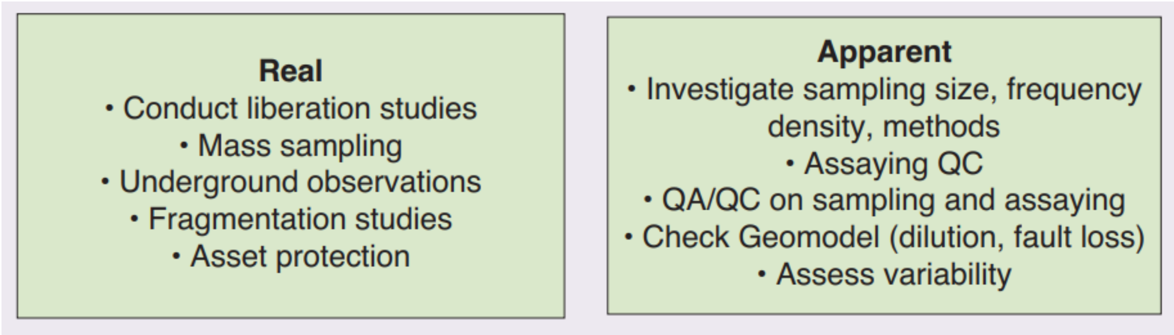


Figure 2-3: Real and apparent loss (Macfarlane, 2013)

2.2.4 Grade gains

A grade gain is a higher grade received over the belt sampler and in the plant than what was called for by the mine sampling and estimation methods. Several factors can contribute to the grade gains: removal of historical accumulations with higher grades, less dilution from external waste in the stoping areas, and removal of high-grade mud. Following poor or inaccurate sampling methods can result in underestimating gold broken on the stope face and a higher value reaching the plant. Mining personnel may inadvertently clean a high-grade stoping area in preparation for mining that illegal miners have blasted. This can therefore increase the value measured in the plant (gold not called for).

2.2.5 Apparent and real gain/loss

Real losses are physical metal losses such as gold lock-up in plants and tramming, hoisting, and processing issues (Tetteh & Cawood, 2014). Overestimation of the gold content in the evaluation process will result in an apparent loss. As stated by Tetteh and Cawood (2014), other factors can contribute to apparent losses, namely, incorrect sampling methods, incorrect relative density applied and inaccurate applications of standards and procedures. Apparent and real losses both have a negative effect on the MCF.

The literature research was done on previous case studies with MCF problems to determine what could cause the low MCF at the Ya Rona shaft.

2.3 Case studies

2.3.1 A case study in the Free State

A study was carried out in 2016 at a Sibanye-Stillwater mine in Welkom, Free State, to "monitor ore loss and dilution for mine-to-mill integration in deep gold mines" (Xingwana, 2016). Fragmentation and dilution were investigated where fragmentation size and distribution of the ore at the stope face were determined by taking photographs of the broken ore with tennis balls placed for size comparison. These photographs were loaded into Split Desktop software to determine the fragmentation sizes. Real losses can be minimised if the correct drilling procedures and explosives are used. When the correct sampling and assay methods are used, apparent losses can be accounted for and kept to a minimum (Xingwana, 2016).

This study showed that real and apparent losses could be broken down into the following:

Real losses:

- Mine survey measuring; and
- Fragmentation: when the rocks are blasted to small (fines), the fines get washed away into the cracks, the large rocks can delay tramming and obstruct the grizzly, and the large rocks cannot pass through the grizzly.

Apparent losses:

- In-situ sampling methods; and
- Assay laboratory quality assurance/quality control (Xingwana, 2016).

There is a conflict between the two studies done by De Jager (2018) and Xingwana (2016) regarding the mine survey measuring classification; according to De Jager, the mine survey measuring is an apparent loss, and according to Xingwana (2016), it is a real loss. According to Xingwana (2016), the mine survey measuring method is a real loss; it is measured. An error in the estimation of the volume could be an apparent gain or loss.

Stope audits with grade control checklists were done, and attention was given to the lock-up tonne in the stope faces, stope gullies, centre raises, and ore pass systems (Xingwana, 2016).

The finding is shown in this study that it is difficult to quantify the ore loss and the time lag between the ore blasted and to ore processed to the final product. This results in revenue losses. The dilution could be estimated to some degree of accuracy by investigating the blasted and head grades. The extra waste rock mined due to unplanned dilution can impact the cost incurred due to the additional mining and treatment costs.

The following factors impact MCF and production: if the ore fragmentation is too fine, it can result in a poor MCF, the lock-up of tonnes (accumulation) and dilution.

2.3.2 Case study at Western Holdings mine

Gold losses of 35% were accounted for monthly. De Jager (1997) conducted a case study at Western Holdings Mine to determine the possible causes of the low MCF. This study was conducted to determine if the gold losses were real or apparent.

De Jager (1997) investigated waterjets, sweeping, and fines in footwall and mud.

The findings were as follows:

Waterjets

The velocity of the stream of water expelled by the waterjets moves the bigger rocks on the footwall but also separates the free gold from the broken rock, which causes gold loss. Carbonaceous reef types must be mined dry because of the free gold particles that can be lost during excessive water use. Gold loss cannot be prevented in some cases, and the recovery is uneconomical (De Jager, 1997).

Sweepings

Sweepings were statistically evaluated, and it was found that sweepings are not a significant contributor to the poor MCF, but it is an indicator of the tonnage removed from the stope.

The focus on sweeping should not be overlooked as it contributes to tonnage and gold targets (De Jager, 1997).

Fines in footwall

Cleaning cracks with a vacuum cleaner estimated loss through fines in the footwall, but no significant amount of gold was recovered to validate the project. It was therefore concluded that gold does not concentrate in the footwall cracks as previously believed (De Jager, 1997).

Mud

De Jager stated that this study had neglected mud loading due to labour cuts. With the presumably large volume of gold left underground, mud is loaded into the hoppers by hand (De Jager, 1997).

Vacuum Cleaners

The vacuum cleaner will improve the MCF if many tonnes can be vacuumed in relation to the broken tonnes. Vacuum cleaners are not the solution for grade and tonnage problems. Only a limited amount of gold remains when the final clean-up has been done; the amount of gold left or lost is not viable to make it profitable or to impact the MCF (De Jager, 1997).

Blasting Barricades

Blasting barricades contain ore in the production zone, controlling the blast's spread and preventing contamination of the areas already swept.

Different blasting barricades are used, such as wooden planks, poles, high-density polyethylene (HDPE) pipes and polymer blankets to contain the blast; these barricades are installed at the second line of permanent support parallel to the face. The mine workers are opposed to re-installing these barricades regularly as the stope face is advancing, resulting in recontamination of previously swept areas (De Jager, 1997).

The investigation led to implicate incorrect density, and the study has shown that Western Holdings Mine was a dirty mine because the broken ore was not brought to the surface timeously. These factors did impact the MCF negatively. Analysis was done on the sweeping percentage and its effect on the MCF. The sweeping percentage only indicates the amount of broken ore removed from the back areas and does not directly influence the MCF. Belt Samplers were installed, most problems were resolved, and the correct gold was allocated to the correct shafts. This study did not investigate gold theft, ore valuation, or plant efficiency (De Jager, 1997).

2.3.3 Case study of gold reef sampling and its impact on the mine call factor

Fourie & Minnitt (2016) conducted this case study to investigate the errors and bias because of poor sampling in the underground sampling environment. Due to loose or fractured materials, chip sampling methods do not always extract samples exactly within the demarcated areas. When the samplers discard excess sample material after the sample has been taken, it impacts the results affecting the errors and bias with every sample taken. Waste discard bias arises when the sampler dumps the waste in the sample, resulting in significant errors in the sample analysed at the assay laboratory (Fourie & Minnitt, 2016).

Mining personnel tend to assign blame for a poor MCF to chip sampling, where they assume there is an overestimation of the in-situ grade. The actual errors leading to the lower MCF are never considered or investigated, such as the dilution, sweepings, and incorrect tramming (Fourie & Minnitt, 2016).

It was concluded that waste discard was the most likely reason for the overvaluation of the carbonaceous reef. The sampler must understand where the errors occur as there is not yet a tool to extract the perfect sample.

2.3.4 Case study on the use and effects of a scraper and the impact on gold loss at Ya Rona shaft

Allers (2021) investigated (graduate student) the effect of using a scraper to clean the stope face and the resulting impact on gold loss. The scraper with the footwall's friction breaks the rock into smaller sizes and causes liberation and gold loss as the VCR is very brittle. The fine gold particles can be washed away into the cracks, and the gold loss can impact the final product and result in a lower MCF. This investigation was done at the Driefontein Ya Rona shaft in a high-grade stoping panel at VC33 34B 5E.

Two different theoretical methods were investigated to replace the use of a scraper possibly by:

1. Using a 2-tonne tub or;
2. A mono winch and weeping bags to remove the broken ore.

Figures 2-4 and 2-5 show the two different stoping infrastructure configurations proposed to implement these alternative cleaning methods.

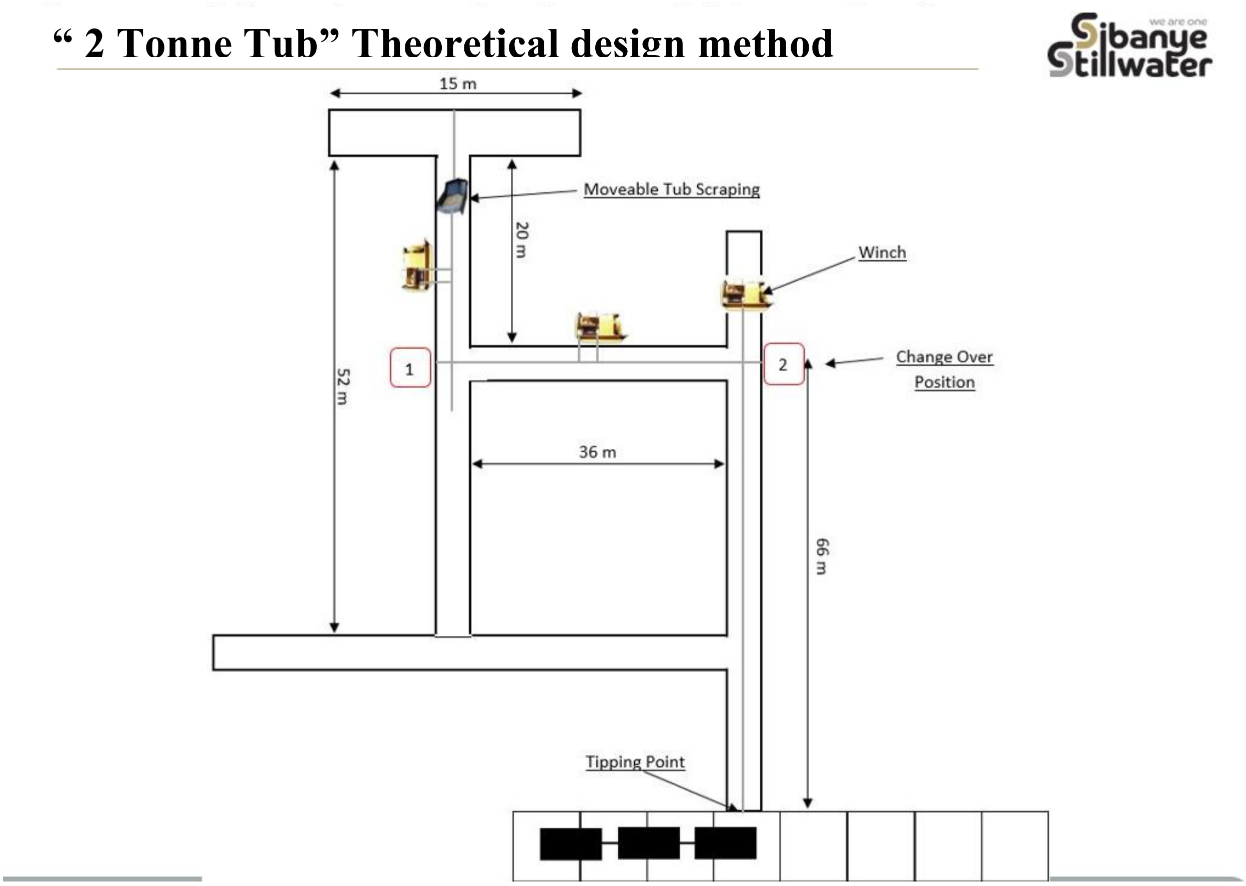


Figure 2-4: 2 Tonne Tub mining method layout (Allers, 2021)

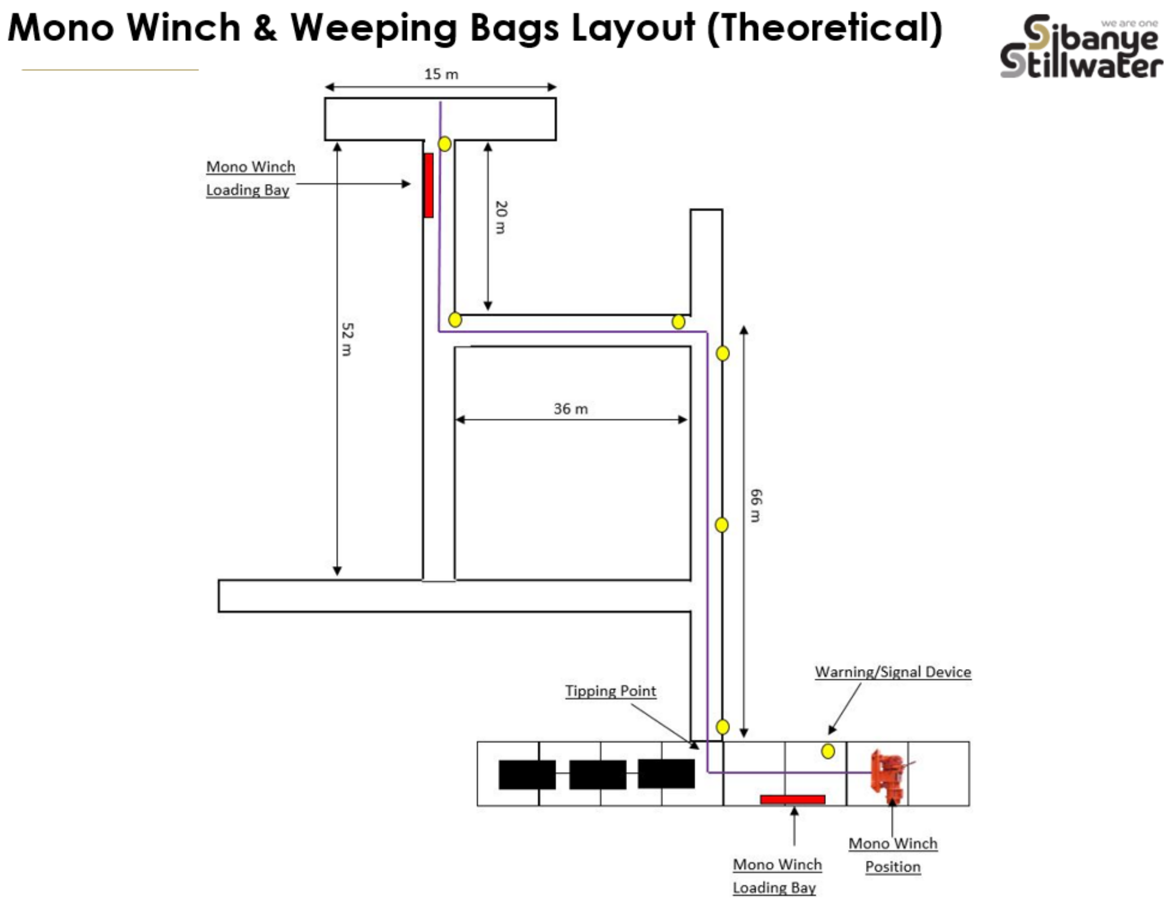


Figure 2-5: Mono winch and weeping bag layout. (Allers, 2021)

The 2-tonne tub, mono winch, and weeping bags must be manually loaded and unloaded. The fragmentation size stays the same as the blast, and no water is used, which should ensure a minimal gold loss. The negative side to this methodology was the potential safety risk to employees because the broken rock would need to be hand-lashed in a freshly blasted area with no installed support. There is also the efficiency of manual loading and unloading of the broken ore to consider, that is, the time it takes to clean the panel. It is estimated that the panel will only be able to be blasted an estimated six times per month, which is less than what a normal mining cycle currently allows with conventional cleaning methods. After considering the negative impact of these alternative cleaning methods on mining efficiency and potential safety risk, the decision was made not to implement the two theoretical methods (Allers, 2021).

2.4 Best Practices for Measuring Factors in the Ore flow

The ore flow figures depend on the accuracy of the mine survey measurement and the sampling data. Honesty and accuracy must be the most important characteristic of the mine survey and valuation department; the mining staff must be aware of the impact of dishonesty and inaccurate information. Best practices must be adhered to; otherwise, the information will be incorrect and impact reporting. The case study of gold reef sampling and its effect on the mine call factor done by Fourie and Minnitt in 2016 concluded that the sampler could be biased and discard the waste in the sample, which will cause an overestimation of the gold called for.

2.5 Gaps in Existing Knowledge

Many factors influence the MCF; these factors must be identified, and any problem areas must be rectified to improve the MCF. Previous studies have investigated most of the factors that influence the MCF. The impact of illegal miners (gold theft) is not understood, and no investigations have been done. It is challenging to determine the amount of gold stolen in the current working areas and the unplanned or old areas in the mine.

There are real and apparent losses in grade and losses in tonnage; these need to be investigated thoroughly to determine what type of loss it is. All the quality control and quality assurance standards and procedures must be investigated to ensure that the best practices have been adhered to.

2.6 Section Summary

An MCF investigation must systematically identify the factors that influence the MCF and the areas where the gold and ore losses occur. Several factors influence the MCF; these can be classified into the following categories: positive or negative tonnage discrepancy, grade gains and losses and real and apparent gains and losses. A system must be put in place to eliminate these MCF losses. The case studies conducted will serve as a guideline in this research.

3 RESEARCH METHODOLOGY

3.1 Section Overview

This section will explain the techniques and processes used to identify and analyse the MCF. Procedures have been identified from the literature review that needs to be investigated to improve the MCF at Ya Rona shaft. The research will use both quantitative and qualitative methods.

The following will be investigated:

- The ore flow spreadsheets from the mine survey department after measuring;
- The mine survey measuring methods;
- Ore dilution;
- The correct relative density used in the calculations;
- The sampling of the VCR reef;
- The valuation methods will be checked and verified;
- The quality installation of the blasting barricade;
- Sweepings and lock up ;
- Cross tramming, results obtained from the electronic Scada system that measures the as it gets trammed;
- Fragmentation results obtained from the explosive co-ordinators the fragmentation get measure monthly underground and on the surface belts;
- Water control, the controls and installation of the sumps and pumps;
- Impact of Illegal mining;
- Weightometer and their calibration;
- Sampling quality of the go-belt sampler;
- The assay laboratory procedures and processes; and
- Plant procedures.

3.2 Quantitative Methods

Data was collected from the Technical Statement and ore flow compiled and supplied by the mine survey department. The Technical Statement contains a summary of all the measuring results and planning figures from the face to the final product produced, the square metres broken, metres advanced, tonnes broken, tonnes hoisted, tonne milled, face grade head grade, yield, gold called-for and gold delivery. The data was analysed to identify the variances, which will be checked and reported.

3.3 Qualitative Methods

Underground sampling, mine survey measuring, and assay laboratory task observations and audits are used to check for accuracy and adherence to the various standards. Quality control and quality assurance are also in place and to standard. A regular audit is done to investigate the quality of sweepings and the adherence to sweeping standards; fragmentation tests are done underground and on the surface belts. Dilution is checked and measured on measuring day and reported on the monthly reviews. This check is to identify the areas where there can be a loss of ore during the mining process.

3.4 Sources of Data

The data sources used in this report will consist of various mining departments' reports and documentation on the mine: mining, mine survey, sampling, grade, and geology. This department collects data from underground when they do routine visits to the working places.

The data sources are as follows:

- After completing the measuring,
    - Ore flows spreadsheets and the Technical Statement were obtained from the mine survey department, with the final measuring data captured and approved. All the information about the MCF is on these sheets, which includes quality factors, sweepings, discrepancy, actual square metres, actual metres, cmg/t, gold called for and gold accounted for.

        - Month-end lock-up report (accumulations estimated on measuring day by the mine surveyor.
- Other departments within the mineral resources department assisted with the following;
    - Supplying sampling sheets information on high-grade areas;
    - Supplying month-end and valuation reports for auditing purposes;
    - Supplying quarterly QA/ QC reports from the group Valuator for analysis;
    - Supplying geology reports from underground visits at problem areas;
    - Supplying quarterly QA/ QC reports on the valuation and geological model in Datamine;
    - Supplying standard procedures documentation on measuring, valuation and assaying methods;
    - Taking photos from underground visits;
    - Sending hoisting and tramming reports on email; and:
    - Sending Process plant reconciliation sheet via email.
- All this data from all the different departments was analysed to investigate where the real or apparent loss occurred and the impact on the MCF.

3.5 Section Summary

This chapter gives an overview of the areas that could impact the MCF. The list in section 3.1 is the areas that need to be investigated to determine the causes of the low MCF. The investigation can assist in minimising the loss of gold though putting systems and procedures in place. Data was collected from various departments. The ore flow, Technical Statement, sampling and valuation data were analysed with underground photos. Quantitative and qualitative methods were used to identify the gold loss and its impact on the MCF.

4 TONNAGE AND GRADE GAIN /LOSS

4.1 Section Overview

This section will investigate the tonnage and grade gains and losses from underground to the plant, looking at and identifying the sources from the ore flow in Table 4-1 and the Technical Statement in the appendix. The sources will be investigated to determine the grade gains and losses on the MCF.

4.2 Ore flow Spreadsheet

Table 4-1 is the ore flow spreadsheet to track the ore flow and monthly reconciliation. The ore flow spreadsheet data, as shown in table 4-1, was used from January 2021 to December 2021. This data was analysed to understand the gains and losses with grade and tonnages.

Table 4-1: Year-to-date Ore flow (Gouws, 2021)

2021 YTD + DEC2020			
REEF TONNAGE FLOW (GOLD)			
DESCRIPTION	**ACTUAL**		
	TONNES	**G/T**	**AU KG**
m²	37479		35601
REEF TONNES BROKEN AT CHANNEL WIDTH	113,099	40.6	4592.7
REEF TONNES BROKEN AT SW FROM m²	181,644	25.3	4592.7
REEF TONNES BROKEN FROM CUBES m³	7,028	9.1	64.2
REEF TONNES BROKEN FROM STOPING	188,672	24.7	4657.0
WASTE TONNES BROKEN (off reef & fault cuts)	8,943		
TONNES BROKEN FROM STOPES @ SW	**197,615**	**23.6**	**4,657**
WASTE TONNES BROKEN OSS (gullies, slushers, winchbeds, etc)	21,858		
TOTAL TONNES BROKEN FROM STOPES	**219,473**	**21.2**	**4657.0**
REEF DEVELOPMENT MEASURED EXC BALLAST THAT WILL BE HOISTED TO MILL	0	620712.7	0.0
WASTE DEVELOPMENT MEASURED EXC BALLAST THAT WILL BE HOISTED TO MILL	91,501		
TOTAL DEVELOPMENT TONNES MEASURED THAT WILL BE HOISTED TO MILL	91,501	0.0	0.0
OLD GOLD (Vamping & Reclamation)	11,726	8.1	95.1
TOTAL UG TONNES MEASURED FROM UNDERGROUND THAT WILL BE HOISTED TO MILL (GOLD CALLED FOR INC OLD GOLD)	**322,699**	**14.7**	**4752.1**
KNOWN ADJUSTMENTS:			
SKIP FLUSHING TONNES	0		
SHAFT SPECIFIC ADJUSTMENTS (eg Backfill spillage, opening up tons, Unmeasured FOG)	0	0.0	**0.0**
ACCOUNTING ERRORS YTD CORRECTIONS	**0**	0.0	**0.0**
TONNES AVAILABLE FOR HOISTING (EXCLUDE UNG ACCUM & U	**322,699**	**14.7**	**4752.1**
UG TONS HOISTED TO SURFACE (Weightometer+Grabbed Belt (	**343,745**	**8.6**	**2965.8**
CHECK1: TONS HOISTED TO SURFACE (Skips)	250,630	8.6	2146.0
CHECK2: TONS HOISTED UG AT 4 SHAFT	339,826	8.6	2930.1
CHANGES IN SURFACE STOCKPILES	0	0.0	0.0
CHANGES IN PLANT MOISTURE & SHAFT MOISTURE	0		0.0
CHECK6: TONS DELIVERED TO PLANTS (Datarail/ Truck Tallies)	343,745	8.6	2,965.8
SURFACE TONS TO MILL (Waste tonnes)	*0*	0.0	*0.0*
TONS REPORTED TO MILL (belt ± stockpile change ± Plant mois	**343,745**	**8.6**	**2965.8**
CHANGES IN PLANT STORAGES (Mill Bins & Stock Piles)	0	0.0	0.0
AVAILABLE TO MILL	343,745	8.6	2,965.8
VARIANCE - SHAFT VS PLANT (PCF)	0	0.8	278.3
ACTUAL TONNES MILLED (RECOVERY + RESIDUE) (MCF - Gold Called For Inc Old Gold)	343,745	9.4	3244.1
ACTUAL TONNES MILLED (RECOVERY + RESIDUE) (MCF - Gold Called For Exc Old Gold)	343,745	9.4	3244.1
RESIDUES (PRF) (Exc Old Gold))		0.2	55.2
TONNES TREATED (reported)	**343,745**	**9.3**	**3188.9**
CHANGE IN GIP			-23.7
TONNES TREATED (REPORTED INC CHANGE IN GIP)	343,745	9.2	3165.3
MEASURED ACCUMULATIONS MOVEMENT MONTH ON MONTH	+1,700	0.1	28.2

Ya Rona shaft ore is transported via hopper from the shaft to the Pitseng shaft underground, hoisted, and transported on conveyor belts to the processing plant.

The measured on the ore flow sheet is 322 699 tonnes for the year 2021, with an average grade of 14.7 g/t, as highlighted in the red block. Furthermore, the grade hoisted and measured on the weightometer /go-belt sampler is 343 745 tonne at a grade of 8.6 g/t, as highlighted in the blue block. A negative grade gap of 6.1 g/t and a positive 21046 tonnes need to be investigated.

4.3 Review of Measuring Techniques against Best practice

Measuring methods and techniques have changed over the years. Measuring was previously done with measuring tapes on dip and strike, which could easily be manipulated using the mining personnel to assist. The mine surveyor often did not have enough labour to assist with measuring, necessitating the use of mining personnel to hold the tapes, which opened the opportunity to manipulate the measurements and get that “extra metre” for an inflated bonus payment.

Currently, the mine survey department at Driefontein uses the Topcon total station. The Topcon total station is a mine survey instrument used in mine surveying, usually to place survey pegs. During the measuring process, the instrument is used to locate the blasting face and development end by offsetting points at regular intervals along the face from a known mine survey point (Topcon, 2022). The measuring accuracy has improved as fewer people are used to doing the work, and human errors and intentional fraud have been eliminated.

Senior mine survey personnel follow regularly planned task observations to test and check that the work is done correctly.

4.4 Analysis of Ore flow

Analysis was done on the production tonnage and grade to identify the percentage tonnage and grade gains and losses, as shown in Figures 4-1 and 4-2. The detailed ore flow can be seen in Appendix 1 (Gouws, 2021). According to the mine survey calculation and measuring methods, the reef tonne available for hoisting is equals to 322 699 tonnes for the year 2021.

Accumulations that have been removed amount to an additional 1 700 tonnes. The delivery variance of 19 346 (6%) tonne is the difference between the reef hoisted (343 745 tonnes) minus the 1 700 tonnes (1%) from accumulations and the reef tones available for hoisting. More tonnes have been removed and hoisted than the actual tonne broken, as shown in Figure 4-1. The extra tonnage can be attributed to underestimating gully widths and heights and cleaning out the mud in the drains. This results in a mine survey shortfall of 10%.

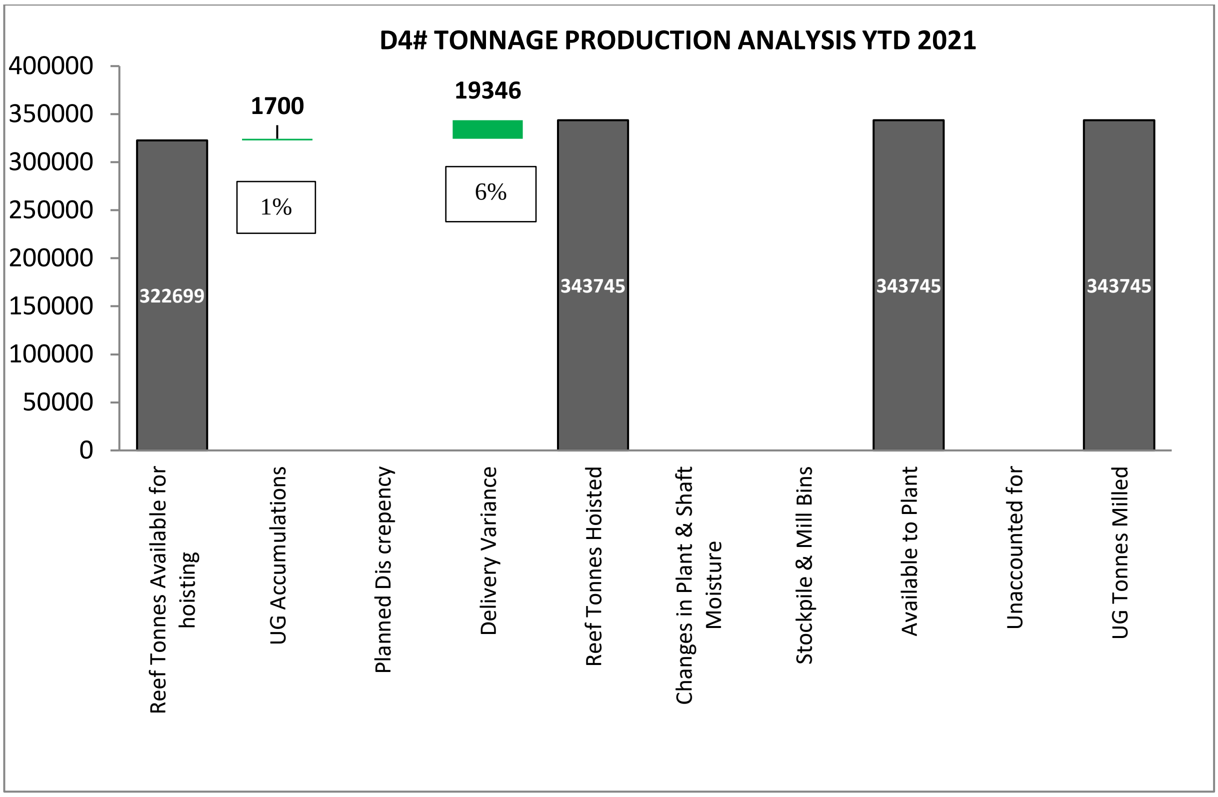


Figure 4-1: Tonnage production analysis (Gouws, 2021)

Figure 4-2 shows that the reef hoisted accounts for only 2 966 kg, gold called for is 4 752 kg for the year 2021, and 28 kg (1%) can be allocated to the removal of accumulations. Due to a poor MCF, the shaft loses 1 515 kg (32%) of its blasted gold and a delivery variance of 0.1%. The gold lost is a major contributor to the poor profit margin.

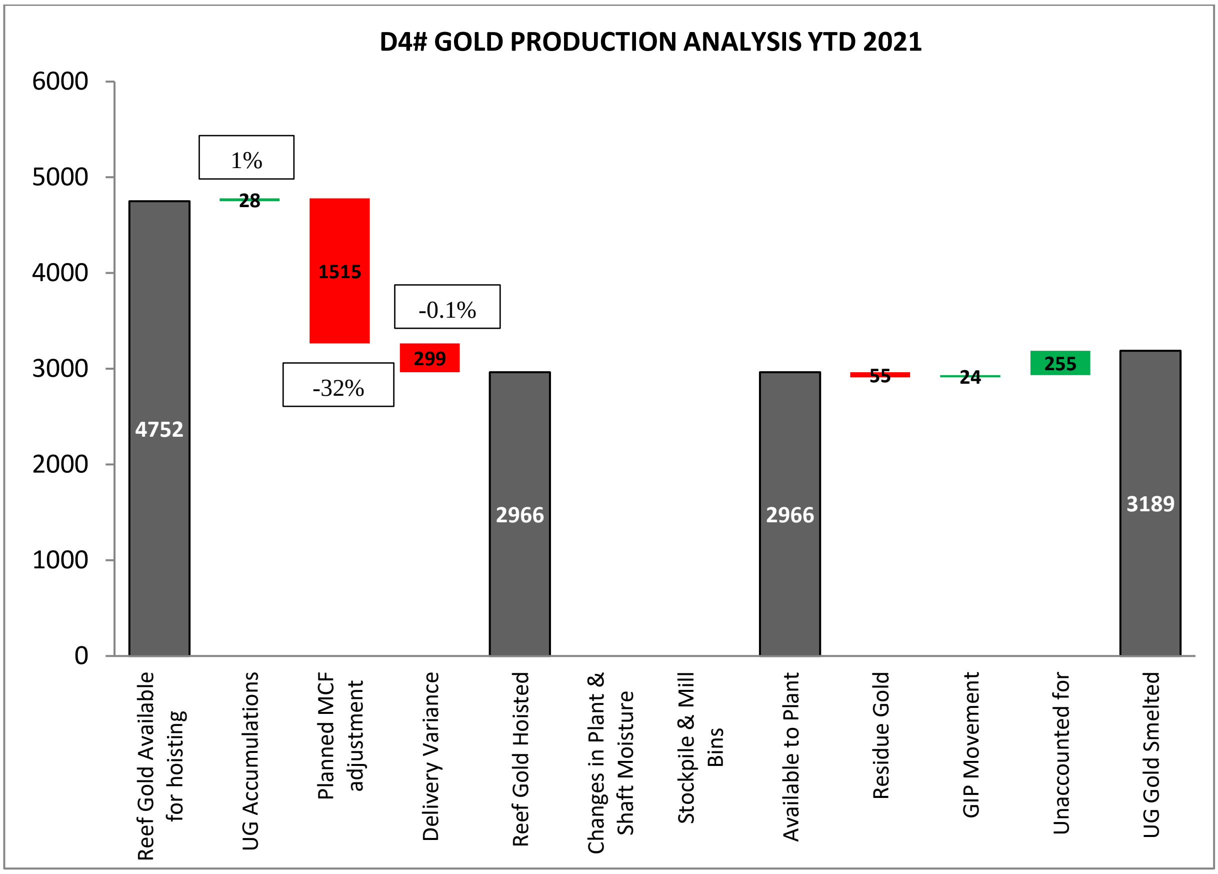


Figure 4-2: Gold production analysis (Gouws, 2021)

4.5 Sources of Tonnage Gains and Losses

The delivery variance of 19 346 tonnes was attributed to mud loading, removal of accumulations and pulling gullies down to the footwall.

The mine surveyor estimates the depth of the tonnes left behind and not removed in the measuring period. Estimations of the depth can be incorrect as the mine surveyor only estimates the areas where they are measuring and does not consider previously mined out or stopped areas. This can account for the extra tonne hoisted and show a positive variance from the measuring tonnes. Historically, a lock-up tonne census was performed after measuring, but due to labour constraints, this is not done anymore and is now done at the same time as the measuring, which can lead to inaccurate estimations of the lock-up tonnes.

There may be cases where tonne and gold are written off; for example, a FOG may make an area inaccessible because it is too dangerous to enter. In this instance, the rock engineering and grade departments issue an abandonment note. The abandonment note will state that the area is too dangerous to enter and that broken tonne and gold must be abandoned.

4.6 Sources of Grade Gains and Losses

The valuation department uses Kriging to estimate the value of the blocks of ground mined after measuring. Kriging is a geostatistical method to create or generate an estimation area from a spatial set of points (using Datamine software). Kriging is used to estimate values in a geospatial area. Actual face sampling and borehole sampling data are used in Kriging on a 5 m x 5 m grid to estimate the planned face values. Face sampling is done during the month at 5m intervals on the face, as shown in Figure 4-3, this is a re-establishment of a 10 m panel which was originally 30 m long.

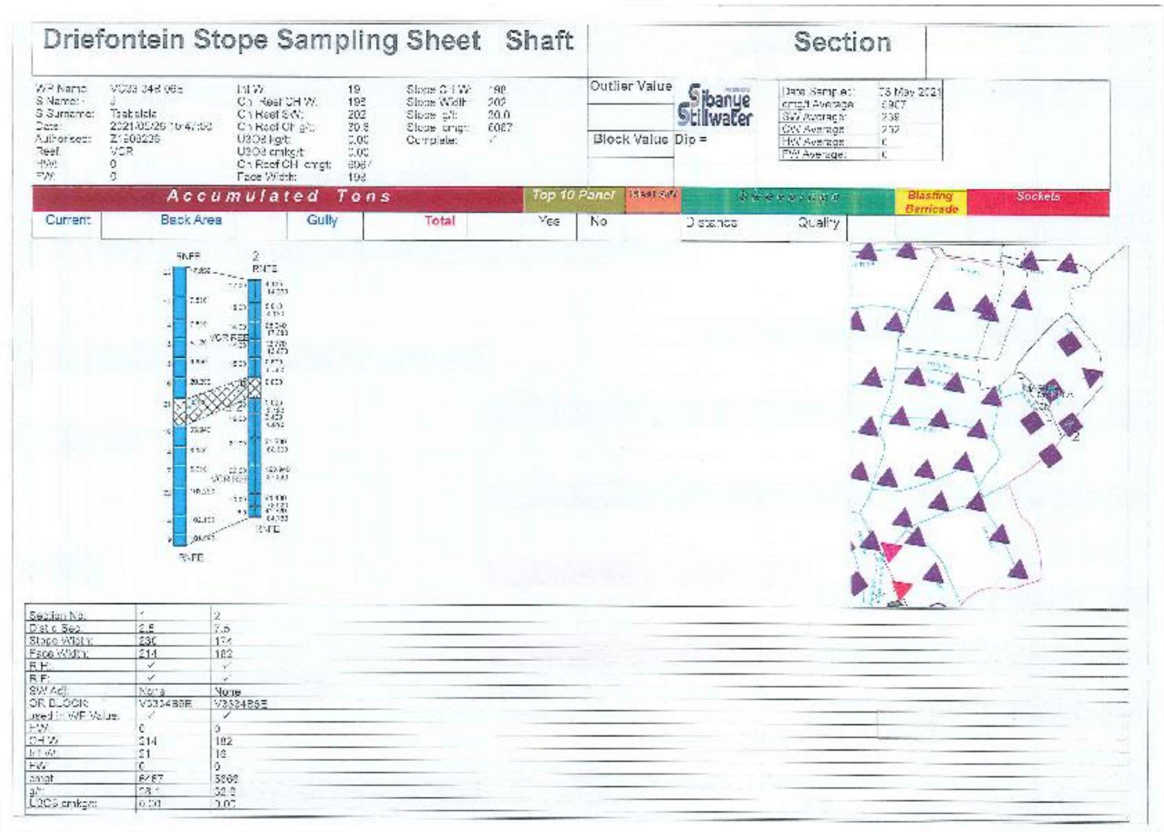


Figure 4-3: Sample sheet of VC33 34B 06E (Valuation Department Driefontein, 2021a)

The face is sampled again when the face has advanced 5 m during the month, and this sampling is done to determine the value that was mined out and to estimate the gold that should be recovered at the end of the month. There are set procedures that must be followed in the sampling process. Monthly planned task observations (PTOs), as shown in Table 4-2, are performed on the sampler (mineral resource technician) to determine if they follow the correct sampling procedures when sampling the face. The PTO is used to ensure that the sampling is being done correctly.

Table 4-2: Planned Task Observation (Valuation Department Driefontein, 2021a)

DRIEFONTEIN D4#				
Evaluation Department: Planned Task Observation				
SAMPLER	MKHUSELENI BUTHELEZI	DATE		09.06.2021
OBSERVER	MZUKHONA MDODANA	WORKING PLACE		CL46 08 06E
TASKS	**CRITERIA**	**TO STD (Yes)**	**NOT TO STD (No)**	**COMMENTS**
Surface Preparation	Planned & alternate workplaces to sample in book (min 3)	Yes		
	Planned sketches and peg numbers in book (min 3)	Yes		
	Check previous sampling special instructions and noted in book - eg location of NFE & off-reef		NO	
	Gang informed on correct level & workplaces	Yes		
	Ensure all equipment is available to be put in bag	Yes		
		4	1	80%
Safety	Determine well-being of assistants before leaving the station	Yes		
	All sampling equipment available & according to standard	Yes		
	PPE for all personnel available @ according to standard	Yes		
	Safety Discussion - monthly topic & other safety issues etc	Yes		
	All assistants to travel together with MRT to designated workplace	Yes		
	Safety practiced in travelling to workplace eg vent doors, loco passing, check surroundings	Yes		
	Permission signature from mining to enter workplace	Yes		
	Travelling in stope safely eg demarcated travelling ways, opposite mono winch	Yes		
	Inform winch operator before entering gullies/raise	Yes		
	Ensure HangWall and face is safe to sample - if not inform competent mine person to make safe	Yes		
	Ensure gate-stalls are in place before sampling steep areas			
	Take cognisance of no-go zones	Yes		
	Are the support nets installed before working at section		NO	
	All persons in team must travel together back to station	Yes		
		12	1	92%
Pre-Sampling Preparation & Tape Construction	Location of 1st section	Yes		
	Dip tape	Yes		
	Top gully - survey peg no 1 - 3 ties to dip tape & check tie to survey peg no 2 & peg to face	Yes		
	Bot gully - survey peg no 1 - 3 ties to dip tape & check tie to survey peg no 2 & peg to face	Yes		
	Marking of intervals - correct interval distance	Yes		
	Reference measurements completed	Yes		
		6	0	100%
Sampling Preparation	Previous NFE & off reef in back area measured and sampled		NO	
	Making section safe	Yes		
	Washing and cleaning of section	Yes		
	Determining of dip & strike accurate		NO	
	Marking of samples according to protocol (sample width and height)	Yes		
	Segregation according to protocol	Yes		
	Correlation between sections	Yes		
	Tickets allocated correctly - bottom to top - correct shaft and reef symbol	Yes		
	Check sample completed	Yes		
	Paint used	Yes		
	Guidelines extended through paint		NO	
		8	3	73%
Chipping	Within guidelines	Yes		
	Correct sequence - bottom to top	Yes		
	Uniform depth		NO	
	Contamination - dish cleaned after each sample	Yes		
	Contamination - bags clean	Yes		
	Contamination - foreign bodies	Yes		
	Spillage - transfer of sample from dish to bag	Yes		
	Supervision conducted on all chipping	Yes		
		7	1	88%
Measurements	Sample widths measured according to protocol	Yes		
	Face widths measured according to protocol	Yes		
	Stope widths measured according to protocol	Yes		
	HW & FW widths measured according to protocol	Yes		
	Sockets measured and recorded	Yes		
	Counting of all samples before leaving workplace	Yes		
		6	0	100%
Geology	Geological features attributes measured - location & dip & strike & throw	Yes		
	Off reef & NFE recorded and measured		NO	Not measured
	Geology observations recorded & correct - conglomerate % etc	Yes		
		2	1	67%
Field Book Data	Correct format & legibly documented	Yes		
	Dips measured and documented per section	Yes		
	Sample ticket numbers are consecutive and clearly indicated	Yes		
	Section distances documented	Yes		
	Planned and actual sketch complete with construction	Yes		
	Tape construction recorded in correct format	Yes		
	All sample widths and measurements recorded correctly	Yes		
	Rock type descriptions recorded	Yes		
	Extraneous observations documented - sweepings & barricades	Yes		
		9	0	100%
Office: Software transfer	Working place and headers transferred accurately	Yes		
	Correct reef type selected for sheet	Yes		
	Tape construction complete as per field book	Yes		
	Dips entered correctly	Yes		
	All sample observations transferred correctly (reef construction&features)	Yes		
	Correct rock type selected per sample	Yes		
	All widths transferred correctly	Yes		
	Ticket numbering transferred correctly	Yes		
	Check samples present and tick box used.	Yes		
	Geology observation transferred correctly	Yes		
	Use for WP Avg ticked		NO	1st sec not ticked
	Bullion correction applied	Yes		
		11	1	92%
Office: Sample sheet	Peer review signed off	Yes		
	Previous comments carried over.	Yes		
	Has current workings referenced into sketch	Yes		
	Extraneous observations correct and complete	Yes		
	Outlier analysis done & attached	Yes		
	Geology observations printed, attached & signed by geologist		No	Not signed
		5	1	83%
Office: Control sheet	Neat and legible & stamps appropriate	Yes		
	Reflects spatial position according to measurements	Yes		
	Reflects values and widths as on sample sheet	Yes		
	Outlier analysis value transferred	Yes		
	Sections indicate RIH, RIF & NFE clearly	Yes		
	Off-Reef clearly indicated	Yes		
		6	0	100%
		TOTAL		**89%**

Before sampling can commence, the face must be barred properly, washed with clean water, and the sample is taken from the bottom to the top of the face; otherwise, the fines would fall and contaminate the unsampled area below. Incorrect sampling and measuring of stoping areas can lead to over or underestimation of gold called for. If the gold called for is overestimated, the mine will have a lower MCF than expected, and vice versa, and this variance may not be fully understood.

Ventersdorp Contact Reef (VCR) is the primary reef horizon extracted at Driefontein Ya Rona shaft. The VCR mined is usually high in value, ranging from 1 500 cmg/t to 15 000 cmg/t, with outliers at 40 000cmg/t. The mineral |resource technician conducted a study at working place VC33 34B, where the face was sampled before the blast, and grab samples were taken after the blast. The face sampling returned an average value of 75 g/t; the grab samples after the blast, with no interference from using a scraper, returned a value of 31 g/t. This indicates a 40% loss or overvaluation. Incorrect sampling techniques could have resulted in this, or the gold was not there in the first place.

Two samples taken adjacent to each other could possibly return different grade values. This is called the “nugget effect” and is a term used to describe the sampling problem that can arise when there are large, valuable particles, particularly gold, in a given deposit. Large gold particles are traditionally referred to as “nuggets.” If a nugget is selected through traditional sampling and analysis procedures, evaluators tend to greatly overestimate the amount of metal in the deposit, however, the opposite is also true. If the nugget is missed, the results undervalue the ore, as shown in Figure 4-4 (Sepro Laboratories, 2019).

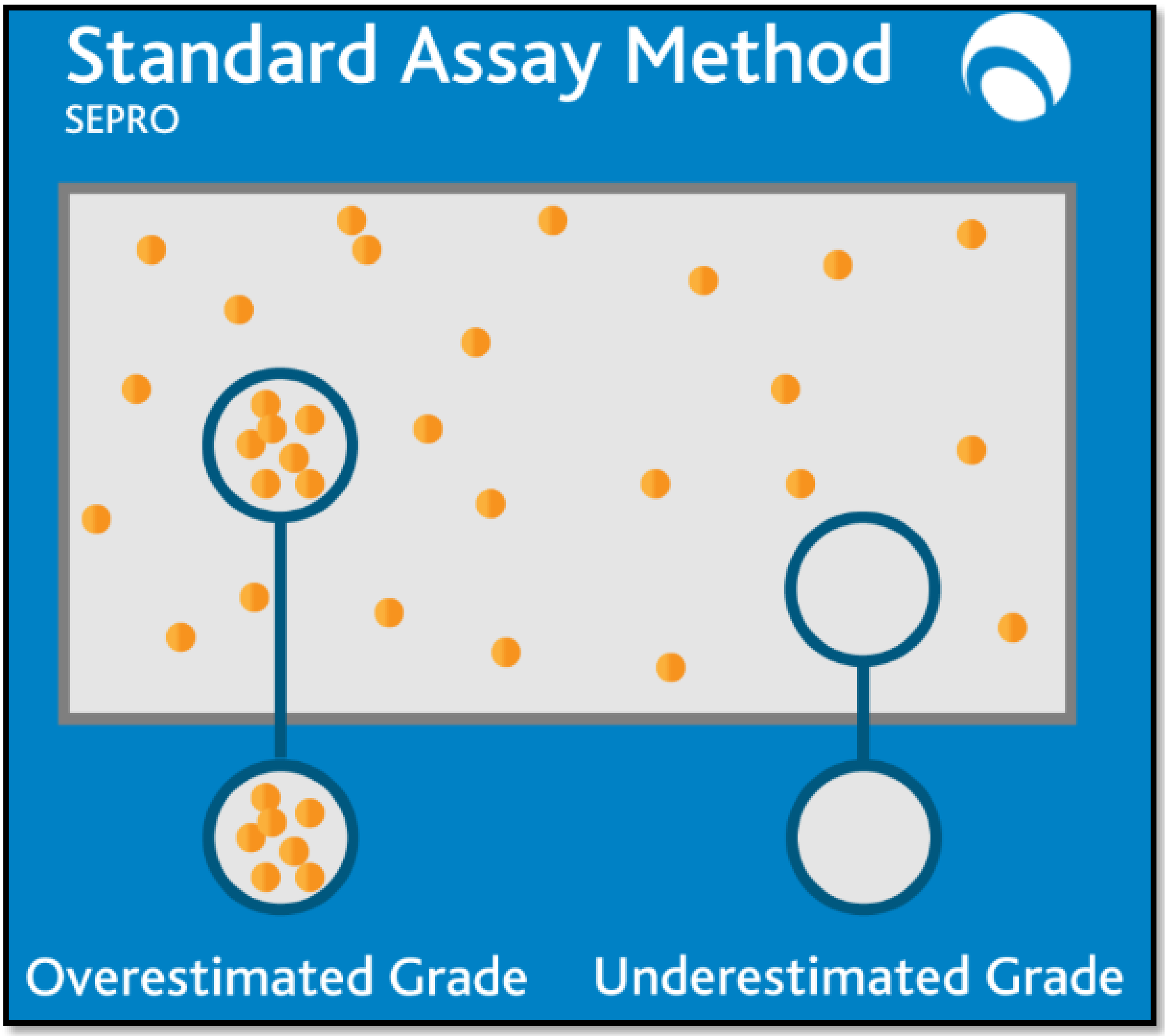


Figure 4-4: Nugget effect in the reef horizon (Sepro Laboratories, 2019)

If the nugget effect is suspected in that area, the factor must be applied. The factor will ensure a more realistic value and resultant gold estimation.

4.7 Section Summary

The mine survey department recorded apparent tonnage gains of 19 346 tonnes due to the underestimation of broken ore in the gullies. Other sources of tonnage gains include FOG mud in the drains and additional lock-up tonnes removed. This resulted in a mine survey shortfall of 10% from January 2021 to December 2021.

Ya Rona shaft has lost 32% of the gold blasted. The gold loss can largely be attributed to the nugget effect; the grab sample shows 40% less than the face sampling. Regular PTOs were carried out on the underground sampling process to minimise the errors in the underground sampling process and minimise apparent grade loss. Correct QAQC practices are in place at the assay laboratory to obtain an accurate sample value.

Real tonnage lost at Ya Rona shaft is due to incorrect installation of barricades and fragmentation issues due to excessive ore handling due to the long gullies.

The fragmentation and the mud in the cross cuts that are not cleaned out timeously are the main contributors to real gold loss at Ya Rona shaft.

4.8 Chapter Conclusion

This chapter investigated tonnage and grade gains and losses. The ore flow analysis figures show a 14% gain in tonnage and 26 % under-delivery of gold against what was available for hoisting.

Incorrect estimations made by the mine survey department of the depth of ore left in the gullies. Some sources of tonnage gains and losses can be accounted for as lock-up tonne that may have or not have been removed. Additionally, FOGs not accounted for and reported in the ore flow under other sources can also lead to tonnage gains.

Incorrect sampling methods can lead to over or underestimation of gold called for. The overestimation results in a poor MCF and overestimation of gold called for. The sampling of VC33 34B shows a gold loss of 40%.

The significant difference between the face sampling and the sampling of the broken ore needs to be explored further. It is not the nugget effect that has a specific cause and is considered statistically during the kriging estimation procedure. The difference could be due to poor face or grab sampling technique or show significant physical loss of metal during the blast (real loss). Blasting techniques need to be investigated to minimise this physical tonnage loss.

5 APPARENT GAINS AND LOSSES AND REAL LOSSES

5.1 Section overview

This chapter focuses on apparent tonnage gains and losses. The focus is placed on quality sampling and mine survey measuring. Apparent tonnage gains and losses were explained in detail in chapter two.

5.2 Apparent Tonnage Gain and Loss

5.2.1 Correctness of volume measuring systems

The actual external waste width is measured in centimetres against the planned external waste mined. Excessive external waste will increase the tonnage delivery, the tramming loads to the shaft, and the supporting and hoisting costs. The increase in external waste will dilute the value, and a lower belt grade will be seen on the belt. Control over the external waste at Ya Rona shaft is generally good (Figure 5-1) as Rock Mechanics require a minimum of 120 cm stoping, and the channel width is generally around 40 cm.

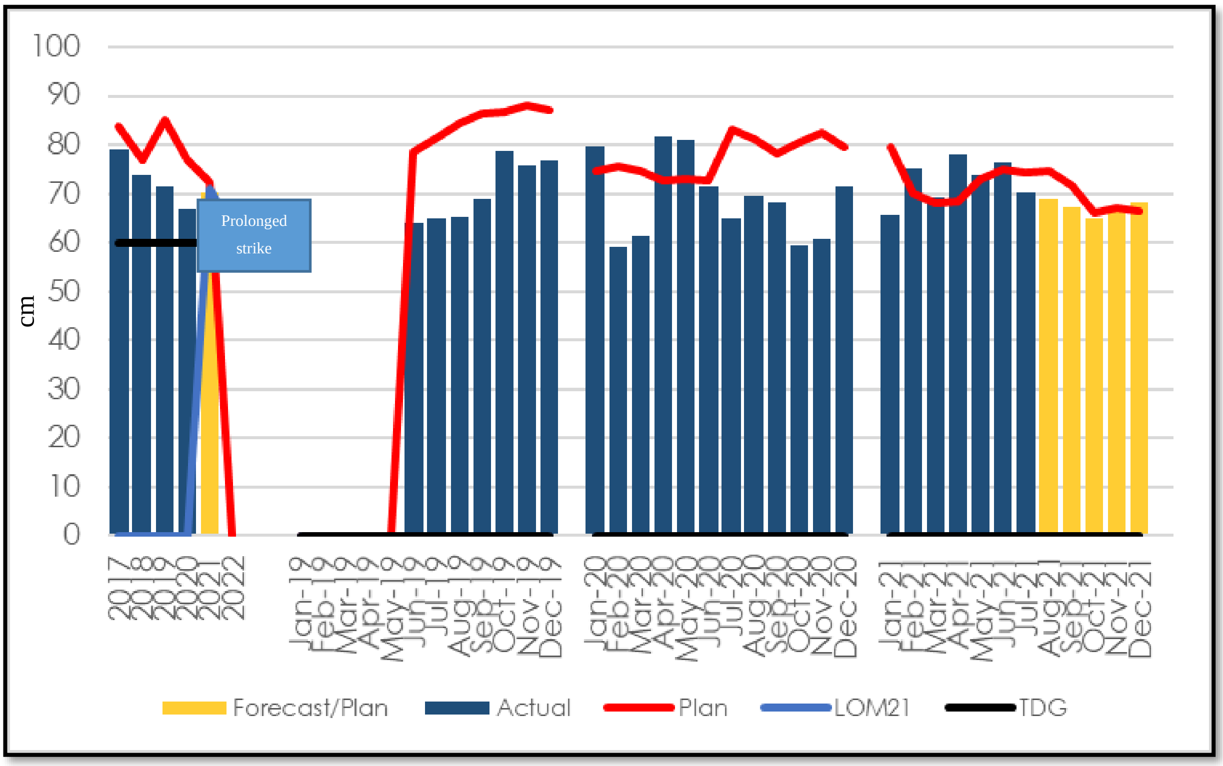


Figure 5-1: External waste mined (Schwartz, 2021)

Unaccounted dilution can be caused by the sampling department utilising an incorrect method to measure the stoping width. Stoping width must be taken one to three metres from the face at a 90-degree angle to the dip of the reef every five metres along the face. Figure 5-2 illustrates the correct and incorrect stope width measuring method.

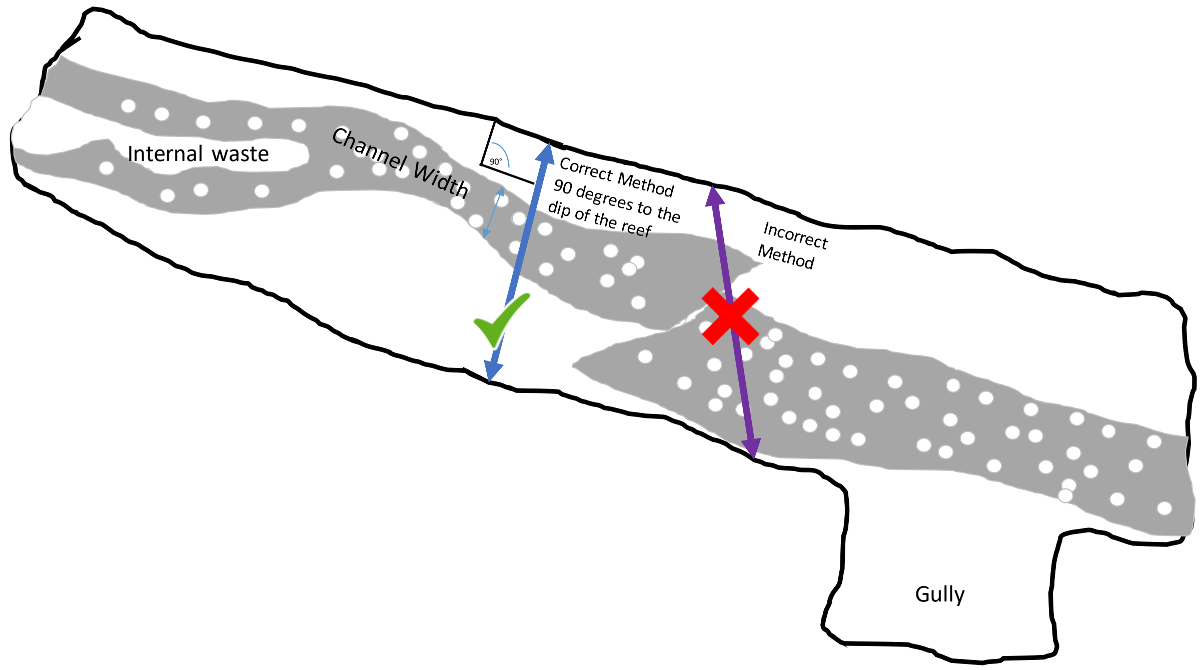


Figure 5-2: Correct and incorrect stoping width measuring

Stoping width (SW) must be measured on the face; if this is done incorrectly, it can contribute to unaccounted dilution (shortfall) by over-measuring the SW, the SW would be "longer", and the volume mined would be less than the estimated. A PTO will identify if the sampler mismeasures the SW, and the measurement will be corrected.

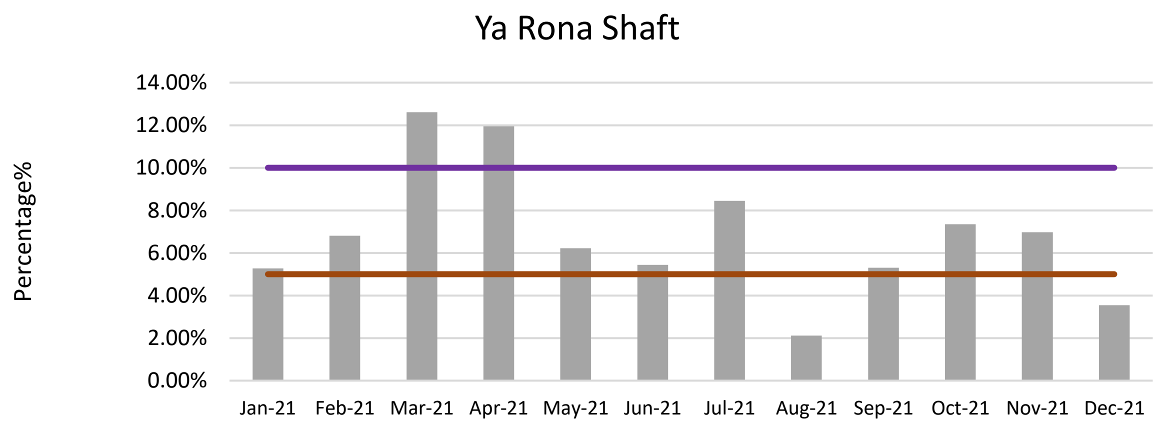
5.2.2 Additional waste from sources not called for by the mine survey

FOG is rarely accounted for in the mine survey volume measurement. The mine survey department measures the stoping face's advance and passes the sweepings. If a FOG occurs on the face or in the area where sweepings are done, the mining personnel must clean out the FOG area; otherwise, the mine survey department will not pass the sweepings. The extra waste usually is not a massive amount, between five to 20 tonnes, but this FOG material is unaccounted for in the mine plan, and it contributes to the tonnage discrepancy and will be a tonnes gain.

During the monthly measuring process, the gully heights and widths are estimated due to the broken ore that may be accumulated in them. This underestimation or overestimation of the gully widths and heights contributes to the plant's tonnage discrepancy in the ore flow.

All the off-reef development is trammed with the reef and sent to the plant at all the Driefontein operations. All the waste development has been planned to go to the plant in the business plan.

Over breaking is where the required dimensions, as per plan, have been exceeded. Under breaking is where the required dimensions were not mined. That is, a smaller volume was mined than required. Overbreak is monitored monthly by the mine survey department by measuring the widths and heights. The baseline figure of 5 % is a historical achievement figure. The 10% line shown in Figure 5-3 is a planned over-breaking figure that the Resource Manager set out. Ya Rona shaft exceeded its baseline figure of 5% for January 2021 to November 2021, as shown in Figure 5-3; this is increasing the tonnage mined that is not planned.



	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21
Ya Rona Actual	5.28%	6.81%	12.60%	11.96%	6.22%	5.44%	8.44%	2.12%	5.30%	7.35%	6.97%	3.54%
Ya Rona Base Line	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Ya Rona Plan	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%

Figure 5-3: Over breaking graphs month on month for 2021 (Schwartz, 2021b)

5.2.3 Mud loading

Regular loading of mud is not part of the standard mining cycle. Mud accumulates in the drains due to excessive water use in the stopes and poor water control measures. The excessive water washes the fine gold particles out of the stope into the crosscut and the drains. Mud loading is done during overtime shifts or over holiday periods. The mud is loaded into a bag by hand, and the bags are hung on the side wall, as shown in Figure 5-4. Once most of the water has drained, these bags are loaded into a hopper and transported to the station.

Figure 5-4: Mud bags hanging on the sidewall (Ndlovu, 2022)

Mud-loading bag tonnes are unaccounted for because Sibanye-Stillwater does not call for old gold, vamping and mud loading in the mine survey measuring system. These tonnes are only accounted for at the belt on the surface. Figure 5-5 shows typical cross-cut mud accumulation during normal mining operations.

Figure 5-5: Accumulation of mud in the crosscut (Ndlovu, 2022)

5.2.4 Relative density

Relative density (RD) determines the estimated rock mass per unit of volume; RD will differ per type of ore mined. If the incorrect RD is used, it could lead to over or underestimation of the grade and tonnes received in the plant compared to what was measured (called for) by the mine survey department and may result in a mine survey shortfall or excess (De Jager, 1997) as well as an inaccurate MCF.

The density used at Driefontein is 2750 kg per cubic metre of rock in situ. No recent laboratory tests have been conducted (as of 2021) to confirm the relative density, as the operation is well-established and has a proven track record through the years.

5.3 Apparent Grade Gain and Loss

The apparent grade gain and loss sources have been explained in detail in Section 3.3. The mineral resource manager relies on accurate sampling and estimation from the sampling department and must decide whether to keep mining a panel if the value is below the cut-off grade.

5.3.1 Sampling

Sampling is one of the essential aspects of mineral resource management and ore extraction. Sampling is done monthly to determine the value of a stope panel and whether it can be extracted profitably. The correct sampling method must be used. The incorrect measuring of the stoping width can positively or negatively influence the grade value. The stope face must be barred and washed with clean water before the face marking can begin and the sample taken. If the stope face is not barred correctly, loose rock from the stope face can fall into the sampling dish and contaminate the sample. The stope face must be sampled from the bottom upwards to avoid contamination; if the face is sampled from the top downwards, the top sample particles may contaminate the in-situ sample below. Figure 5-6 shows a stope face marked off, painted, and ready for sampling by chipping the rock with a hammer and chisel (Valuation Department Driefontein, 2021a).

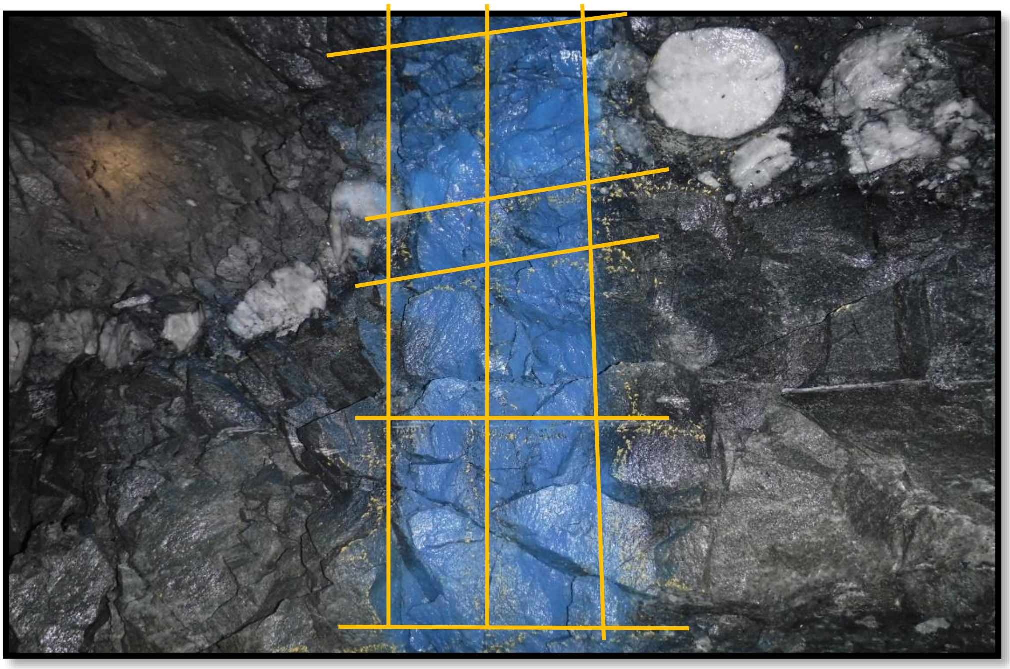


Figure 5-6: Stope face marked off and ready for sampling (Valuation Department Driefontein, 2021a).

A sampler can falsify sampling results by taking samples of broken rock at the tips rather than sampling on the face. These activities can be detrimental to the mine as decisions based on incorrect data can lead to the closure of an entire section or even the mine. A number of samplers have also been found to not adhere to the correct sampling methods on the stope face. These breaches in protocol result in the dismissal of the guilty employees, and the sample information is discarded and not used in the estimation process.

Sampling and valuation involve the following:

- The face is sampled at 5 m intervals from the top of the panel (top gully) to the bottom of the panel (bottom gully).
- The face width is marked and segregated from the bottom contact of the reef to the top contact of the reef.
- The width measured on each sampling is noted in the sampler's notebook, and unique sampling tickets are allocated to each sample.

- The face sampling is done with a hammer, chisel, and a dish to collect the sample. The sample is taken from the bottom (footwall to the hanging wall) to prevent contamination.

The following can contaminate the sample:

- The stope face is not adequately barred and washed with clean water;
- Taking a sample from a different location on the stope face and not at the demarcated location; and
- Contamination can occur if a piece of the sample falls on the ground and is picked up. In this instance, the sampling must be redone.

Incorrect stoping width measuring is an area with potential error (but only affects tonnages).

The stopes are high-risk areas for gold loss due to poor sampling procedures. Sampling is critical in grade valuation, and inadequate sampling can lead to a false conclusion on gold content (Cawood, 2003). The face is spatially divided into a section with dip tape tied into at least two pegs in each gully and strike tapes in the gullies (top and bottom), as shown in Figure 5-7.

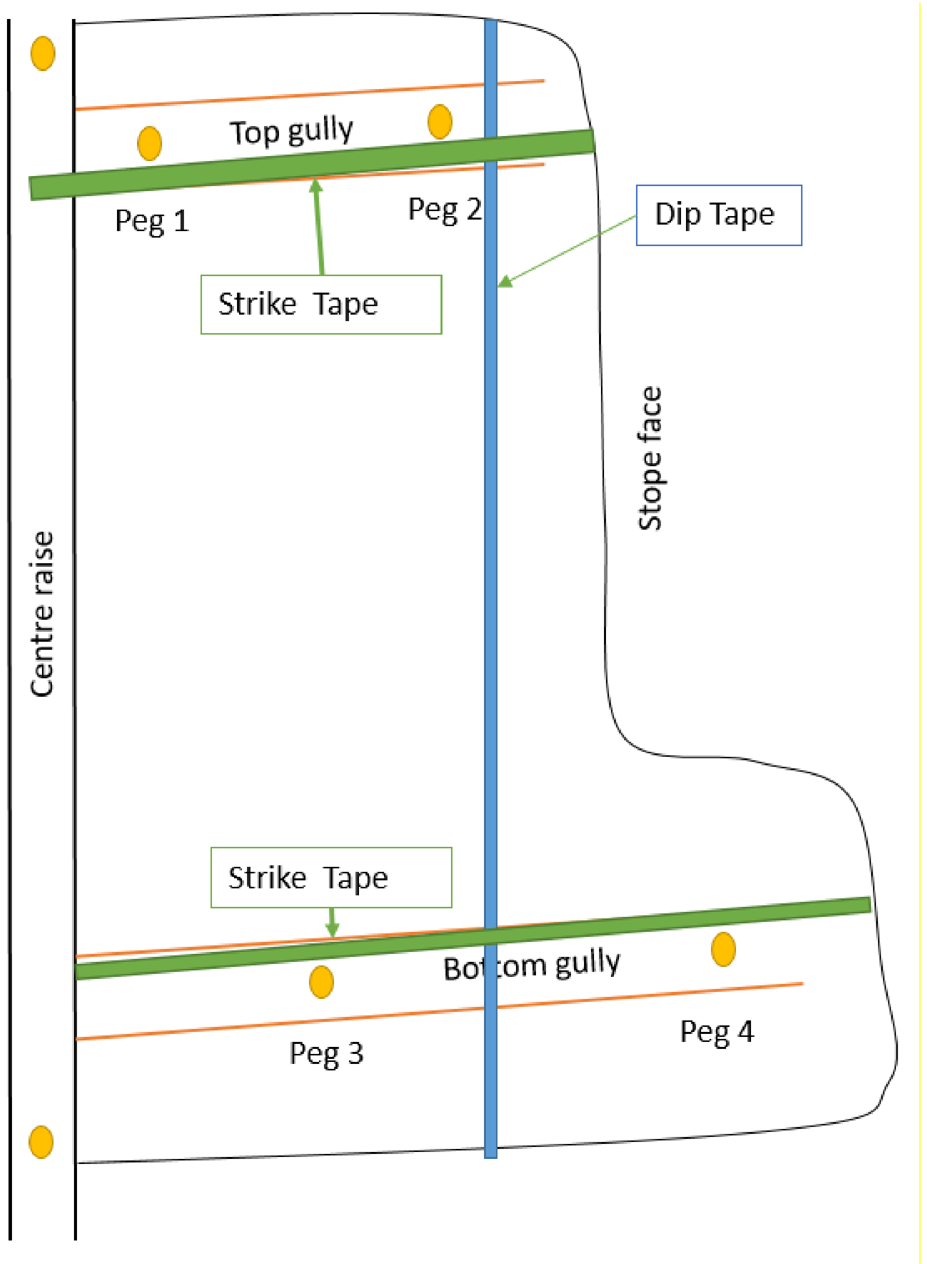


Figure 5-7: Spatially allocation of the face before sampling starts

The first sampling is taken 2.5 m from the top of the panel and followed at every 5 m intervals. The samples must be taken in a safe area on the face; the face must be barred and washed with clean water after baring. The top and bottom contact of the reef must be identified and marked off with the clinometer rule, as shown in Figure 5-8 (Driefontein, 2021).

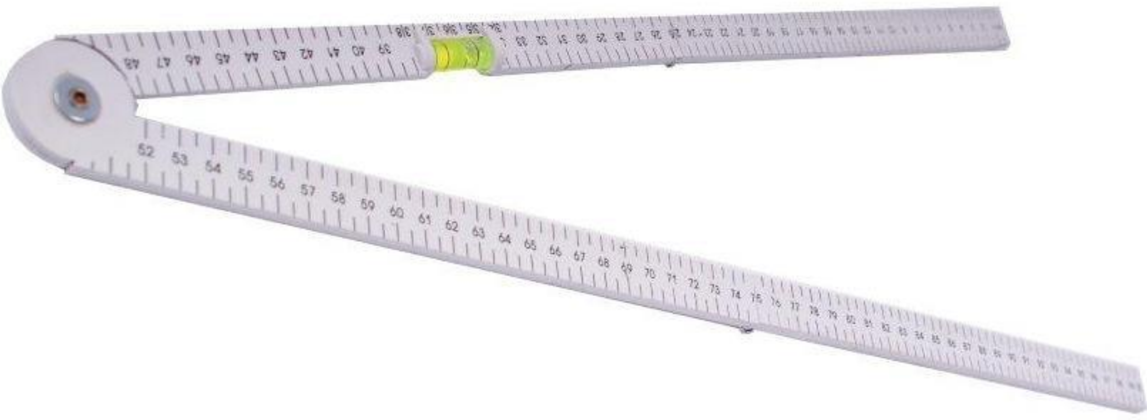


Figure 5-8: Clinometre rule to measure the sample (Flux-Co, 2022)

The face sampling is called chip sampling and is done with a hammer, chisel, and sampling dish. The sample is bagged, and ticket numbers are allocated as shown in Figure 5-9, as measured sample width and the ticket numbers must be recorded in a sampler's book.

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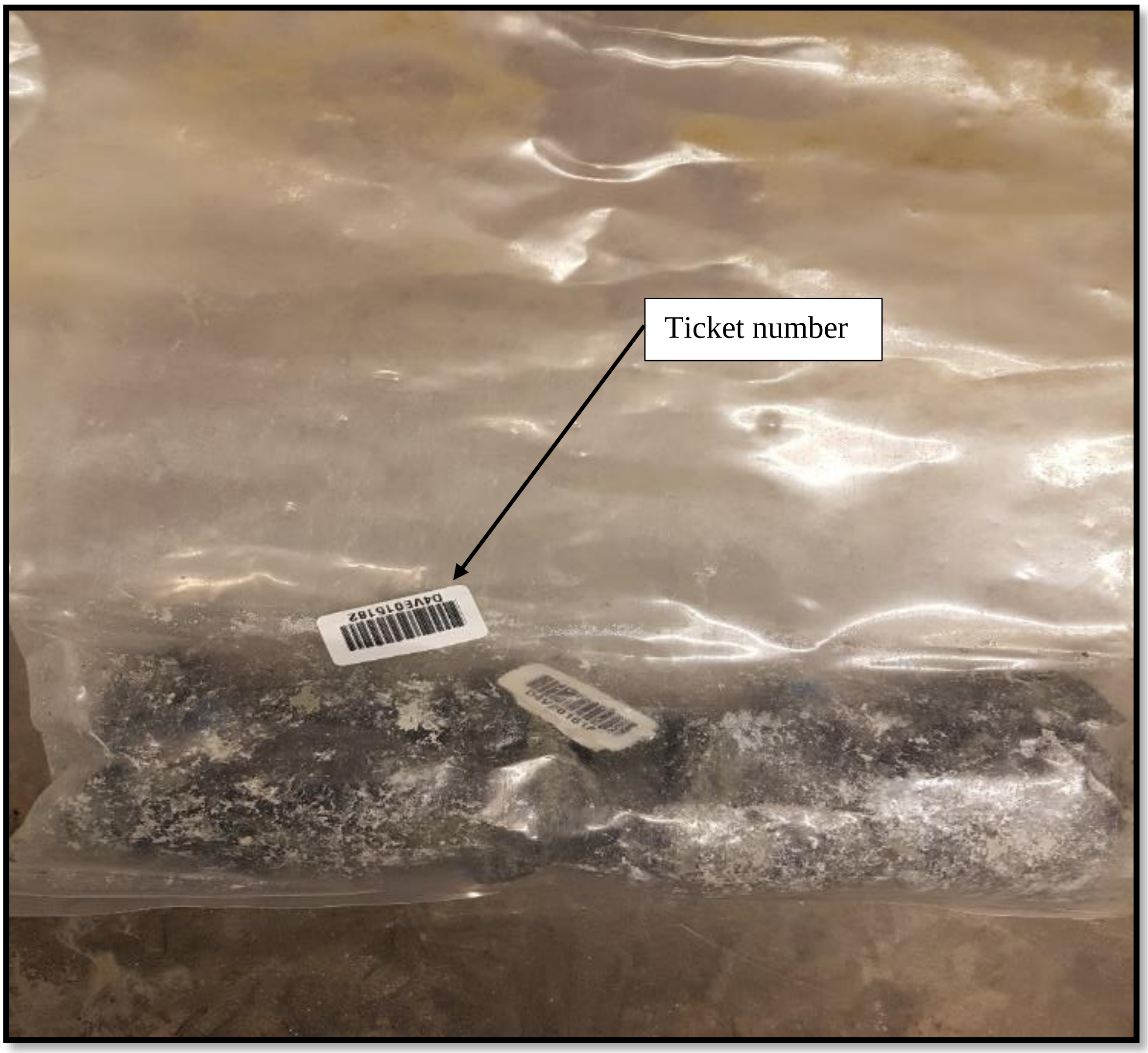

Figure 5-9: Sample in sample bag with a ticket number (Hurter, 2020)

As mentioned, samples are taken from the bottom up to prevent contamination. Contaminated samples must be discarded, and a new sample must be taken. After each sample is taken, the sampling dish must be washed (Driefontein, 2021). Once the Sampler or Mineral Resource Technician arrives on the surface, the samples are sent to the assay laboratory. The Sampler will use the MineRP software program (this programme is used to generate sample sheets) to plot their face sampling, and once the values have been received, the sample sheet will be printed, signed off by the mineral resource department with comments and sent to the mining department for comments and actions. The sample values are transferred into the Datamine software suite, and the geostatistician uses the information to generate a Kriging estimate; this grid is used for measuring and planning purposes.

Sampling is one of the essential activities in the mining chain. A sampler must always work correctly. The accuracy of the sampling and the measuring of the channel width are the most important aspects of the sampling procedure. Channel width is the sum of the widths of the various reef bands combined with the widths of the internal waste. Incorrect channel width measurement will influence the sampled value, the sample value in cmg/t can be higher or lower, and this will cause an over or under-estimation of the gold. As illustrated in Table 5-1, the true sample width is 10 cm at a grade of 150 g/t, which gives a correct value of 1 500 cmg/t. If the width is over-measured by 1cm, the new sample width of 11 cm at the same grade of 150 cmg/t now calculates to an incorrect value of 1 650 cmg/t; this is a false value and is overestimating the sample section value by 10%. If incorrect sampling methods are used, the mine can experience apparent losses in content (Cawood, 2003).

Table 5-1: Impact of over-measuring the reef channel width (Cawood, 2003)

	Channel Width (cm)	**Grade (g/t)**	**Value (cmg/t)**
True width	10	150	1500
1 cm over-measuring	11	150	1650
Result			**10% error**

5.3.2 Valuation

The current estimation method used on the mine is Kriging, where "*Kriging is a multistep process; it includes exploratory statistical analysis of the data, variogram modelling, creating the surface, and (optionally) exploring a variance surface. Kriging is most appropriate when you know there is a spatially correlated distance or directional bias in the data* (ArcMap, 2020).

Kriging is used to estimate the value of ore to be blasted in the stope from the actual sampling and boreholes taken underground. Kriging uses the actual sampling data to estimate the gold called for by the valuation and mine survey departments. Kriging is only as accurate as the accuracy of the data and the sampling procedures used to collect the data. Any anomalies in the sampling will affect the results used to estimate the final value and gold content. The Kriging process is checked through a peer review process as well as by external auditors with expertise in this field. The auditors picked up no anomalies concerning the Kriging process during audit cycles over the last few years.

5.3.3 Sampling quality assurance and quality checks

Regular control samples from African Minerals Standards (AMIS), as shown in Figure 5-10, are sent to the assay laboratories to check the accuracy of the assaying process, as the control sample gold content is known.

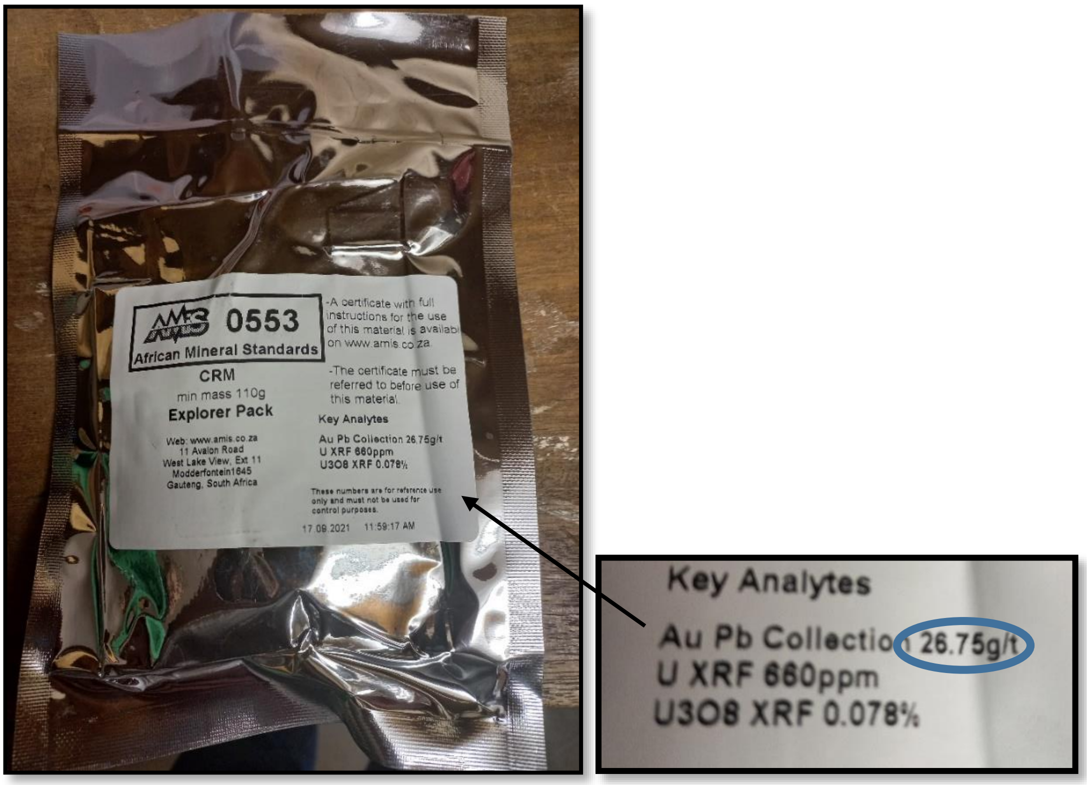

Figure 5-10: African mineral Standard controlled sample (Valuation 2021b).

Figure 5-10 shows a value of 26.75 g/t sent to the assay laboratory for a check; this check sample can have a variance of 10%. The 10% is the acceptable variance as it is a universal rule (rule of thumb) and a globally accepted error (Valuation Department Driefontein, 2021b).

The assay laboratory assays the underground samples to determine the gold content. Regular quality checks are carried out in the assay laboratory to ensure quality assurance. The reviews are done quarterly and ad hoc by the grade department.

The assay laboratories assayed for 2022,19320 samples with 1644 duplicate check samples and 303 repeat samples, as shown in Figure 5-11 (Derckson, 2022).

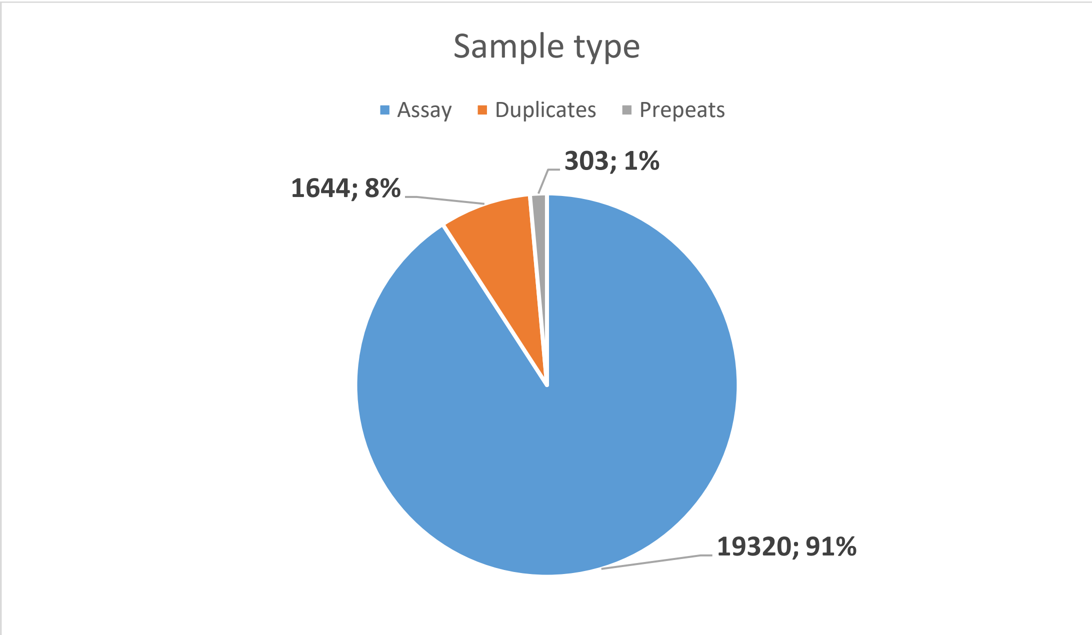

Figure 5-11: Sample type (Derckson, 2022)

The repeat samples (303) have been re-assayed for quality assurance and 56 failed the QA/QC, as shown in Figure 5-12 (Derckson, 2022).

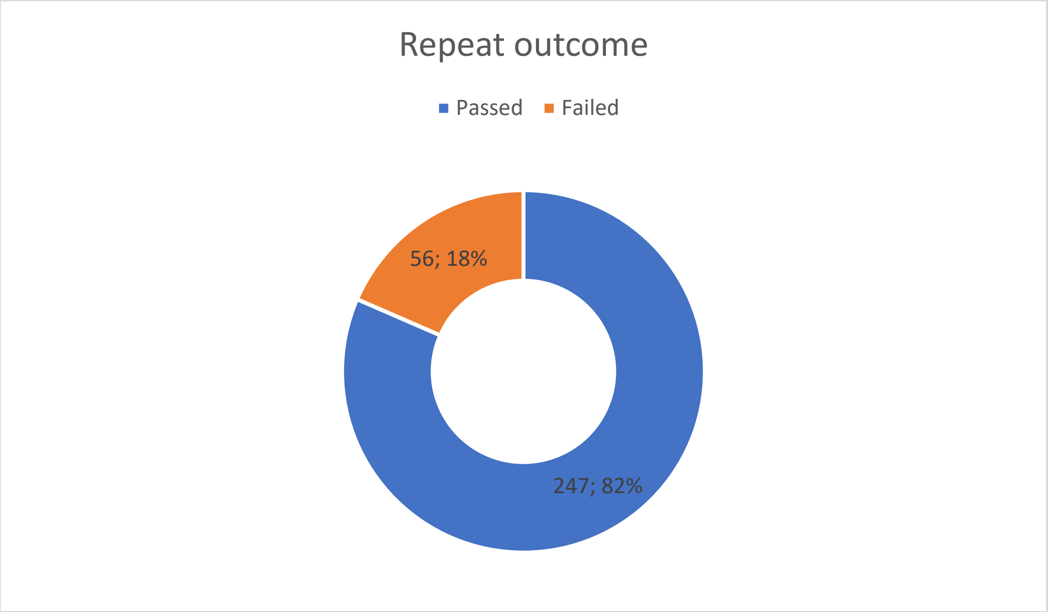

Figure 5-12: Sample outcome of re-assay (Derckson, 2022)

The grade officer is qualified, with an Advanced Valuation Certificate from the Minerals Council and is trained in the assaying process with at least five years of experience. A quarterly feedback session is held to address any issues arising from the audits performed on all the mineral resource departments, including the assay laboratories.

5.4 Real Tonnage Losses

5.4.1 Blasting barricades

Effective blasting barricades are only installed shortly before the measuring period at some of the shafts and this causes contamination in the old areas. To prevent this, regular checks are carried out to ensure that blasting barricades are installed from the footwall to the hanging wall and at the mining standard of 6 metres from the face, as shown in Figure 5-13.

Figure 5-13: Effective blasting barricade installation (Ndlovu, 2022)

Ineffective installation of barricades causes blasted material to get thrown into the old swept areas, and that gold can be lost if it is not retrieved. Poor blasting barricade installation is shown in Figure 5-14.

Figure 5-14: Ineffective installation of blasting barricades (Ndlovu, 2022)

Blasting barricades are checked regularly on routine visits by the sampling department to determine the effectiveness of the installation. Figure 5-15 shows the panels visited and the results of the monthly inspection, particularly the "not effective" blast barricades installations.

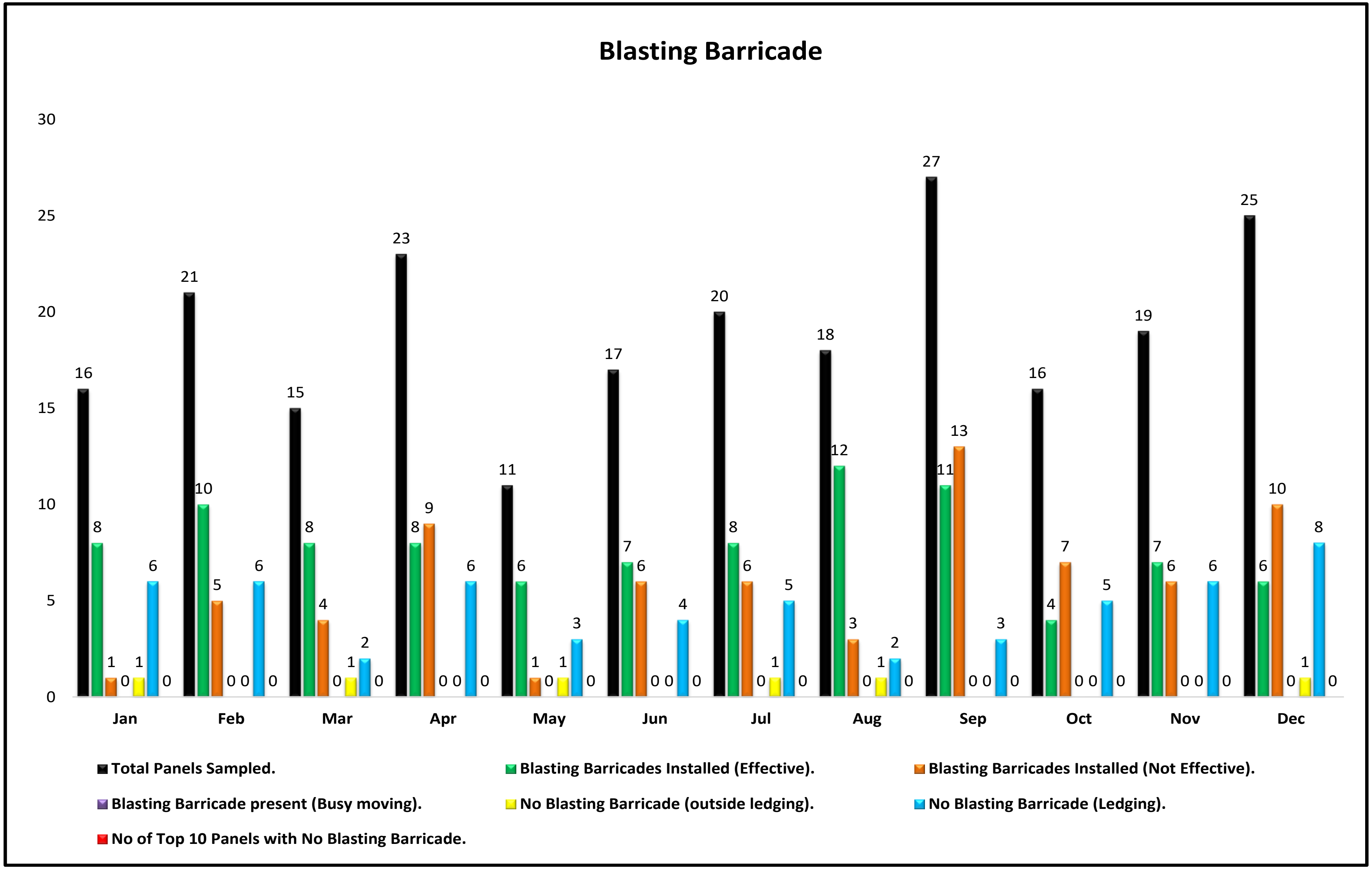

Figure 5-15: Blasting barricade's effectiveness (Coetzee, 2021)

5.4.2 Bulk sweeping and locking up tonnes

The mine survey department checks and measures the sweepings monthly on measuring day to ensure that all the broken ore has been removed and the sweeping is done to the mine standard of 6 metres from the face with proper barricades installed. Bulk broken ore must be removed, 60% of the footwall in the gully must be visible, and 6 metres from the face backwards must be washed with no fines visible.

Lock-up tonnes are estimated by the mine survey department every month on measuring day, The mine survey department estimates the depth of the gully and the depth of the accumulations, but this can be incorrectly estimated. The detail of the lock-up tonnes report is given in Appendix 7. Table 5-2 summarises the monthly estimate from January 2021 to December 2021 (Ramaila, 2021).

Table 5-2: Lock-up summary for Ya Rona shaft (Ramaila, 2021)

Lock up tons Ya Rona shaft 2021

January-21

	Stoff Census			Value
	Face tons	Gully Tons	KG	g/t
	1027	1107	58.23	27.3
Total	2133			

February-21

	Stoff Census			Value
	Face tons	Gully Tons	KG	g/t
	1091	1362	68.12	27.8
Total	2453			

March-21

	Stoff Census			Value
	Face tons	Gully Tons	KG	g/t
	1276	1638	70.74	24.3
Total	2914			

April-21

	Stoff Census			Value
	Face tons	Gully Tons	KG	g/t
	1417	1252	55.32	20.7
Total	2669			

May-21

	Stoff Census			Value
	Face tons	Gully Tons	KG	g/t
	1483	1360	67.92	23.9
Total	2843			

June-21

	Stoff Census			Value
	Face tons	Gully Tons	KG	g/t
	1429	1198	44.15	16.8
Total	2627			

July-21

	Stoff Census			Value
	Face tons	Gully Tons	KG	g/t
	1194	1436	51.14	19.4
Total	2630			

August-21

	Stoff Census			Value
	Face tons	Gully Tons	KG	g/t
	1204	1281	57.63	23.2
Total	2485			

September-21

	Stoff Census			Value
	Face tons	Gully Tons	KG	g/t
	934	1018	41.63	21.3
Total	1952			

October-21

	Stoff Census			Value
	Face tons	Gully Tons	KG	g/t
	1220	1335	50.11	19.6
Total	2555			

November-21

	Stoff Census			Value
	Face tons	Gully Tons	KG	g/t
	1443	2483	64.02	16.3
Total	3926			

December-21

	Stoff Census			Value
	Face tons	Gully Tons	KG	g/t
	1383	1535	52.42	18.0
Total	2918			

The lock-up tonnes contribute to a poor MCF, resulting in less revenue and lower or no profits. Lock-up tonnes can be lost due to the installation of the backfill bags when they are placed on broken ore. Most of the shafts at Driefontein, of which Ya Rona is one, use backfill as support. Backfill uses material removed during the mining process and processed through the plant. Backfill is pumped back underground and piped into bags in the mined-out area of a stope. (Rockeng, 2019).

There was a schedule in place until 2017 for the grade officers to check the stope panels to be backfilled on a specific day of the month to permit the backfill bags to be placed, ensuring that the area has been swept first. Due to increasing costs and the marginality of many of the mines, this grade officer function was made redundant as a cost-saving measure. At this stage, the miners and production supervisor use their discretion to place the backfill bags. It is possible that broken ore can be left behind below the backfill bag. If gold is left below the backfill bag, the loss can be estimated using an average current belt grade of 9.0 g/t as determined by the belt sampling. If backfill bags are placed onto broken ore, there will be a gold loss that can never be retrieved. The calculations are as follows: 25 m panel x 2.5 m width bag x 0.3m of broken ore x 1.67 density x 9.0 g/t = 0.3kg of gold left below the backfill bag. At an estimated gold price of R800 000 per kg used, the real unaccounted loss in revenue amounts to R240 000.

When a panel has to be abandoned because it is unsafe, material that has been blasted and not removed will be lost. An example of when this situation may occur is when a fall on the ground makes an area unsafe for mine personnel to access. An abandonment note is issued after an investigation and assessment by the rock engineering department, grade officer and other relevant mining personnel. The tonnes and gold that the mine surveying methods have accounted for are lost.

5.4.3 Spillages

In some instances, gullies are not blasted to standard to the correct width and height. The ore into the downdip side or can contaminate old mined-out areas if sufficient barricades are not installed. This ore's removal usually only occurs at the end of the mining cycle in the final vamping stage. This means that there will be a tonnage loss in the current month, but overall if the tonnes are recovered at a later stage, it will balance out.

Spillages occur from the loading of the hopper to the transporting of ore to the station. Overloading hoppers in the crosscuts cause spillage, which is loaded to the sidewall and not cleaned immediately. This is a tonnage loss and will impact the MCF.

5.4.4 Cross tramming

Cross tramming is done from Ya Rona shaft to Pitseng shaft and hoisted to surface. The cross-tramming path is always kept clean as it is high-speed tramming, and any spillage would cause an "A" hazard (immediately fixable hazard) tonnes trammed are measured with the Smart Rail system.

5.5 Real Grade Loss

This section investigates real grade loss. Some factors that influence real grade loss are poor drilling and blasting methods that can lead to leaving the reef in the footwall and the hanging wall, poor fragmentation, sweeping not done to mine standard and illegal mining.

5.5.1 Over fragmentation

If incorrect blasting and drilling methods are used, such as incorrect drilling direction and spacing, it can lead to ore not being mined, for example, leaving reef in the footwall (RIF) or hanging wall (RIH). The VCR at Ya Rona is bottom-loaded, meaning the highest content concentration is in the channel's lower part. Content (gold) ends up being left behind in the footwall as RIF, which goes against the purpose of mining for profit. As a result, the miners are destroying the value of that panel; quality mining is needed to minimise gold loss and maximise revenue.

The explosive technician checks fragmentation at each shaft and belt audits are done to check the fragmentation regularly during the month. Figure 5-16 shows an image of the surface belt and the rock fragment size.

Figure 5-16: Surface belt audit to check fragmentation (Nair, 2021)

The VCR reef is very brittle, and the ore on the belt is much smaller due to excessive handling during the ore transporting process from underground to surface.

Fragmentation of the rock blasted in the stope is affected by blasting practices, including blast pattern and the explosives (type and amount) used. The explosive technician monitors the type and the cost of explosives used monthly, as shown in Figure 5-17.

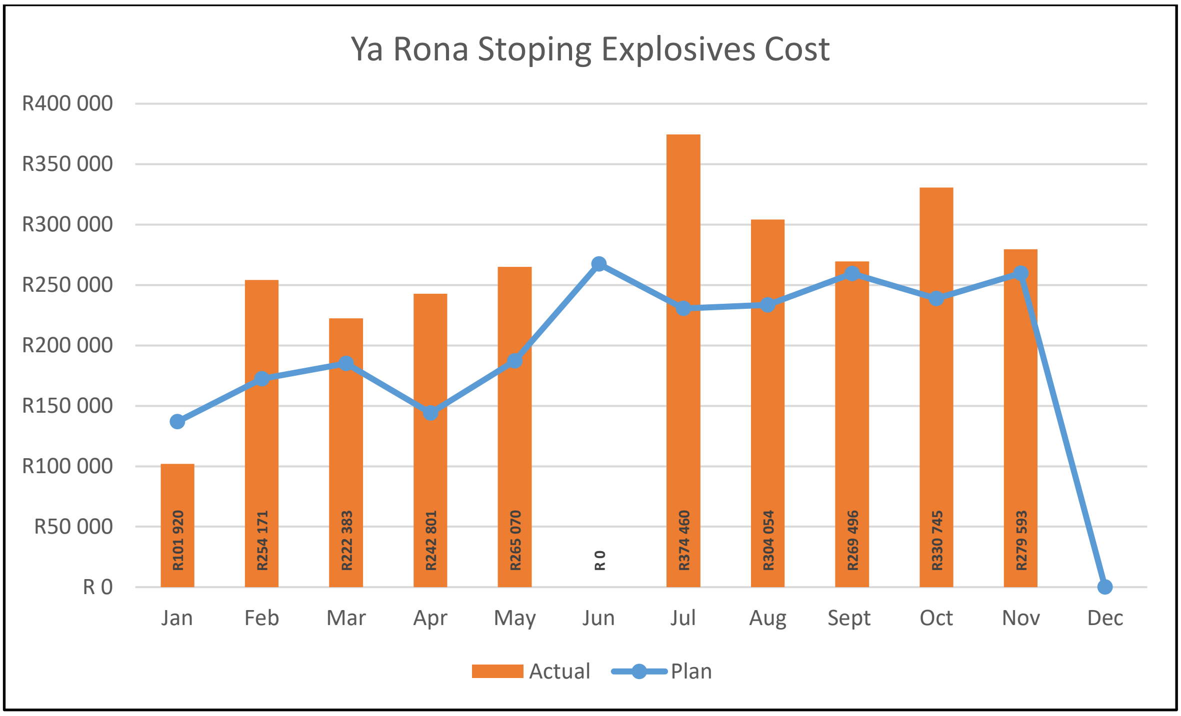

Figure 5-17: Explosive cost comparison per month (Beer, 2021)

Different explosives are used in the stoping area, such as the Sasol Combipack and AEL Emulsion. The different explosives are used to ensure that the fragmentation of the blasted rock is of the correct size and that gold loss is prevented. The Sasol Combipack is suitable for optimal fragmentation in the Carbon leader reef (CL), and the AEL Emulsion is proven suitable for the VCR reef's optimal fragmentation.

The explosive co-ordinator monitors best blasting practices at each shaft with his team. Marking drilling and charging up are checked to assist in the correct face advance and fragmentation and that the hanging wall is not damaged as Ya Rona shaft is mining VCR with Alberton Lava in the hanging wall; the lava is very brittle and can cause major FOG.

Ya Rona's explosives cost continuously exceeds the planned explosive cost. This can be attributed to the over-achievement on the square metres mined in the stoping or possibly because of theft of explosives by the illegal miners. This over-achievement is illustrated in

Figure 5-18. The mining teams are rewarded with a bonus if they overachieve their targets. The over-achievement results justify the explosive costs.

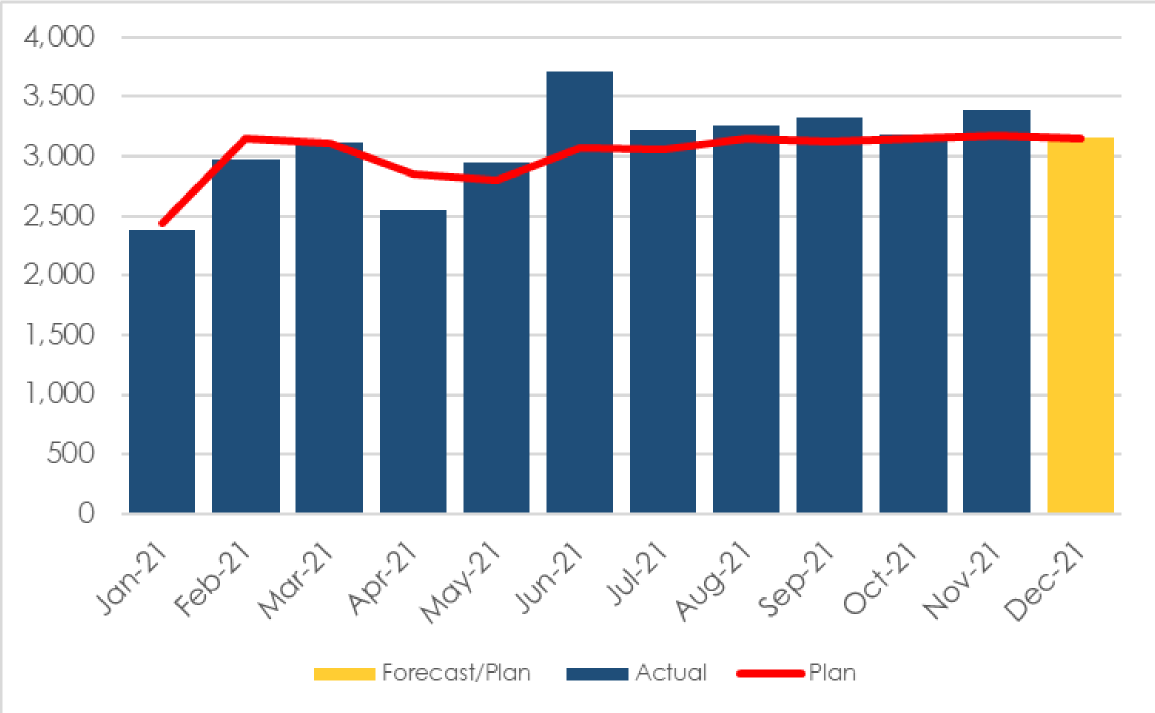

Figure 5-18: Square metre plan versus actual measured (Wild, 2021a)

5.5.2 Fine sweepings

The mine survey department must ensure that the sweeping quality is up to standard before payment can be made to mining personnel. A sweeping standard is in place to ensure that the mining personnel adhere to it and that the mine survey department has a guideline. The sweepings standard states that the sweepings must be completed no further than 6 m from the face with barricades or backfill installed. No more than a quarter sample bag of fines must be found in the swept area. The grade officer does random checks on the measuring day after the mine survey department has completed its task to ensure that the standard is adhered to. The sweeping percentage is monitored and reported monthly, as shown in Figure 5-19.

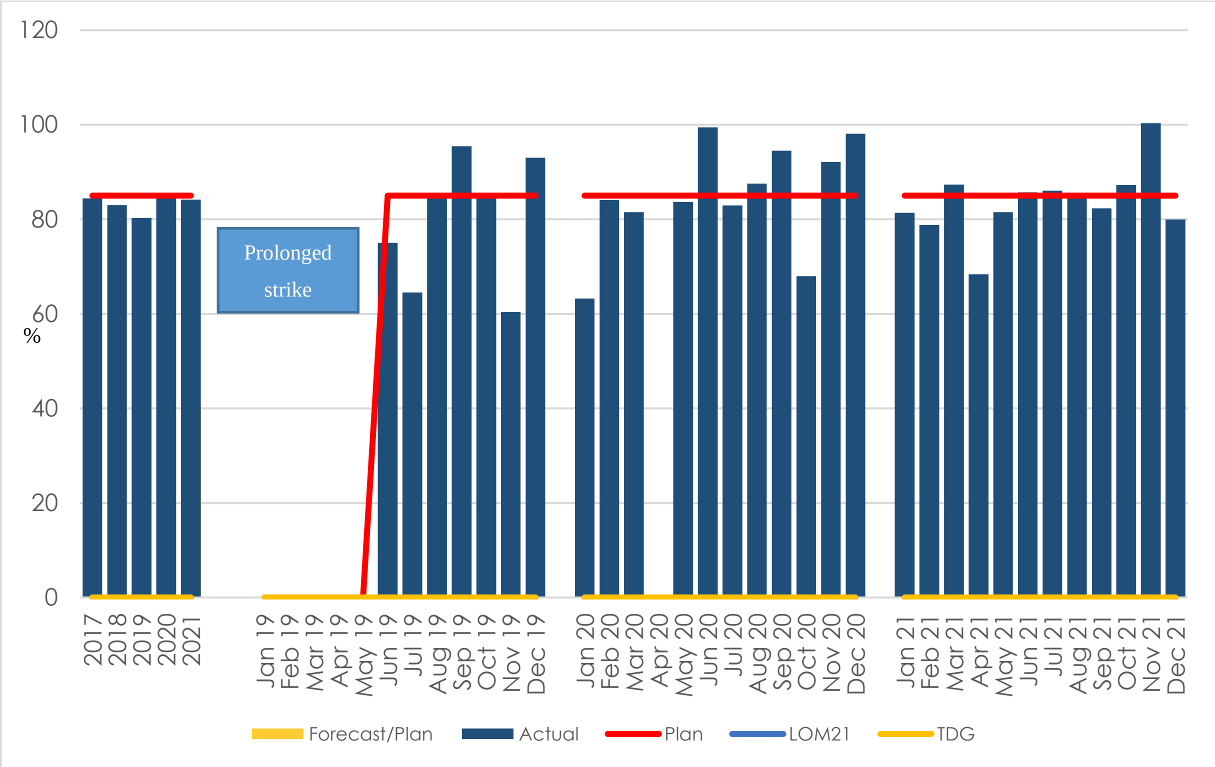

Figure 5-19: Monthly sweepings percentage (Sibanye-Stillwater 2021)

The mine target of 85% is set for sweepings up to 4 m from the face, and ledging panels are not swept until they have advanced more than 4 m. Action plans must be implemented when the mine personnel do not achieve their sweeping target. The action plan includes when the sweepings will be removed and re-checked by the grade officer or mine survey department. According to the bonus department, a sweeping penalty will be applied and the crew will be penalised 33% of their bonus.

5.5.3 Water control in stopes

Water must be used in the mining areas to suppress silica dust, a health risk that can cause silicosis. As the face advances, sumps are blasted in the bottom gully of the stope panel to catch the water. The water is pumped out of the sump in a water column using a centrifugal pump, as shown in Figure 5-20.

Figure 5-20: Centrifugal pump to pump water out of the stope (Botes, 2021)

Not all the water will be collected in the sump as some of the water bypasses the sump and the pumps. In this instance, the water runs down the centre raise and washes the fines out of the box hole into the crosscut, where the mud accumulates in the drains. This accumulation of mud in the drains is not cleaned regularly. However, all this material will be taken out when vamping is done.

If the mud grade is the same as the stope it comes from, then it can be shown that fines are not being enriched with fine gold particles. If the grade is significantly higher than the stope grade, this could cause the lower head grades due to losing the highest grade in the fines.

5.6 Impact of Illegal Mining

Illegal mining takes place in both abandoned shafts and operating mines. The increase in illegal mining can be attributed to difficult economic times, unemployment, immigration, poor border controls, and limited police resources to stop illegal activities (Minerals Council 2021).

It is illegal in South Africa to have rough diamonds and gold-bearing material in your possession. The Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA) does not allow mining without a license. Illegal miners, also known as "Zama zamas", are sometimes connected to organised crime. The illegal miners are trespassing in operating mines, and in some instances, the illegal miners are armed, and they set traps for the mine employees and the security personnel (Minerals Council 2021).

In 2017 when the Cooke Operation of Sibanye-Stillwater closed down, 797 illegal miners were apprehended. As a result of illegal mining, financial and social issues arise, including a loss of taxes and employee revenue opportunities. Illegal miners are a safety threat to themselves and the mine employees. Illegal miners often bribe or threaten mine employees to assist them in going underground or to supply them with food and mine equipment once they are underground. Illegal miners die in dangerous areas due to FOG, injuries, and explosions. They also make use of refinery materials that are unsafe and put their health at risk.

Mining companies spend a lot of money and time to make their mine secure and employ extra security. There is an increasing cost for the mines to seal off open entrances and do maintenance on damaged equipment that illegal miners have damaged.

In some instances, there is an unexplainable grade drop on the belts, with the sampling estimation being much higher than the actual belt grade. Sometimes the belt grade drop can be attributed to illegal mining activities resulting in a gold loss. For example, face sampling was done at VC 33 34B 6 East panel, and the results showed a value of 46.6 g/t, as shown on the sample sheet in Figure 5-21.

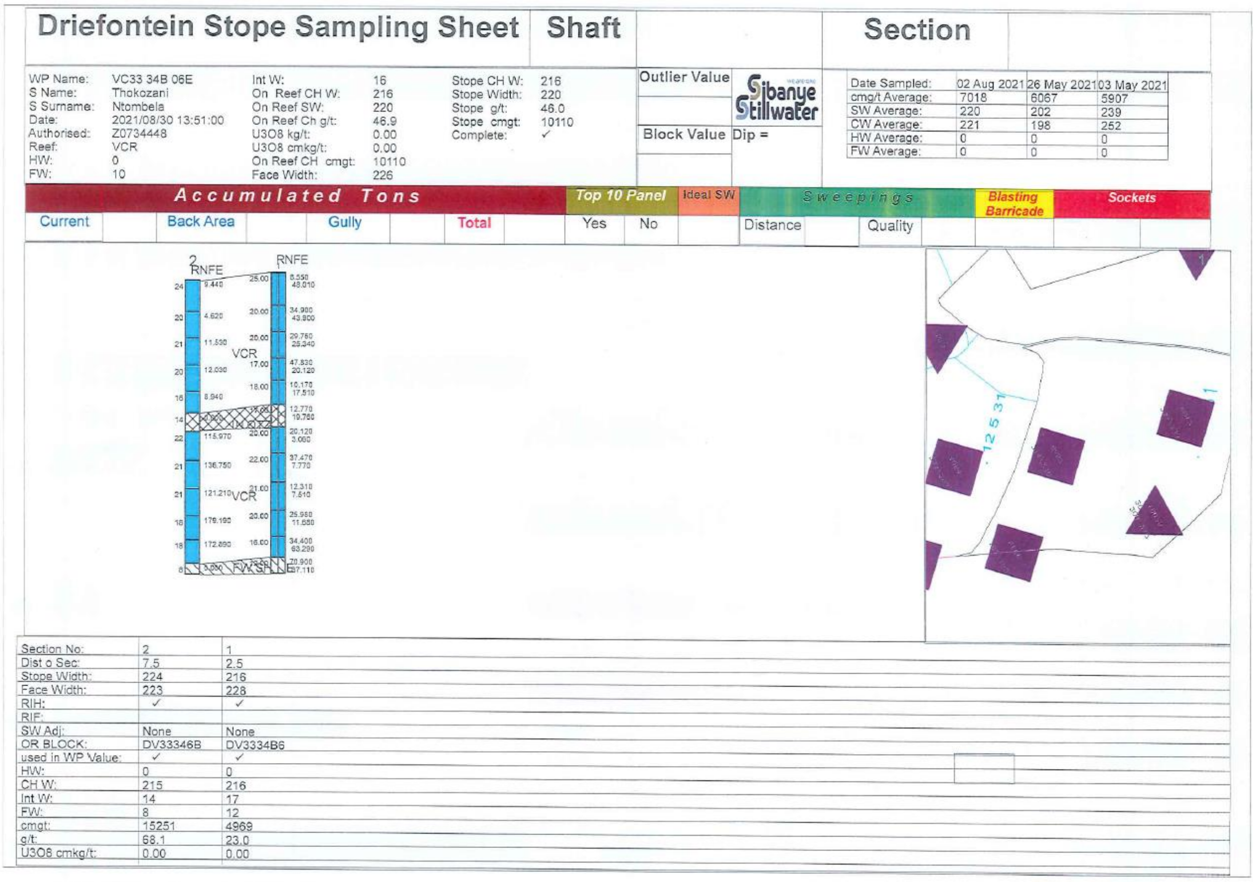

Figure 5-21: Sample sheet of VC 33 34B 06E (Ntombela, 2021)

Illegal miners place mats in the gully to catch the fine gold particles. Grab samples taken in the gully after the illegal miners have removed the mats show a drop to 20.63 g/t, as shown in Table 5-3.

Table 5-3: Grab samples taken at VC 33 34B 06E (Ntombela, 2021)

	Ticket Numbers	Location	G/t	Average g/t
Grab Samples	D4VE018849	1. On the face	42.63	43.24
Grab Samples	D4VE018850	2. On the face	36.5	
Grab Samples	D4VE018851	3. On the face	50.6	
Grab Samples	D4VE018852	4. Gully	19.52	20.63
Grab Samples	D4VE018853	5. Gully	21.74	

The samples indicate that illegal mining has eliminated 56% of the gold in this specific stope panel. The mine is losing revenue, and it is impacting the MCF.

Illegal miners are active over the whole of the mine in all the high-grade panels. High-grade panels have a high concentration of gold content in the deposit. Illegal miners get their mining information from mine employees who accept bribes and work with them. The illegal miners generally work in panels or areas where a restriction is placed on mine employees during the night shift. Due to a higher probability of seismic activity in the so-called “seismic window" in the hours after a blast, the mine restricts the entry of employees on the night shift to those specific panels.

Illegal miners enter these high-grade panels after the dayshift mine employees have left. The illegal miners load the fines onto the mats made of carpet fibre with a shovel. The mats are placed in the gully and are used to trap fine gold particles. Once the mats have trapped the gold fines, the illegal miners remove them and take them to their refinery plant, which is presumed underground even though mine personnel have searched for the concentrate plant but has never been found. Figure 5-22 shows the mats in the gully.

Figure 5-22: Mat in the gully to collect the fine gold particles (Visser, 2021)

The following experiment was conducted to estimate the amount of material the illegal miners typically remove from the stopes and gullies. After the blast, the mine surveyor scanned the volume of broken ore in the area where illegal mining activity had taken place to determine the tonnes in the gully. The mine surveyor used a total station with scanning capability to measure the volume of broken ore and rock in the gully. When the mine surveyor returned for the following shift, he only found mats placed 2 m apart in the gully and holes had been dug close by the mats. The mine surveyor did not re-scan the area as he could not scan the holes and no change in the volume of the broken ore and rock was evident. It was reported before by a mine overseer that the illegal miner is using the mine's scraper to pull the broken ore over mats in the gully. Presumably, the fines are loaded on the mats, and the fine particles are caught in the mats. If the presumption is made that the illegal miners can pull 50% of tonnes over these mats, then the explanation of the calculations is as follows:

The measured tonnes blasted for August 2021 was 551 tonnes. An estimate of tonnes the illegal miners pull over the mats is 50%. The 50% of the tonnes the illegal miners will be pulling over the mats will account for 275,5 tonnes, and the grade is 26.27g /t. The calculated gold will account for 7.2 kg assuming all the gold has been removed. By applying an MCF of 72% and a plant recovery factor of 97%, the final gold recovered could be as much as 5.1 kg. This is the gold the mine is losing from illegal mining. The impact on the MCF can be calculated to be 1% on the MCF. The impact on revenue is R4 million at an estimated gold price of R800 000/kg. The calculation follows: 551 tonne x 50% = 275.5 tonne, 275.5 tonne x 26.27 g/t / 1000 = 7.2 kg broken, 7.2 kg x 0.72 x 0.97 = 5.1 recovered kg, 5.1 kg x R800 000 = R4,0 million.

Ledging operations were underway in a new raise line at Masakane shaft in October 2020. The mining crew was mining in the top area of the raise line. A new stoping panel was required to start at the bottom of the raise line. When the mine overseers and the risk assessment team consisting of a safety officer, rock mechanic, geologist and mine surveyor went to do a risk assessment on that new panel, they found that the panel had already been blasted and mined by illegal miners. Bags of broken ore had already been filled, as shown in Figure 5-23. The panel mined by the illegal miners is shown in Figure 5-24, with the area mined highlighted in yellow.

Figure 5-23: Bags with broken ore from illegal mining activities (Kriel, 2021)

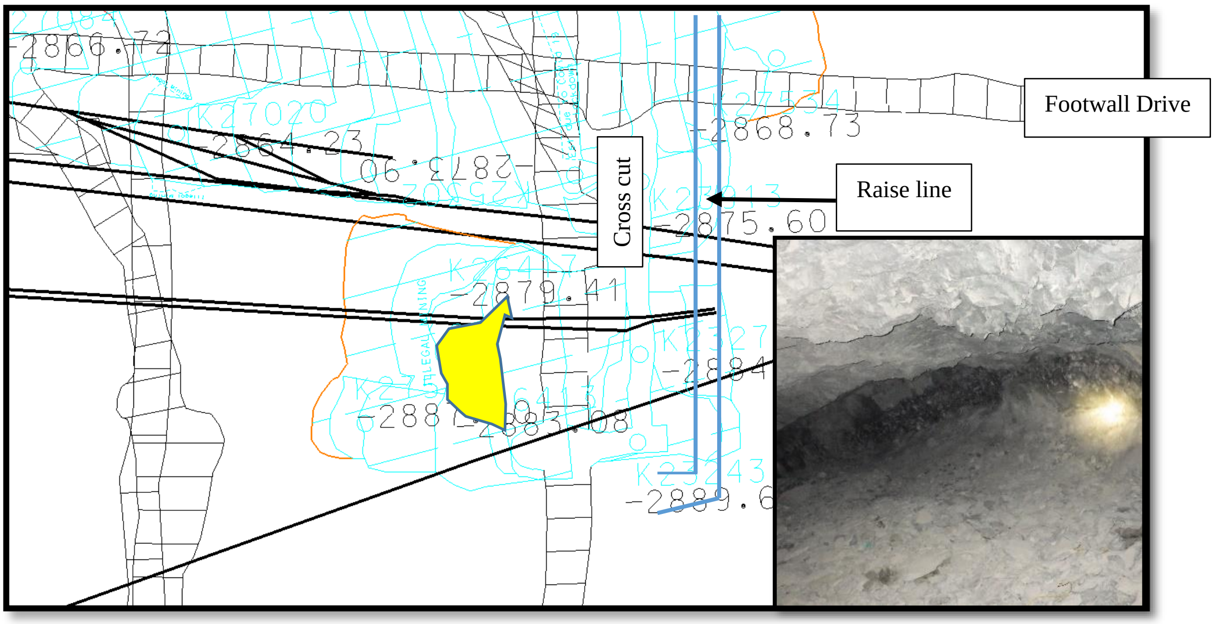

Figure 5-24: Panel mined by illegal mining (Kriel, 2021)

An investigation by the security department into the level of illegal mining activity was held, and the day shift mining crew were suspended for the duration of the investigation. When the investigation was concluded, the day shift mining crew was dismissed as it was found that they were all assisting the illegal miners.

The illegal miners steal the gold, equipment, and explosives, as shown in Figure 5-25. The illegal miners loaded the broken ore in bags (as shown in Figure 24) to transport it to their refinery plant. This plant's location was unknown as it was not found, but it is most likely underground. The measured area mined by the illegal miners was 42 m² at a value of 2 577 cmg/t with a gold content of 2.97 kg. If the illegal miners refined 90% of the ore at a recovery rate of 90%, they would have refined an estimated 2.41 kg (2.97 x 0.9 = 2.67. 2.67 x 0.9 = 2.41 kilograms) of gold; at an estimated gold price of R800 000/kg used in the planning process, means a revenue loss of R 2,1 million.

Figure 5-25: Stolen explosives in bags from illegal mining activities (Kriel, 2021)

The theft of gold ore and explosives and any damage to mine property ultimately affect the revenue and operating cost of the mine negatively. The illegal miners also damage equipment and jeopardise the lives and livelihood of the mine personnel through dangerous activities. The ore removed by illegal miners will affect the MCF.

When using the MCF calculation without the stolen 2.41 kg, the MCF is 73.4%, as shown in the calculation.

$$\mathbf{MCF} = \frac{243}{331} x \; 100 = 73.4\%$$

Adding the stolen 2.41 kg

$$\mathbf{MCF} = \frac{245.41}{331} X \; 100 = 74.1\%$$

When the 2.41 kg is added to the MCF calculation, the MCF increase by 0.9%, this shows that a relatively small amount of stolen gold can affect the MCF.

Over mining can be a safety risk and mining the required mining layout. Figure 5-26 shows another area where illegal mining activities have occurred at VC40 21 at Driefontein 1 Shaft. It is unknown if illegal miners mined this area or if the mining personnel claimed it was mined by illegal miners not to get a bonus penalty for over-mining.

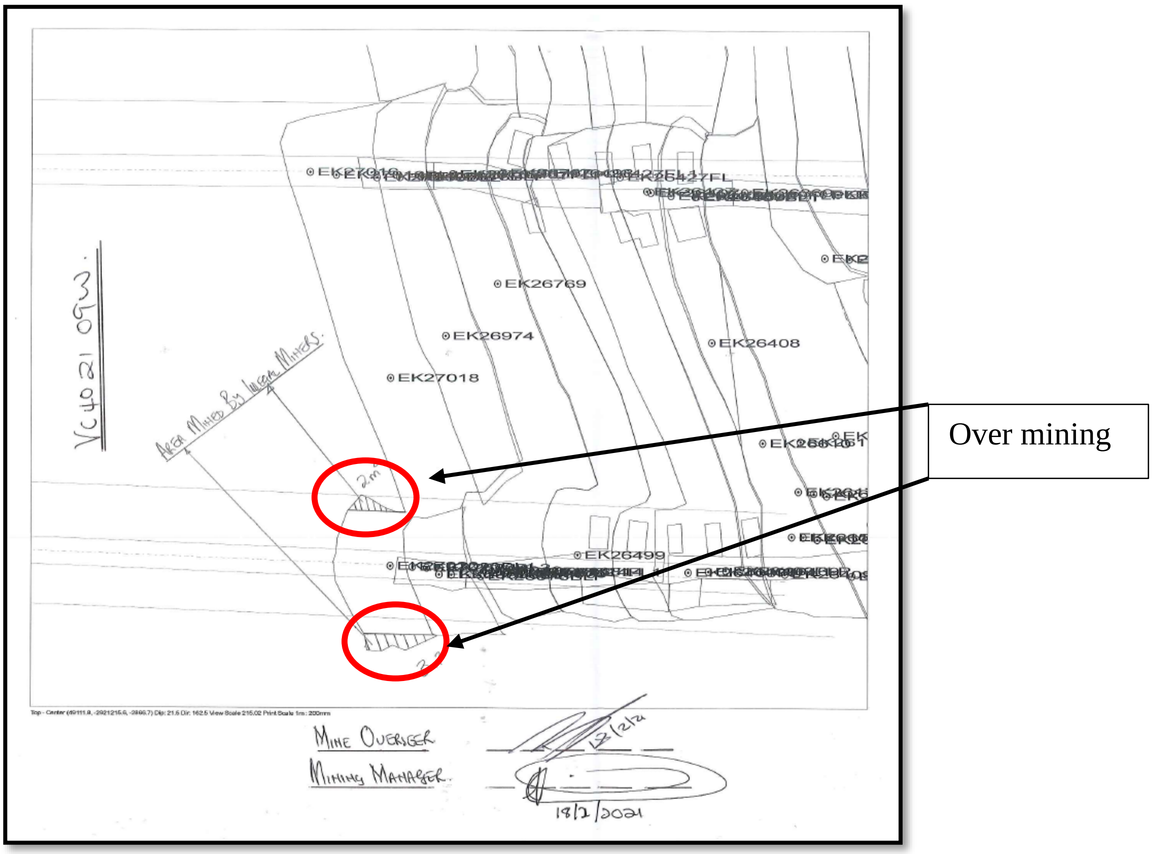

Figure 5-26: Plan showing illegal mining activities at VC40 21 at 1 Shaft Driefontein (Kriel, 2021)

Mine employees are assisting or joining illegal miners in their activities. On the 7th of October 2021, one mine employee was apprehended at the Beatrix Number 1 Plant. Beatrix is another operation of Sibanye-Stillwater with theft of gold-bearing material weighing 4.05 kg, as shown in Figure 5-27 (Protection Services, 2021).

Figure 5-27: Gold-bearing material from Beatrix Number 1 Plant (Protection Services, 2021).

In another incident, a mine employee assisted illegal miners by hiding items inside a material car. The mine employee moved the material car to the "drop off" area at the back of a workshop. 15 Suspects were apprehended, including the mine employee with 17 cell phones and mine property to the value of R45 000 (Protection Services, 2021). Figure 5-28 shows all the items the security department collected from the illegal miners.

Figure 5-28: Items from the illegal miners collected by the security department Plant (Protection Services, 2021).

The security personnel neutralised a gold theft syndicate in Driefontein Mine on the 24th of November 2021. A mine employee was caught and arrested with two gold bars concealed on his person, resulting in the recovery of gold-bearing product of an estimated R7 million, as shown in Figure 5-29. Mine employees have been suspended and are under investigation.

Figure 5-29: Gold bars and gold-bearing products seized by the security department of Driefontein Mine

5.7 The Process Plant

The process plant's call factor was planned at 97% for 2020, and the actual process plant call factor is 98% (see the Technical Statement in Annexures 2 to 5). The plant is performing well in releasing the gold product from the ore.

Driefontein monitors the daily tonne hoisted over a belt system running into the process plant. A belt sampler takes samples (as shown in Figure 5-30) over the belt at regular 200-tonnes intervals.

Figure 5-30: Belt Sampler at Driefontein 2 Shaft

The amount of sample taken depends on the tonnes per shaft hoisted and transported over the belt. The samples are collected in a one-tonne container, as shown in Figure 5-31.

Figure 5-31: One-ton sample containers

The daily samples are collected in one container per the specific shaft, and these containers are transported to the assay laboratory the following day. From these samples, the head grade is determined.

The head grade report is updated daily by the surface grade officer with the daily tonnes transported over the belt and assay results received from the bin sampling, shown in Table 5-4. The full head grade report is shown in Appendix 6.

Table 5-4: Head grade split daily for July 2021 (Legoabe, 2021)

Driefontein Headgrade Splits				
25	Jul 2021 (Surface Belts)			
DAILY	DATE	Ya Rona Shaft D4#Sampled @ Pitseng		
SHIFT		Dry tons	G/t	Content
	Monthly Business Plan	25507	8.19	208887
	Daily Business Plan	1020	8.19	8355
	Prog. Business Plan	25507	8.19	208887
	Prog. Actual	27667	8.46	234103
	Difference	2160		25215
Milling Shift	Gold Allocation	27667	8.55	236520
1	July 1, 2021	995	6.80	6758
2	July 2, 2021	490	5.73	2805
3	July 3, 2021	0	0.00	0
4	July 4, 2021	0	0.00	0
5	July 5, 2021	441	3.03	1334
6	July 6, 2021	1332	3.03	4034
7	July 7, 2021	1113	5.78	6431
8	July 8, 2021	1504	7.57	11392
9	July 9, 2021	1072	5.97	6399
10	July 10, 2021	298	5.97	1776
11	July 11, 2021	0	0.00	0
12	July 12, 2021	965	5.24	5055
13	July 13, 2021	1608	6.81	10955
14	July 14, 2021	1046	8.69	9091
15	July 15, 2021	1324	8.62	11415
16	July 16, 2021	714	13.87	9907
17	July 17, 2021	1108	13.87	15366
18	July 18, 2021	803	13.87	11132
19	July 19, 2021	943	15.45	14563
20	July 20, 2021	1378	8.11	11172
21	July 21, 2021	1105	10.12	11177
22	July 22, 2021	843	6.71	5658
23	July 23, 2021	1296	8.66	11228
24	July 24, 2021	743	8.66	6438
25	July 25, 2021	313	8.66	2711
26	July 26, 2021	1542	9.18	14159
27	July 27, 2021	1332	9.22	12277
28	July 28, 2021	1344	13.94	18740
29	July 29, 2021	1335	5.62	7505
30	July 30, 2021	531	3.53	1875
TOTAL		27667	8.46	234103

At the end of the month, the plant reports its final gold-smelt figure. This figure is used in the ore flows (see example in Appendix 1). The final gold smelt figure is used for the total underground operation. The split is as follows; the weightometer tonnes are used to allocate the tonnes per shaft, and the final plant smelt figure, in conjunction with the belt sampling values, is used to allocate the gold to each shaft by the Chief Mine Surveyor. The declared gold figures are very close to the belt grade figure, as seen in Table 5-5. The belt grade estimate and final gold measurement are very close. The content smelted for July 2021 is 742 kg and the belt kg was estimated at 735.6 kg with a shaft call factor of 83.5%.

Table 5-5: Gold Split Driefontein (Tandree, 2021)

MONTH: JUL 2021							
SUMMARY OF DECLARED GOLD RECOVERED							
	D1	**D2**	**D4**	**D5**	**D6**	**D8**	**Total DFT UG**
D1 Plant	155.1073	15.9777	238.4240	254.5418	0.0000	78.1673	**742.2181**
Ezulwini BLACK REEF						8.3872	**8.3872**
Ezulwini D10 SRD for UG						4.1884	**4.1884**
Total Gold Declared	**155.1073**	**15.9777**	**238.4240**	**254.5418**	**0.0000**	**90.7429**	**754.7937**
GIP D1	8.061	0.830	12.391	13.228	0.000	4.062	38.573
GIP D2	0.000	0.000	0.000	0.000	0.000	0.000	
Total GIP	8.061	0.830	12.391	13.228	0.000	4.062	38.573
SUMMARY OF DECLARED TONS MILLED							
	D1	**D2**	**D4**	**D5**	**D6**	**D8**	**Total DFT UG**
D1 Plant	20036	1178	27667	49908	0	27307	126096
Ezulwini BLACK REEF						4542	4542
Ezulwini D10 SRD for UG						10093	10093
Total tons milled	**20036**	**1178**	**27667**	**49908**	**0**	**41942**	**140731**
MCF	75.3%	0.0%	73.3%	134.4%	0.0%	74.8%	**89.4%**
Shortfall	5.2%	100.0%	13.4%	18.1%	0.0%	37.4%	**21.8%**
SCF	72.6%	0.0%	70.7%	129.5%	0.0%	79.1%	83.5%

5.8 Section Summary

This chapter focused on the real and apparent tonnage and grade, gains, and losses. The incorrect measuring from incorrect sampling and mine survey methods can cause apparent tonnage gains and losses.

Incorrect sampling methods can cause apparent gains or losses. Sampling is one of the most important aspects in ore accounting, and incorrect sampling methods can lead to incorrect estimation with Kriging during both the planning and measuring stages.

Accumulations (FOG), mud in the drains and poor measuring methods can lead to real tonnage losses or gains if not accounted for.

Illegal mining activities that removed an estimated 5 kg of gold resulted in a revenue loss of R4 million and a poor MCF for Ya Rona shaft. Real grade gain and losses can be attributed to incorrect drilling and blasting practices leaving reef in footwall (RIF) and reef in hangingwall (RIH). Sweepings not being done to the mine standard leaves broken ore and fines behind. Ya Rona had a poor sweeping percentage at the start of 2021, but it finally ended at 84% out of 85% for the 2022 financial year.

In conclusion of this chapter the question needs to be answered, what is the cause of poor MCF? Due to the poor quality of mining, poor installation of barricades, lock-up tonnes left behind, mud in the cross cuts and the theft of illegal mining, the loss can be classified as a real loss. Best practices and procedures are in place to mitigate the apparent and real losses.

6 CONCLUSION

Many factors contribute to the MCF, including face sampling, blasting through fragmentation, and the transportation of the broken ore. In this chapter, the findings of the previous two chapters, chapter four and chapter five, are summarised to identify the real and apparent grade or tonnage gains or losses.

6.1 Key Findings

For the financial year 2021, from January 2021 to December 2021, the Ya Rona shaft had an MCF of 69.3% against a planned MCF of 73%. The MCF variance significantly impacts the profit for Ya Rona shaft because, despite the high-grade nature of the orebody, it is a marginal operation. The actual kilograms recovered were 2 946 kg against gold called for by the mine survey department of 4 250 kg. Unaccounted gold amounts to 1 304 kg with an estimated loss in revenue of R1 billion using an estimated gold price of R800 000 per kg.

In 2021, Ya Rona shaft had a shortfall of 10%, resulting in 19 346 t in apparent tonnage gains. The primary sources of tonnage gains are from underestimating accumulations depths, gully widths and heights, and FOG mixed into the reef and not reported to the mine survey department for measuring. Mud was also loaded and sent to the plant, which the mine survey department did not quantify.

Backfill bags placed onto broken ore will result in gold loss. At an estimated gold price of R800 000 per kg, the real unaccounted loss, as highlighted in this study, accounts for R240 000.

Regular PTOs are carried out on samplers to check the correct methods and procedures to obtain accurate samples and sample results. Standards and procedures are in place to minimize the apparent grade loss. The assay laboratory is regularly checked to compare the values from check samples, waste samples and AMIS samples to ensure good QAQC. The valuation method used is the Kriging method. The nugget effect causes a 40% grade loss in the VCR panels at Ya Rona shaft.

Illegal miners accounted for 1% of the MCF variance, that is, in the known current areas in the mine plan. Poor fragmentation by incorrect blasting practices and excessive ore handling is causing the grade loss. The fines get washed away by water into cracks and collect as mud in the drains.

6.2 Tonnage Loss

Lock-up tonnes, accumulation in the gullies and centre raises, sweepings that are not done to standard and poor blasting barricades cause real tonnage losses. Regular reports are done to report on the blasting barricades so that the mining personnel can rectify the barricades, as seen in section 5.4.1. Mud in the cross cuts, not loaded, hoisted and transported to the plant, may affect the MCF. The accumulations in the gully, stope face, centre raise and box holes that are not removed can also have an impact. After all the mining activities have been completed, these accumulations and the final clean-up of the stope and the crosscut will only be done by the sweeping and vamping crews. Over breaking of excavation in the development ends, mud clean-up in the crosscuts and the stope accumulations will contribute to a gain in tonnes. When these tonnes are not removed during the month, this will result in a poor MCF.

Apparent tonnage loss can be attributed to incorrect measuring methods and stoping width measuring methods. Samplers are checked to determine if they use the correct techniques to mitigate measuring errors. The mine survey measuring method errors have been mitigated by taking out 90% of the human error using a Top Con total station. A FOG in the stope face or in the sweeping area that was not measured by the sampler when taking the stoping width and a FOG in the development areas are additional sources of tonnage that are not measured and accounted for by the mine survey department. FOGs contribute to tonnage gains.

6.3 Grade Loss

Apparent grade loss or gains can be attributed to poor sampling and assaying practices. The nugget effect can skew the sampling value of the stope face. Standards and procedures are in place to eliminate and mitigate the error of poor sampling and assay results. Sampling standards and procedures are in place, and PTOs are done regularly on the samplers to ensure that they use the correct sampling procedure to sample the stope panels. Quarterly audits are conducted in the assay laboratory by the grade department to monitor the quality of the assay procedure and results. Daily controlled samples from AMIS, check samples and duplicates are sent to the assay laboratory to check the accuracy of the assay value of the check samples.

The scraper breaks the rock into small particles resulting in a loss of gold that impacts the MCF. Different cleaning methods were investigated by removing the scraper. The weeping bag cleaning methods were investigated using a 2-tonne tub or a mono winch. The study shows that these methods were time-consuming for cleaning, the desirable blast frequency cannot be adhered to, and the mine employees will work in an unsafe, unsupported area.

6.4 Illegal Mining Loss

An increasing threat to the gold mining industry is illegal miners who damage mine infrastructure to access old, abandoned mines and shafts or areas that have been closed off in working mines. To access working operations, illegal miners bribe mine personnel and security staff. Food is smuggled into the mine in explosives cars or carried by mine personnel who conceal the food about their person. Illegal miners pay a great deal of money for food from mine personnel; for example, a loaf of bread has been known to be sold for up to R200. In October 2021 and November 2021, respectively, two mine personnel never came out of the mine after their shifts, and rescue operations took place for two days in the respective months, but these two mine personnel could not be found. The management team and security personnel presumed that the two miners had joined the illegal activities. Mining personnel are turning to illegal mining because there is more money to be earned than working for the mine.

As mentioned in chapter 5.6, illegal mining results in a gold loss. In the example mentioned above, the shaft stood for those two days in October and November 2021 to search for the two miners, resulting in a production loss of 10 kg per day; the Ya Rona shaft produces 230 kilograms over a 23-shift period. In the previously given example where the illegal miners blasted their panel, the area accounted for 2.97 kg and influenced the MCF by 1%. These losses are only accounted for in the planned working places. The gold stolen in the unplanned or mined-out panels due to rock mechanic engineering (RME) and geological constraints is unknown.

The illegal miners arrested by the security staff had gold, cell phones, food, and mining equipment that accounts for millions of Rand. The gold loss in this instance was not even calculated for in the MCF, and the MCF impact due to illegal miners will vary month on month.

Marginal mines may have to close if illegal mining is not stopped because of the loss of revenue and increased costs. It has been suggested that Helena Gold Mine was closed after 50 years due to the threat of illegal miners starting fires. The Driefontein security department apprehended an employee with R7 million worth of gold bars and gold-bearing material, which means that in this instance, for this one event, the mine has directly lost R7 million in revenue, not counting all the other non-direct losses from his interfering with other employees and the cost of security measures. If we assume that the gold comes from an active area in the mine, then illegal miners are not just stealing gold but also stealing explosives, damaging cables, and stealing copper and mine support materials. These factors contribute to the increase in mining costs, indirectly increasing the pay limit and limiting the areas that can be mined profitably.

Illegal mining is a threat to the economy of South Africa and to the communities that are near abandoned or working mines. The gold that illegal miners steal and sell is not always accounted for. In turn, the country is losing money in taxes and royalties. The affected communities are living in fear of the illegal miners because the illegal miners are threatening these communities.

No theft in the process plant has been reported in the last few years. This theft has been stopped due to the intensive security presence with surveillance all over the plant.

In a perfect mining environment, an MCF can be 100%. The activities affecting the MCF are sampling, blasting/fragmentation, sweeping, spillage, mud in the cross cuts, assay laboratory and illegal mining. Good procedures and practices are in place to mitigate sampling and assay laboratory errors. Blasting and fragmentation are monitored regularly.

Sweeping and accumulation are checked and measured monthly. Illegal miners are working in current and old areas. It is difficult to ascertain where the MCF has been affected because of many different activities contributing to the MCF.

7 RECOMMENDATIONS

7.1 Actions to be taken to improve Tonnage and Grade estimation Techniques to minimise Apparent Gains / Loss

All sources must be considered for a better estimate of the ore that will be sent to the plant, including FOG., which must be measured and accounted for in the ore flow. The correct dimension of the gully must be measured. To get accurate estimations, a new standard needs to be implemented, which specifies that all the accumulations must be removed in the gully for the mine survey department to measure the gully dimensions on or by measuring day. If the accumulation in the gully is not removed, no sweepings will be paid.

The crosscut dimension must be scanned or offset before the ledging and stoping phases commence. The mud and accumulation tonnes estimation will be correct if the measurements are known. The mud can be sampled every five metres to have a value assigned to the tonnes. Old working crosscuts must be cleaned and then scanned. This new standard will assist in quantifying the mud tonnes and accumulation tonnes in the crosscut after mining has been completed to do the final clean-up, this will help with the correct estimation. The accurate volumes and gold are called for by mine survey.

7.2 Actions to be taken to Minimise Real Tonnage losses

Most of the Driefontein shafts use backfill for support, and when a panel utilises backfill, no blasting barricades are required because the backfill prevents contamination in the back areas of the stope. Stope panels that do not utilise backfill must install blasting barricades to prevent tonnage loss. For example, on the stope panel mining methods that use blasting barricades, the mining area barricades must be installed and moved forward as the mining cycle dictates, or the back mined out area will become contaminated from fly rock. Routine visits are done to ensure barricades have been installed to the standard and are performed by the Mineral Resource Department. These checks are performed by a sampler, geologist, and mine surveyor on their visits to the stoping areas. Bonus penalties in the form of reduced bonus payments must be implemented on the miner if the barricades are not permanently installed to standard.

A new crosscut standard has been implemented to concrete all the new crosscuts to ease the cleaning of mud and spillages. A recommendation to ensure that crosscuts are kept clean through good housekeeping is to offer a bonus for the best crosscut for the month. The criteria for achieving the best-kept crosscut should include the following:

- All pumps installed per standard and the correct sump dimensions;
- Rails are correctly installed and maintained to prevent spillages;
- All drains must be clean;
- No spillage or accumulation in the crosscut and below the box hole front;
- No water running from the box holes;
- All restricted areas, “for example, at the entrance of the crosscut at the bull nose,” are demarcated; and
- All notice boards are updated with the relevant standards.

Mud bags are currently hanging on the sidewall. The mud bags are used to prevent spillages and gold loss. The mud bags must be transported in a hopper, emptied at the station tips, or taken immediately to the station. Mud bags must be used because spillages occur along the haulages when transporting the mud in a hopper to the station tips.

Best blasting practices must be enforced through routine checks by the explosive coordinator. Regular checks must be done to get the correct fragmentation. They must check that the face is correctly marked and drilled according to the mine standard and that the mine personnel use suitable drilling steel and drill at the correct angle to eliminate poor fragmentation and gold loss. Explosive coordinators are available to monitor and analyse the fragmentation to indicate which explosive to use and what quantities are required for a successful blast. The explosives ordered and used must be reported weekly and reconciled back to the booked square metres. During the research report, poor fragmentation was addressed and explosives have changed to an emulsion type of explosive.

Using a scraper to move broken ore out of the stope breaks the rock even further into smaller sizes and causes gold loss. Alternative cleaning methods must be investigated to assist in minimising the gold loss.

7.3 Steps to be Taken to Minimise Grade Loss

Studies need to be done to minimise the use of water. In gold mining, water must be used to suppress the silica dust, which causes health-related illnesses. Excessive and uncontrolled water is washing away fine gold particles. When the mine personnel do sweepings, water is used to clean out and wash the footwall. Alternative methods need to be investigated to minimise the use of water. They are also investigating alternative drilling machines to minimise water usage. All gullies must have sumps blasted with a centrifugal pump to control the water and minimise the gold loss. These controls seem to effectively control the bulk of the water used in the stopes. Some water still passes the sumps and the pumps and can find its way to the crosscuts. Some of the sumps are blasted too shallow to form an effective collection point. An investigation needs to be initiated to determine the amount of water used on a stope panel. The recommendation is that the sumps are blasted in the correct dimensions to handle all the water. The investigation of specific conditions will determine the dimensions. There must be a backup pump to replace a broken pump to minimise the water going to the crosscut.

The valuation department has considered the nugget effect in the VCR value distribution, and the outlier values must be removed. The panel must be sampled more frequently when the nugget effect is suspected. The high gold-content values associated with the nugget effect in the VCR are inconsistent and give a false estimation of the gold value for that stope. This expected gold, as a result of the nugget effect, is not seen in the plant, and the false high gold values are impacting the estimation process for the gold called for and the resultant MCF.

A team of technicians can be employed whose only work is to photograph all the stope faces regularly, more often than sampling, for instance, every second day or third day, depending on the advance booked. The photos can be processed centrally and sent “face mapping” a few times a week to the mining teams ensuring they are:

- Staying on reef;
- Accounting faulting/waste mining correctly;
- Getting good peg-to-face recons on bookings;
- Checking blasting/drilling patterns; and

- Installing support to standard.

The explosive technician team can go through many panels a day. Taking photos with a reference stick against the face.

Illegal miners must be prevented from accessing underground workings, and old mines and redundant shafts must be sealed off properly to prevent access. The shaft must be filled with old waste rock, and a concrete slab must be placed over the shaft. The concrete slab standard needs to be revised, as illegal miners are still digging below the slab to access the shaft.

Employees must be rewarded for reporting illegal mining activities. The mine employees need to be protected, and whistle-blowers should remain anonymous because the illegal miners have previously threatened and killed people who have reported them.

Illegal miners are frequently involved with syndicates. The mine security department has to work together with the police intelligence service. The syndicates need to be identified, investigated and prosecuted as they are the driving force behind the illegal miners; otherwise, the illegal mining activities will continue and cause a safety risk for themselves and mine employees, loss in revenue for the mining company and loss of income for the government. Currently, illegal miners caught underground are only prosecuted for trespassing, not theft. The law has to be amended in this regard and will act as a deterrent in minimising illegal mining activities.

Poverty and unemployment are contributing to the increase in illegal mining activities. More people and mine employees are turning to illegal mining as it is a lucrative business. Further studies must be done to understand more about illegal miners, for instance, the lack of unemployment, their social standing, and how to prevent them from accessing operating mines. Recommendations can be made that old shafts, which are not profitable for more prominent mining companies, could be made available to illegal miners. Government can assist illegal miners with the maintenance and initial costs. Illegal miners must still comply with all the safety rules and regulations and the MPRDA.

Suitable security measures are in place regarding the clock card issued to each employee for access control, security personnel at the entrance of each shaft, the turnstile gates and biometric scanning. Illegal miners still manage to get past these security systems, and these security systems need to be enhanced because the human factor is still in play. A fingerprint and biometric system must be installed to control all the access gates at the mine. The gate is locked with a lock and can be opened with a key, anyone can open the gate for the illegal miners, and they can make a copy of a key. Each employee's biometric scan of the face, eyes, and fingerprint should be in the system to verify the employee's identity. No gate must be equipped with a lock and key, ensuring that gates can only be opened with a biometric scan and fingerprint. The installation or implementation of a cap lamp tracking system to track and report the movement of each employee. If the movement does not match the area where the employee works, security staff can be sent down to investigate. Security staff are working hard to stop illegal miners from accessing the mine and apprehending them. The law must change to apprehend illegal miners and ensure they get prosecuted for gold theft.

The impact of illegal miners is still not fully understood. Further studies must be done to understand illegal miners and their driving force. Additional strategies and measures need to be developed and implemented to combat and counter illegal mining activities.

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Appendices

Appendix 1: Ore flow 2021 YTD

2021 YTD + DEC2020												
REEF TONNAGE FLOW (GOLD)	YA RONA SHAFT D4											
DESCRIPTION	CHW	BUDGET			CHW	MONTH PLAN			CHW	ACTUAL		
	SW	TONNES	G/T	AU KG	SW	TONNES	G/T	AU KG	SW	TONNES	G/T	AU KG
m²		40677		38492		39410		38011		37479		35601
REEF TONNES BROKEN AT CHANNEL WIDTH	96	101,412	36.2	3667.3	101	105,387	36.3	3829.5	116	113,099	40.6	4592.7
REEF TONNES BROKEN AT SW FROM m²	160	168,863	21.7	3667.3	167	180,508	21.2	3829.5	185	181,644	25.3	4592.7
REEF TONNES BROKEN FROM CUBES m³		9,331	7.6	71.3		6,735	7.2	48.6		7,028	9.1	64.2
REEF TONNES BROKEN FROM STOPING		178,194	21.0	3738.6		187,243	20.7	3878.1		188,672	24.7	4657.0
WASTE TONNES BROKEN (off reef & fault cuts)		9,800		0.0		0		0.0		8,943		0.0
TONNES BROKEN FROM STOPES @ SW		**187,993**	**19.9**	**3,739**		**187,243**	**20.7**	**3,878**		**197,615**	**23.6**	**4,657**
WASTE TONNES BROKEN OSS (gullies, slushers, winchbeds, etc)		24,119		0.0		26,214		0.0		21,858		0.0
TOTAL TONNES BROKEN FROM STOPES		**212,113**	**17.6**	**3738.6**		**213,457**	**18.2**	**3878.1**		**219,473**	**21.2**	**4657.0**
REEF DEVELOPMENT MEASURED EXC BALLAST THAT WILL BE HOISTED TO MILL		0	0.0	0.0		0	0.0	0.0		0	620712.7	0.0
WASTE DEVELOPMENT MEASURED EXC BALLAST THAT WILL BE HOISTED TO MILL		71,460		0.0		77,044		0.0		91,501		0.0
TOTAL DEVELOPMENT TONNES MEASURED THAT WILL BE HOISTED TO MILL		71,460	0.0	0.0		77,044	0.0	0.0		91,501	0.0	0.0
OLD GOLD (Vamping & Reclamation)		10,494	5.8	60.4		8,290	7.1	59.2		11,726	8.1	95.1
TOTAL UG TONNES MEASURED FROM UNDERGROUND THAT WILL BE HOISTED TO MILL (GOLD CALLED FOR INC OLD GOLD)		**294,067**	**12.9**	**3799.0**		**298,791**	**13.2**	**3937.3**		**322,699**	**14.7**	**4752.1**
KNOWN ADJUSTMENTS:												
SKIP FLUSHING TONNES		0				0				0		
SHAFT SPECIFIC ADJUSTMENTS (eg Backfill spillage, opening up tons, Unmeasured FOG)		0	0.0			0	0.0			0	0.0	
ACCOUNTING ERRORS YTD CORRECTIONS		**0**	0.0	**0.0**		**0**	0.0	**0.0**		**0**	0.0	**0.0**
TONNES AVAILABLE FOR HOISTING (EXCLUDE UNG AC		**294,067**	**12.9**	**3799.0**	**3738.6**	**298,791**	**13.2**	**3937.3**		**322,699**	**14.7**	**4752.1**
UG TONS HOISTED TO SURFACE (Weightometer+Grab		**319,678**	**8.2**	**2605.4**	**70%**	**341,689**	**14.3**	**4894.9**		**343,745**	**8.6**	**2965.8**
CHECK1: TONS HOISTED TO SURFACE (Skips)		319,678	8.2	2605.4	**8%**	341,689	14.3	4894.9		250,630	8.6	2146.0
CHECK2: TONS HOISTED UG AT 4 SHAFT		319,678	8.2	2605.4		341,689	14.3	4894.9		339,826	8.6	2930.1
CHANGES IN SURFACE STOCKPILES		0	0.0	0.0		0	0.0	0.0		0	0.0	0
CHANGES IN PLANT MOISTURE & SHAFT MOISTURE		0	0.0	0		0	0.0	0		0	0.0	0
CHECK6: TONS DELIVERED TO PLANTS (Datarail/ Truck Ta		319,678	8.2	2,605.4		341,689	14.3	4,894.9		343,745	8.6	2,965.8
SURFACE TONS TO MILL (Waste tonnes)		*0*	0.0	*0.0*		*0*	0.0	*0.0*		*0*	0.0	*0.0*
TONS REPORTED TO MILL (belt ± stockpile change ± F		**319,678**	**8.2**	**2605.4**		**341,689**	**14.3**	**4894.9**		**343,745**	**8.6**	**2965.8**
CHANGES IN PLANT STORAGES (Mill Bins & Stock Piles)		0	0.0	0.0		0	0.0	0.0		0	0.0	0
AVAILABLE TO MILL		319,678	8.2	2,605.4		341,689	14.3	4,894.9		343,745	8.6	2,965.8
VARIANCE - SHAFT VS PLANT (PCF)	100%	0	0.0	0.0	63%	0.0	5.3	1823.1	109%	0	0.8	278.3
ACTUAL TONNES MILLED (RECOVERY + RESIDUE) (MCF - Gold Called For Inc Old Gold)	69%	319,678	8.2	2605.4	78%	341,689	9.0	3071.8	68%	343,745	9.4	3244.1
ACTUAL TONNES MILLED (RECOVERY + RESIDUE) (MCF - Gold Called For Exc Old Gold)	**70%**	319,678	8.2	2605.4	**79%**	341,689	9.0	3071.8	**70%**	343,745	9.4	3244.1
RESIDUES (PRF) (Exc Old Gold))	**97%**	0	0.2	78.2	**97%**	0	0.2	82.0	**98%**	0	0.2	55.2
TONNES TREATED (reported)		**319,678**	**7.9**	**2527.2**		**341,689**	**8.8**	**2989.8**		**343,745**	**9.3**	**3188.9**
CHANGE IN GIP		0		**0.0**		0		**0.0**	**69%**	0		**-23.7**
TONNES TREATED (REPORTED INC CHANGE IN GIP)		319,678	7.9	2527.2		341,689	8.8	2989.8		343,745	9.2	3165.3
MEASURED ACCUMULATIONS MOVEMENT MONTH ON MONT		*Minus (-) = Increase in Accumulations & Plus (+) = decrease in Accumulations*								+1,700	0.1	28.2

Appendix 2: Technical Statement Quarter one

	D4 Shaft								1 st Quarter	
			Jan-21		Feb-21		Mar-21		Jan 21 - Mar 21	
	Salient Features		**Plan**	**Actual**	**Plan**	**Actual**	**Plan**	**Actual**	**Plan**	**Actual**
1	**Kilograms Produced**	kg	135	176	216	287	219	279	570	743
2	**Mill Tons**	t	18785	25347	26847	25111	26095	28468	71727	78926
	Development									
3	Total	metres	186.6	193.7	221.4	249.7	206.3	249.0	614.3	692.4
	Capital	metres	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	Total Main Including Capital	metres	69.6	83.4	82.2	151.3	88.6	126.8	240.4	361.5
5	Total Main Off reef Including Cap	metres	68.1	63.4	79.8	120.8	79.6	86.6	227.4	270.8
7	Main WC "Off Reef"	metres	68.1	63.4	79.8	120.8	79.6	86.6	227.4	270.8
8	Secondary WC "Off Reef"	metres	117.0	110.3	139.2	98.4	117.7	122.2	373.9	330.9
	Development On Reef									
9	Main	metres	1.5	20.0	2.4	30.5	9.0	40.2	13.0	90.7
10	Secondary	metres	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Average Development value									
11	Main	cmg/t	8546	6407	3184	4864	5279	3035	5275	4394
12	Secondary	cmg/t	0	0	0	0	0	0	0	0
	Percentage Payability									
13	Main	%	100%	100%	0%	93%	39%	42%	39%	72%
14	Secondary	%	0%	0%	0%	0%	0%	0%	0%	0%
15	**Paylimit**	cmg/t	3220	3560	3220	2450	3220	1950	3220	2626
	Stoping									
20	Total	m²	2437	2375	3143	2973	3110	3112	8690	8460
21	Avg. Value	cmg/t	3435	5175	3476	5574	3563	4641	3496	5119
22	Waste	m²	128	171	165	177	159	62	451	410
23	m² Above Paylimit	m²	856	1373	1072	2010	991	1943	2919	5326
24	Avg. Value above Pay Limit	cmg/t	6899	7931	7149	7745	7652	6474	7246	7329
25	m² Below Paylimit	m²	1453	831	1906	786	1961	1107	5320	2724
26	Avg. Value below Pay Limit	cmg/t	1698	1687	1710	1277	1786	1685	1735	1568
27	Current Plan Au blasted	kg	230	338	300	456	305	397	835	1191
28	Cubics blasted (Reef)	m³	261	97	261	125	261	136	783	358
29	Cubics Au blasted	kg	6.184	0.321	6.184	0.364	6.184	1.325	19	2
1	Pay face length mined	metres	199	259	187	311	186	333	572	903
2	Total face length mined	metres	566	442	548	448	585	487	1700	1377
3	Face advance	metres	4.3	5.4	5.7	6.6	5.3	6.4	5.1	6.1
4	No of times crew blasted	No	6	7	9	8	8	8	8	8
	Width									
5	Channel	cm	87	115	101	103	103	94	98	103
6	Stope	cm	162	172	166	172	166	161	165	168
7	Milling (excl dumps)	cm	280	388	311	307	305	333	300	339
	Plant									
8	Shortfall/Excess	%	2%	25%	13%	8%	13%	17%	10%	17%
9	Mine Call Factor (MCF)	%	59%	53%	73%	64%	73%	72%	69%	64%
	Milling									
16	Underground	tons	18785	25347	26847	25111	26095	28468	71727	78926
17	Surface Dumps	tons								
18	Total	tons	18785	25347	26847	25111	26095	28468	71727	78926
	Yield									
19	Underground	g/t	7.2	6.9	8.0	11.4	8.4	9.8	7.9	9.4
20	Surface Dumps	g/t								
21	Total	g/t	7.2	6.9	8.0	11.4	8.4	9.8	7.9	9.4
	Gold produced									
22	Underground	kg	135	176	216	287	219	279	570	743
23	Surface Dumps	kg								
24	Total	kg	135	176	216	287	219	279	570	743
	Factors									
25	% MO Sweepings	%	85%	81%	85%	79%	85%	87%	85%	83%
26	% Swept Total	%	100%	96%	100%	97%	100%	101%	100%	98%
27	% Swept Total Cleaning	%	120%	140%	120%	129%	120%	162%	120%	144%
28	% Pay	%	35%	58%	34%	68%	32%	62%	34%	63%
29	% Waste Mining	%	5%	7%	5%	6%	5%	2%	5%	5%
30	Ave Blasting frequency	ratio	4.3	3.4	3.2	2.8	3.5	2.9	3.6	3.0
32	Sampling Coverage	%	90%	98%	90%	100%	90%	95%	90%	98%
33	Old Gold	kg	3	2	3	4	3	9	10	15
34	Cut-off cm.g/t	cm.g/t	1470		1470		1470		1470	
	Tons Mined									
35	Total Stope Tons	tons	13020	13397	16983	15905	16815	16228	46818	45530
36	Development Reef Tons	tons	0	0	0	0	0	0	0	0
37	Development Waste Tons	tons	5714	5825	6823	7665	6229	7668	18765	21158
38	Total Development Tons	tons	5714	5825	6823	7665	6229	7668	18765	21158

Appendix 3: Technical Statement Quarter Two

	D4 Shaft								2 nd Quarter	
			Apr-21		May-21		Jun-21		Apr 21 - Jun 21	
	Salient Features		Plan	Actual	Plan	Actual	Plan	Actual	Plan	Actual
1	**Kilograms Produced**	kg	201	243.928	184	218	202	243	587	705
2	**Mill Tons**	t	23993	23310	23450	29747	25589	28161	73032	81219
	Development									
3	Total	metres	191.4	222.0	192.7	257.4	210.6	244.4	594.7	723.8
	Capital	metres	0.0	0.0	0.0	0.0	30.0	0.0	30.0	0.0
4	Total Main Including Capital	metres	110.4	103.1	115.2	128.3	135.6	109.0	361.2	340.4
5	Total Main Off reef Including Cap	metres	102.0	76.1	106.8	92.9	126.1	69.0	334.9	238.0
7	Main WC "Off Reef"	metres	102.0	76.1	106.8	92.9	96.1	69.0	304.9	238.0
8	Secondary WC "Off Reef"	metres	81.0	118.9	77.5	129.1	75.0	135.4	233.5	383.4
	Development On Reef									
9	Main	metres	8.4	27.0	8.5	35.4	9.5	40.0	26.3	102.4
10	Secondary	metres	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Average Development value									
11	Main	cmg/t	5326	4772	4986	4344	4554	3434	4938	4101
12	Secondary	cmg/t	0	0	0	0	0	0	0	0
	Percentage Payability									
13	Main	%	40%	76%	40%	59%	40%	84%	40%	73%
14	Secondary	%	0%	0%	0%	0%	0%	0%	0%	0%
15	**Paylimit**	cmg/t	3220	2140	3220	2420	3220	2130	3220	2239
	Stoping									
20	Total	m²	2850	2541	2794	2946	3066	3706	8711	9193
21	Avg. Value	cmg/t	3568	3875	3323	3773	3339	3523	3409	3701
22	Waste	m²	151	292	159	323	187	310	497	925
23	m² Above Paylimit	m²	885	1460	993	1787	984	1341	2861	4588
24	Avg. Value above Pay Limit	cmg/t	7622	6383	6338	5600	6446	7110	6772	6290
25	m² Below Paylimit	m²	1814	789	1643	836	1895	2055	5352	3680
26	Avg. Value below Pay Limit	cmg/t	1889	670	1823	1327	2056	1714	1928	1402
27	Current Plan Au blasted	kg	280	270.80	255	306	282	359	817	936
28	Cubics blasted (Reef)	m³	261	294	261	381	261	160	783	835
29	Cubics Au blasted	kg	6.184	4.30	6.184	14	6.184	15	19	33
1	Pay face length mined	metres	183	281	223	290	183	162	588	733
2	Total face length mined	metres	588	548	628	462	570	458	1786	1468
3	Face advance	metres	4.8	4.6	4.5	6.4	5.4	8.1	4.9	6.3
4	No of times crew blasted	No	8	6	7	8	8	10	8	8
	Width									
5	Channel	cm	103	98	97	112	95	105	98	106
6	Stope	cm	166	165	165	173	164	173	165	171
7	Milling (excl dumps)	cm	306	334	305	367	303	276	305	321
	Plant									
8	Shortfall/Excess	%	13%	16%	13%	19%	13%	4%	13%	13%
9	Mine Call Factor (MCF)	%	73%	91%	73%	69%	73%	66%	73%	74%
	Milling									
16	Underground	tons	23993	23310	23450	29747	25589	28161	73032	81219
17	Surface Dumps	tons								
18	Total	tons	23993	23310	23450	29747	25589	28161	73032	81219
	Yield									
19	Underground	g/t	8.4	10.5	7.8	7.3	7.9	8.6	8.0	8.7
20	Surface Dumps	g/t								
21	Total	g/t	8.4	10.5	7.8	7.3	7.9	8.6	8.0	8.7
	Gold produced									
22	Underground	kg	201	244	184	218	202	243	587	705
23	Surface Dumps	kg								
24	Total	kg	201	244	184	218	202	243	587	705
	Factors									
25	% MO Sweepings	%	85%	68%	85%	82%	85%	86%	85%	80%
26	% Swept Total	%	100%	85%	100%	97%	100%	95%	100%	93%
27	% Swept Total Cleaning	%	120%	129%	120%	143%	120%	132%	120%	135%
28	% Pay	%	31%	57%	36%	61%	32%	36%	33%	50%
29	% Waste Mining	%	5%	11%	6%	11%	6%	8%	6%	10%
30	Ave Blasting frequency	ratio	3.8	4.0	4.1	2.9	3.4	2.3	3.8	2.9
32	Sampling Coverage	%	90%	89%	90%	100%	90%	98%	90%	96%
33	Old Gold	kg	3	7	3	3	3	23	10	33
34	Cut-off cm.g/t	cm.g/t	1470		1470		1470		1470	
	Tons Mined									
35	Total Stope Tons	tons	15457	13579	15077	16892	16454	20206	46989	50677
36	Development Reef Tons	tons	0	0	0	0	0	0	0	0
37	Development Waste Tons	tons	5745	6540	5650	7587	6124	7045	17519	21172
38	Total Development Tons	tons	5745	6540	5650	7587	6124	7045	17519	21172

Appendix 4: Technical Statement Quarter Three

	D4 Shaft								3 rd Quarter	
			Jul-21		Aug-21		Sep-21		Jul 21 - Sep 21	
	Salient Features		Plan	Actual	Plan	Actual	Plan	Actual	Plan	Actual
1	**Kilograms Produced**	kg	203	238	192	294	193	223	588	756
2	**Mill Tons**	t	25507	27667	26099	29973	25342	29628	76948	87268
	Development									
3	Total	metres	201.0	229.7	201.0	307.0	177.3	257.8	579.4	794.5
	Capital	metres	30.0	16.7	30.0	38.8	0.0	35.8	60.0	91.3
4	Total Main Including Capital	metres	106.9	129.7	99.9	132.8	70.0	91.6	276.8	354.1
5	Total Main Off reef Including Cap	metres	97.0	96.8	90.0	112.3	60.0	85.1	247.0	294.2
7	Main WC "Off Reef"	metres	67.0	80.1	60.0	73.5	60.0	49.3	187.0	202.9
8	Secondary WC "Off Reef"	metres	94.1	100.0	101.2	174.2	107.3	166.2	302.6	440.4
	Development On Reef									
9	Main	metres	9.9	32.9	9.9	20.5	10.0	6.5	29.7	59.9
10	Secondary	metres	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Average Development value									
11	Main	cmg/t	4598	3027	4389	5570	4256	2399	4414	3829
12	Secondary	cmg/t	0	0	0	0	0	0	0	0
	Percentage Payability									
13	Main	%	40%	31%	40%	56%	40%	0%	40%	36%
14	Secondary	%	0%	0%	0%	0%	0%	0%	0%	0%
15	**Paylimit**	cmg/t	3220	1740	3220	2300	3220	2540	3220	2204
	Stoping									
20	Total	m²	3056	3224	3143	3261	3126	3328	9326	9813
21	Avg. Value	cmg/t	3354	3646	3106	4536	3141	3986	3199	4057
22	Waste	m²	161	282	172	77	179	42	512	401
23	m² Above Paylimit	m²	1147	1970	1079	1736	1038	1636	3265	5342
24	Avg. Value above Pay Limit	cmg/t	5894	5365	5493	6995	5357	6392	5591	6209
25	m² Below Paylimit	m²	1748	972	1891	1448	1909	1650	5549	4070
26	Avg. Value below Pay Limit	cmg/t	1996	1218	2027	1830	2231	1702	2087	1632
27	Current Plan Au blasted	kg	282	323	268	407	270	365	820	1095
28	Cubics blasted (Reef)	m³	261	218	261	218	261	196	783	632
29	Cubics Au blasted	kg	6.184	8	4	7	4.375	1	15	17
1	Pay face length mined	metres	231	240	220	273	210	203	660	716
2	Total face length mined	metres	614	446	640	502	633	454	1887	1402
3	Face advance	metres	5.0	7.2	4.9	6.5	4.9	7.3	4.9	7.0
4	No of times crew blasted	No	8	9	8	9	8	10	8	9
	Width									
5	Channel	cm	98	112	98	98	103	105	100	105
6	Stope	cm	167	173	168	166	169	173	168	171
7	Milling (excl dumps)	cm	303	312	302	334	295	324	300	323
	Plant									
8	Shortfall/Excess	%	14%	13%	14%	13%	14%	14%	14%	14%
9	Mine Call Factor (MCF)	%	73%	73%	73%	72%	73%	62%	73%	69%
	Milling									
16	Underground	tons	25507	27667	26099	29973	25342	29628	76948	87268
17	Surface Dumps	tons								
18	Total	tons	25507	27667	26099	29973	25342	29628	76948	87268
	Yield									
19	Underground	g/t	7.9	8.6	7.4	9.8	7.6	7.5	7.6	8.7
20	Surface Dumps	g/t								
21	Total	g/t	7.9	8.6	7.4	9.8	7.6	7.5	7.6	8.7
	Gold produced									
22	Underground	kg	203	238	192	294	193	223	588	756
23	Surface Dumps	kg								
24	Total	kg	203	238	192	294	193	223	588	756
	Factors									
25	% MO Sweepings	%	85%	86%	85%	85%	85%	82%	85%	84%
26	% Swept Total	%	100%	92%	100%	99%	100%	92%	100%	94%
27	% Swept Total Cleaning	%	120%	135%	120%	155%	120%	132%	120%	141%
28	% Pay	%	38%	61%	34%	53%	33%	49%	35%	54%
29	% Waste Mining	%	5%	9%	5%	2%	6%	1%	5%	4%
30	Ave Blasting frequency	ratio	3.7	2.5	3.7	2.8	3.7	2.5	3.7	2.6
32	Sampling Coverage	%	90%	90%	90%	98%	90%	100%	90%	96%
33	Old Gold	kg	3	7	3	4	3	9	10	20
34	Cut-off cm.g/t	cm.g/t	1470		1470		1470		1470	
	Tons Mined									
35	Total Stope Tons	tons	16653	17605	17153	16916	17202	17719	51008	52240
36	Development Reef Tons	tons	0	0	0	0	0	0	0	0
37	Development Waste Tons	tons	5768	6681	5748	9598	4866	8384	16382	24663
38	Total Development Tons	tons	5768	6681	5748	9598	4866	8384	16382	24663

Appendix 5: Technical Statement Quarter Four and YTD

	D4 Shaft								4 th Quarter		YTD	
			Oct-21		Nov-21		Dec-21		Oct 21 - Dec 21		Jan21 - Dec21	
	Salient Features		Plan	Actual	Plan	Actual	Plan	Actual	Plan	Actual	Plan	Actual
1	**Kilograms Produced**	kg	227	202	224	280	173	211	624	692	2368	1
2	**Mill Tons**	t	26777	28899	25982	26742	22088	16471	74847	72112	296554	2896
	Development											
3	Total	metres	202.5	213.3	182.1	216.1	166.3	230.2	551.0	660	2339.4	2870.3
	Capital	metres	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	90.0	91.3
4	Total Main Including Capital	metres	88.7	72.6	56.4	102.0	51.3	110.0	196.5	285	1074.8	1340.6
5	Total Main Off reef Including Ca	metres	72.9	64.9	47.9	90.3	45.0	97.6	165.8	253	975.1	1055.8
7	Main WC "Off Reef"	metres	72.9	64.9	47.9	90.3	45.0	97.6	165.8	253	885.1	964.5
8	Secondary WC "Off Reef"	metres	113.8	140.7	125.7	114.1	115.0	120.2	354.5	375	1264.5	1529.7
	Development On Reef											
9	Main	metres	15.9	7.7	8.5	11.7	6.3	12.4	30.7	32	99.7	284.8
10	Secondary	metres	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0
	Average Development value											
11	Main	cmg/t	3104	275	3413	6644	1825	6375	2926	4997	4205.5	4237
12	Secondary	cmg/t	0	0	0	0	0	0	0	0	0.0	0
	Percentage Payability											
13	Main	%	22%	0%	26%	100%	0%	100%	18%	76%	33%	65%
14	Secondary	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
15	**Paylimit**	cmg/t	3220	2400	3220	1630	3220	2140	3220	2055	3220	229406
	Stoping											
20	Total	m²	3148	3174	3167	3387	3150	3275	9465	9836	36191	37302
21	Avg. Value	cmg/t	3676	3464	3609	3515	3500	3721	3595	3567	3424	4081
22	Waste	m²	175	86	169	23	166	33	509	142	1970	1878
23	m² Above Paylimit	m²	1432	1209	1572	1403	1572	1770	4576	4382	13621	19638
24	Avg. Value above Pay Limit	cmg/t	5584	6391	5463	6082	5243	5548	5426	5951	6138	6474
25	m² Below Paylimit	m²	1541	1879	1427	1961	1412	1472	4379	5312	20600	15786
26	Avg. Value below Pay Limit	cmg/t	2318	1739	1992	1719	1970	1608	2100	1695	1957	1589
27	Current Plan Au blasted	kg	318	302	314	327	303	335	936	965	3408	4186
28	Cubics blasted (Reef)	m³	261	253	261	366	261	49	783	668	3132	2493
29	Cubics Au blasted	kg	4.375	2.434	4	7	4.375	2	13	12	65	64
1	Pay face length mined	metres	312	174	334	190	339	273	985	637	0	0
2	Total face length mined	metres	686	443	673	467	679	494	2039	1404	0	1
3	Face advance	metres	4.6	7.2	4.7	7.3	4.6	6.6	4.6	7.0	0.0	53052.1
4	No of times crew blasted	No	8	9	8	10	7	8	8	9	0	68877
	Width											
5	Channel	cm	112	122	105	117	102	104	106	114	7737	4675
6	Stope	cm	172	175	166	175	163	173	167	175	0	1556
7	Milling (excl dumps)	cm	309	331	298	287	255	183	288	267	0	10846
	Plant											
8	Shortfall/Excess	%	14%	15%	14%	4%	3%	-44%	10%	-3%	12%	0%
9	Mine Call Factor (MCF)	%	73%	67%	73%	85%	58%	63%	68%	72%	0%	0%
	Milling											
16	Underground	tons	26777	28899	25982	26742	22088	16471	74847	72112	2368	2896
17	Surface Dumps	tons										
18	Total	tons	26777	28899	25982	26742	22088	16471	74847	72112	2368	2896
	Yield											
19	Underground	g/t	8.5	7.0	8.6	10.5	7.8	12.8	8.3	9.6	0.0	0.0
20	Surface Dumps	g/t										
21	Total	g/t	8.5	7.0	8.6	10.5	7.8	12.8	8.3	9.6	0.4	0.3
	Gold produced											
22	Underground	kg	227	202	224	280	173	211	624	692	0	0
23	Surface Dumps	kg										0
24	Total	kg	227	202	224	280	173	211	624	692	1	1
	Factors											
25	% MO Sweepings	%	85%	87%	85%	100%	85%	80%	85%	89%	85%	0%
26	% Swept Total	%	100%	92%	100%	113%	100%	98%	100%	101%	100%	0%
27	% Swept Total Cleaning	%	120%	125%	120%	155%	120%	127%	120%	136%	120%	857%
28	% Pay	%	46%	38%	50%	41%	50%	54%	48%	45%	38%	53%
29	% Waste Mining	%	6%	3%	5%	1%	5%	1%	5%	1%	5%	5%
30	Ave Blasting frequency	ratio	4.0	2.6	3.9	2.5	4.0	2.8	4.0	2.6	0.0	0.0
32	Sampling Coverage	%	90%	100%	90%	94%	90%	100%	90%	98%	0%	0%
33	Old Gold	kg	3	7	3	9	3	2	10	18	296554	319525
34	Cut-off cm.g/t	cm.g/t	1470		1470		1470		1470		1470	
	Tons Mined											
35	Total Stope Tons	tons	17580	17860	17154	18778	16728	16908	51462	53547	0	0
36	Development Reef Tons	tons	0	0	0	0	0	0	0	0	0	0
37	Development Waste Tons	tons	5930	7137	5673	7157	5134	7240	16737	21534	0	0
38	Total Development Tons	tons	5930	7137	5673	7157	5134	7240	16737	21534	0	0

Appendix 6: Head grade split for July 2021

		Driefontein Headgrade Splits																		
25		Jul 2021 (Surface Belts)																		
DAILY		DATE	Masakhane			Pitseng Shaft D2# Sampled @ Pitseng			Ya Rona Shaft D4#Sampled @ Pitseng			Hlanganani Shaft D5# Sampled @ Pitseng			Khomanani D8#			All DFT Shafts Tons		
SHIFT			Dry tons	G/t	Content	Dry tons	G/t	Content	Dry tons	G/t	Content	Dry tons	G/t	Content	Dry tons	G/t	Content	Dry tons	G/T	Content
		Monthly Business Plan	28630	6.19	177146	1429	4.26	6091	25507	8.19	208887	47032	5.31	249927	26448	3.35	88671	129045	5.66	730723
		Daily Business Plan	1145	6.19	7086	57	4.26	244	1020	8.19	8355	1881	5.31	9997	1058	3.35	3547	5162	5.66	29229
		Prog. Business Plan	28630	6.19	177146	1429	4.26	6091	25507	8.19	208887	47032	5.31	249927	26448	3.35	88671	129045	5.66	730723
		Prog. Actual	20036	7.62	152609	1178	13.23	15584	27667	8.46	234103	49908	5.07	253061	30606	3.26	99759	129395	5.84	755117
		Difference	-8593		-24537	-251		9493	2160		25215	2877		3134	4158	-0.09	11089	351		24394
Milling Shift	Hoisting Shifts	Gold Allocation	20036	7.70	154186	1178	13.37	15745	27667	8.55	236520	49908	5.12	255675	30606	3.29	100790	129395	5.90	762916
1	1	July 1, 2021	597	11.34	6771	0	0.00	0	995	6.80	6758	1619	3.26	5272	1207	3.24	3907	4417	5.14	22709
2	1	July 2, 2021	655	6.51	4259	0	0.00	0	490	5.73	2805	488	3.75	1829	0	0.00	0	1632	5.45	8893
3		July 3, 2021	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00	0	0	0.00	0
4		July 4, 2021	291	6.51	1892	0	0.00	0	0	0.00	0	1430	3.75	5364	918	1.33	1218	2639	3.21	8475
5	1	July 5, 2021	631	6.56	4136	0	0.00	0	441	3.03	1334	1703	4.86	8268	1370	2.08	2846	4144	4.00	16584
6	1	July 6, 2021	989	3.14	3105	0	0.00	0	1332	3.03	4034	899	3.87	3477	1223	6.47	7907	4443	4.17	18523
7	1	July 7, 2021	968	5.69	5506	0	0.00	0	1113	5.78	6431	2699	5.39	14538	780	1.60	1247	5559	4.99	27722
8	1	July 8, 2021	629	4.14	2605	0	0.00	0	1504	7.57	11392	837	4.10	3432	1404	1.92	2689	4374	4.60	20119
9	1	July 9, 2021	1092	5.74	6271	0	0.00	0	1072	5.97	6399	2213	5.21	11521	1049	2.69	2818	5427	4.98	27009
10	1	July 10, 2021	207	5.74	1190	356	9.48	3376	298	5.97	1776	1231	5.21	6408	0	0.00	0	2092	6.09	12749
11		July 11, 2021	34	5.74	193	0	0.00	0	0	0.00	0	996	3.72	3705	1207	2.98	3596	2236	3.35	7494
12	1	July 12, 2021	1279	6.86	8767	0	0.00	0	965	5.24	5055	1771	13.62	24127	1236	2.64	3266	5251	7.85	41215
13	1	July 13, 2021	708	5.83	4130	0	0.00	0	1608	6.81	10955	2405	2.93	7040	1457	3.82	5563	6179	4.48	27688
14	1	July 14, 2021	722	8.24	5945	0	0.00	0	1046	8.69	9091	2493	7.57	18873	873	3.85	3355	5134	7.26	37264
15	1	July 15, 2021	855	13.93	11911	0	0.00	0	1324	8.62	11415	2220	2.83	6281	1326	1.57	2075	5724	5.53	31682
16	1	July 16, 2021	962	6.54	6291	0	0.00	0	714	13.87	9907	1343	6.39	8575	1690	2.72	4587	4709	6.24	29360
17	1	July 17, 2021	328	6.54	2147	0	0.00	0	1108	13.87	15366	2719	6.39	17359	0	0.00	0	4155	8.39	34872
18		July 18, 2021	367	6.54	2398	0	0.00	0	803	13.87	11132	0	0.00	0	844	2.72	2291	2013	7.86	15821
19	1	July 19, 2021	549	7.26	3987	0	0.00	0	943	15.45	14563	3210	4.29	13764	1215	1.24	1504	5917	5.71	33817
20	1	July 20, 2021	782	8.74	6840	350	9.48	3321	1378	8.11	11172	1941	3.66	7104	1327	3.59	4760	5778	5.75	33197
21	1	July 21, 2021	750	6.92	5188	0	0.00	0	1105	10.12	11177	1874	6.63	12420	1930	9.00	17358	5658	8.16	46143
22	1	July 22, 2021	575	7.68	4418	0	0.00	0	843	6.71	5658	2134	5.43	11584	1179	1.59	1877	4731	4.98	23538
23	1	July 23, 2021	1005	6.76	6790	0	0.00	0	1296	8.66	11228	1621	4.79	7767	1235	3.20	3946	5157	5.76	29730
24	1	July 24, 2021	33	6.76	220	0	0.00	0	743	8.66	6438	729	4.79	3490	0	0.00	0	1504	6.75	10148
25		July 25, 2021	625	6.76	4222	0	0.00	0	313	8.66	2711	1058	4.79	5067	1221	3.20	3903	3217	4.94	15903
26	1	July 26, 2021	621	8.04	4995	0	0.00	0	1542	9.18	14159	2214	3.58	7914	599	4.97	2979	4976	6.04	30047
27	1	July 27, 2021	785	14.37	11287	251	9.48	2375	1332	9.22	12277	1793	3.03	5438	1927	4.22	8126	6087	6.49	39503
28	1	July 28, 2021	1189	8.69	10340	0	0.00	0	1344	13.94	18740	1958	5.73	11221	819	2.41	1970	5311	7.96	42271
29	1	July 29, 2021	915	9.04	8266	0	0.00	0	1335	5.62	7505	1959	4.61	9023	1426	2.48	3539	5635	5.03	28333
30	1	July 30, 2021	678	9.08	6151	0	0.00	0	531	3.53	1875	2353	5.18	12197	0	0.00	0	3562	5.68	20222
31																				
		TOTAL	20036	7.62	152609	1178	13.23	15584	27667	8.46	234103	49908	5.07	253061	30606	3.26	99759	129395	5.84	755117

Appendix 7: Lock up tonnes per working place 2021

YA RONA

January-21

D4	Stoff Census			Value
Workplace	Face tons	Gully Tons	KG	g/t
CL35 M 04AW	40	32	0.18	2.5
VC28 J WRS	33	100	2.46	18.5
VC29 IB 02E	20	102	1.24	10.2
VC30 IB 08B W	61	109	5.80	34.1
VC30 J 04W	44	55	1.05	10.6
VC33 34B 05E	35	89	11.34	91.4
VC33 H WRS	73	61	3.39	25.3
VC39 30 01W	32	152	0.79	4.3
VC39 M WRS 2	112	32	7.54	52.4
VC40 30A 03AE	NA	NA		
VC40 30A 02AW	36	30	0.00	0.0
VC40 30A 02BW	43	32	0.53	7.0
VC40 30A 02W	43	32	1.98	26.4
VC40 30A 03AW	36	30	0.00	0.0
VC40 30A 03BE	80	31	6.06	54.4
VC40 31 07W	94	52	2.60	17.8
VC40 32 01W	58	48	7.76	73.0
VC40 32 WRS	119	95	5.18	24.2
VC40 L 01W	67	25	0.34	3.7
	1027	1107	58.23	27.3
Total	2133			

February-21

D4	Stoff Census			Value
Workplace	Face tons	Gully Tons	KG	g/t
CL35 M 04AW	57	36	0.25	2.7
VC28 J 04AW	36	57	1.46	15.7
VC28 J WRS	94	215	4.06	13.1
VC29 IB 02E	65	108	1.90	11.0
VC30 IB 08B W	22	77	1.81	18.3
VC33 34B 05E	27	79	12.32	116.2
VC33 H WRS	86	69	2.51	16.2
VC39 30 01W	18	160	0.80	4.5
VC39 M WRS 2	81	38	3.68	30.9
VC40 30A 02AW	68	0	1.80	26.4
VC40 30A 02BW	74	173	3.24	13.1
VC40 30A 02W	28	36	0.31	4.9
VC40 30A 03BE	118	77	9.56	49.0
VC40 31 07W	11	68	1.44	18.2
VC40 32 01W	70	45	10.25	89.1
VC40 32 WRS	134	54	8.71	46.3
VC40 L 01W	65	23	1.66	18.9
VC40 L 04AW	29	47	2.34	30.8
VC42 31 WRS	8	0	0.02	2.0
	1091	1362	68.12	27.8
Total	2453			

March-21

D4	Stoff Census			Value
Workplace	Face tons	Gully Tons	KG	g/t
CL35 M 04AW	44	64	0.40	3.7
VC28 J 04AW	96	166	8.09	30.9
VC28 J WRS	134	302	4.66	10.7
VC29 IB 02E	0	118	1.79	15.2
VC29 IB WRS	10	98	0.67	6.2
VC30 IB 08B W	30	91	4.19	34.6
VC33 34B 05E	25	55	6.01	75.2
VC33 H WRS	96	25	1.84	15.2
VC39 30 01W	42	111	0.55	3.6
VC39 M WRS	38	43	2.16	26.6
VC39 M WRS 2	38	43	3.62	44.8
VC40 30A 02AW	57	42	2.02	20.4
VC40 30A 02BW	122	43	2.22	13.4
VC40 30A 02W	34	66	1.41	14.1
VC40 30A 03BE	52	44	3.90	40.6
VC40 32 01E	84	0	2.91	34.6
VC40 32 01W	122	23	9.57	66.0
VC40 32 WRS	64	163	7.59	33.4
VC40 L 01AW	83	29	3.19	28.5
VC40 L 04AW	65	112	3.80	21.5
VC42 31 WRS	40	0	0.14	3.5
	1276	1638	70.74	24.3
Total	2914			

April-21

D4	Stoff Census			Value
Workplace	Face tons	Gully Tons	KG	g/t
CL35 M 01E	6	5	0.05	4.7
CL35 M 04AW	0	109	0.13	1.2
VC28 J 03AW	114	97	0.13	0.6
VC28 J 04AW	63	88	4.40	29.2
VC28 J WRS	0	0		
VC29 IB WRS	45	112	0.82	5.2
VC30 IB 08B W	86	87	2.57	14.8
VC30 IB 10W	24	62	0.03	0.3
VC33 34B 05E	26	117	10.87	76.0
VC33 H WRS	26	117	2.68	18.8
VC39 30 01W	72	49	0.34	2.8
VC39 M WRS	23	15	1.00	26.3
VC40 30A 02AW	133	29	0.24	1.5
VC40 30A 02BW	37	32	0.74	10.7
VC40 30A 02W	25	37	1.82	29.4
VC40 30A 03BE	100	63	3.25	19.9
VC40 32 01E	21	0	0.77	36.9
VC40 32 01W	170	45	11.32	52.6
VC40 32 WRS	253	67	7.20	22.5
VC40 L 01AW	32	52	1.43	17.0
VC40 L 04B W	140	65	5.47	26.7
VC42 31 WRS	21	4	0.06	2.2
	1417	1252	55.32	20.7
Total	2669			

May-21

D4	Stoff Census			Value
Workplace	Face tons	Gully Tons	KG	g/t
CL35 M 01E	19	9	0.08	3.0
VC28 J 03AW	136	93	3.26	14.3
VC28 J 04AW	73	69	4.71	33.2
VC29 IB WRS	20	36	0.37	6.6
VC30 IB 08B W	27	126	0.00	0.0
VC30 IB 10W	43	46	0.02	0.2
VC33 34B 05E	32	61	11.64	125.2
VC33 34B 06E	43	18	1.34	21.9
VC33 H WRS	143	119	4.01	15.3
VC39 30 01W	55	96	0.74	4.9
VC39 M WRS	1	0	0.05	54.7
VC39 M WRS 2	63	71	4.13	30.8
VC40 30A 02BW	136	53	1.25	6.6
VC40 30A 02W	113	79	4.52	23.5
VC40 30A 03BE	0	0		
VC40 31 07W	0	0		
VC40 32 01E	36	5	1.58	38.5
VC40 32 01W	95	68	8.43	51.7
VC40 32 WRS	128	60	5.34	28.4
VC40 L 01AW	55	133	4.99	26.6
VC40 L 04B W	210	80	7.35	25.4
VC42 31 WRS	55	138	4.09	21.2
	1483	1360	67.92	23.9
Total	2843			

June-21

D4	Stoff Census			Value
Workplace	Face tons	Gully Tons	KG	g/t
CL35 M 01E	73.0	32.0	0.35	3.4
VC28 J 03AW	176.0	123.0	5.13	17.1
VC28 J 04AW	94.0	123.0	6.34	29.2
VC29 IB WRS	97.0	103.0	1.84	9.2
VC30 IB 08B W	38.0	104.0	0.00	0.0
VC30 IB 10W	58.0	39.0	0.04	0.4
VC33 34B 05E	21.0	25.0	2.75	59.8
VC33 H WRS	66.0	80.0	2.00	13.7
VC39 30 01W	59.0	112.0	0.57	3.3
VC39 M WRS	40.0	0.0	1.62	40.5
VC39 M WRS 2	71.0	52.0	0.94	7.7
			0.00	
VC40 30A 02BW	106.0	94.0	2.59	13.0
VC40 30A 02CW	81.0	32.0	1.29	11.4
VC40 30A 02W	22.0	57.0	0.29	3.7
VC40 32 01E	29.0	19.0	1.93	40.2
VC40 32 01W	148.0	50.0	10.40	52.5
VC40 L 01AW	56.0	59.0	0.80	7.0
VC40 L 04B W	74.0	67.0	3.52	25.0
VC42 30A 03W	58.0	17.0	0.54	7.2
VC42 31 WRS	62.0	10.0	1.20	16.7
	1429	1198	44.15	16.8
Total	2627			

July-21

D4	Stoff Census			Value
Workplace	Face tons	Gully Tons	KG	g/t
CL35 M 01E	0	95	0.52	5.5
VC28 J 03BW	36	63	1.66	16.8
VC28 J 04AW	62	80	4.26	30.0
VC29 IB WRS	44	69	2.54	22.5
VC30 IB 08B W	103	98	0.00	0.0
VC33 34B 05E	58	105	5.74	35.2
VC33 H WRS	99	154	2.42	9.6
VC39 30 02W	40	151	0.32	1.7
VC39 M WRS	44	69	0.65	5.7
VC39 M WRS 2	35	63	0.65	6.6
VC40 30A 02BW	39	61	0.69	6.9
VC40 30A 02CW	82	43	2.76	22.0
VC40 30A 02W	91	37	1.06	8.3
VC40 32 01E	87	47	5.61	41.9
VC40 32 01W	176	52	11.77	51.6
VC40 L 01AW	76	54	4.82	37.1
VC40 L 04B W	80	95	3.96	22.6
VC42 30A 03W	18	50	0.38	5.6
VC42 31 WRS	24	50	1.34	18.1
	1194	1436	51.14	19.4
Total	2630			

August-21

D4	Stoff Census			Value
Workplace	Face tons	Gully Tons	KG	g/t
CL35 M 02E	24	59	1.40	16.9
VC28 J 03BW	49	35	2.01	24.0
VC28 J 04AW	58	87	2.87	19.8
VC29 IB 02 W	36	41	0.72	9.3
VC29 IB WRS	0	75	1.57	21.0
VC30 IB 08B W	15	83	0.00	0.0
VC33 34B 06E	20	46	2.32	35.1
VC33 H 03AE	38	86	2.16	17.4
VC33 H 04E	24	86	0.62	5.7
VC33 H WRS	46	87	2.21	16.6
VC39 30 02W	71	112	0.75	4.1
VC39 M WRS	62	23	4.83	56.8
VC40 30A 02BW	95	43	1.00	7.3
VC40 30A 02CW	98	25	2.65	21.5
VC40 30A 02W	45	39	1.07	12.7
VC40 32 01E	86	54	6.47	46.2
VC40 32 01W	51	35	4.12	47.9
VC40 L 01AW	74	59	6.35	47.7
VC40 L 04B W	92	101	11.39	59.0
VC42 30A 03W	101	94	0.39	2.0
VC42 31 01W	119	11	2.75	21.2
	1204	1281	57.63	23.2
Total	2485			

September-21

D4	Stoff Census			Value
Workplace	Face tons	Gully Tons	KG	g/t
CL35 M 02E	0	44	0.63	14.4
VC28 J 03BW	35	38	1.17	16.0
VC28 J 04AW	70	67	2.90	21.2
VC29 IB 02 W	8	112	0.84	7.0
VC30 J 02AW	66	73		
VC33 34B 06E	34	41	3.20	42.6
VC33 H 03AE	38	56	1.62	17.2
VC33 H 04E	0	0		
VC33 H WRS	0	0		
VC39 30 02W	64	178	0.64	2.6
VC39 M 01W	31	4	1.19	34.0
VC39 M WRS	0	0		
VC40 30A 02BW	71	39	0.48	4.3
VC40 30A 02CW	70	53	1.70	13.9
VC40 30A 02D W	43	0	0.32	7.5
VC40 30A 02W				
VC40 32 01E	65	30	5.04	53.1
VC40 32 01W	60	42	4.08	40.0
VC40 L 01AW	68	95	8.94	54.8
VC40 L 04B W	72	78	7.05	47.0
VC42 30A 03W	68	64	0.87	6.6
VC42 31 01W	71	4	0.96	12.8
	934	1018	41.63	21.3
Total	1952			

October-21

D4	Stoff Census			Value
Workplace	Face tons	Gully Tons	KG	g/t
CL35 M 02E	8	46	0.38	7.0
VC28 J 03BW	76	91	1.93	11.5
VC28 J 04AW	60	166	6.62	29.3
VC29 IB 02 W	56	111	1.38	8.3
VC30 J 02AW	126	131	3.63	14.1
VC33 34B 06E	30	38	3.66	53.9
VC33 H 03AE	85	36	1.67	13.8
VC39 30 02W	42	114	0.39	2.5
VC39 M 01W	31	13	1.21	27.5
VC39 M WRS 2	11	175	0.14	0.7
VC40 30A 02BW				
VC40 30A 02CW	118	35	2.19	14.3
VC40 30A 02D W	46	14	0.11	1.8
VC40 30A 02W	55	74	0.67	5.2
VC40 32 01E				
VC40 32 01W	169	73	7.46	30.8
VC40 32 02E	114	49	8.43	51.7
VC40 L 01AW				
VC40 L 02E	46	62	3.67	34.0
VC40 L 04B W	147	107	6.56	25.8
	1220	1335	50.11	19.6
Total	2555			

November-21

D4	Stoff Census			Value
Workplace	Face tons	Gully Tons	KG	g/t
CL35 M 02E	105	630	6.96	9.5
VC28 J 03BW	82	64	1.03	7.0
VC28 J 04AW	68	103	3.72	21.8
VC29 IB 02 W	56	55	1.84	16.6
VC30 J 02AW	85	237	2.94	9.1
VC33 34B 05E	62	40	4.23	41.5
VC33 34B 06E	0	0		
VC33 H 03AE	106	65	2.18	12.7
VC39 30 02W	0	223	0.79	3.6
VC39 M 01W	26	30	1.71	30.5
VC39 M WRS2 01W	67	24	0.41	4.5
VC39 L 02E	32	0	1.12	35.0
VC39 L WRS	187	203	15.74	40.4
VC40 30A 02CW	97	125	2.36	10.6
VC40 30A 02D W	53	155	0.58	2.8
VC40 30A 02W	27	94	1.24	10.3
VC40 32 01W	61	33		
VC40 32 02E	85	54	6.31	45.4
VC40 32 WRS	79	41	3.44	28.6
VC40 L 02E	0	183	5.39	29.5
VC42 30A 03W	165	124	2.02	7.0
	1443	2483	64.02	16.3
Total	3926			

December-21

D4	Stoff Census			Value
Workplace	Face tons	Gully Tons	KG	g/t
CL35 M 02E	35	47	0.97	11.8
VC28 J 02AW	54	172	0.50	2.2
VC28 J 03AW	98	164	3.53	13.5
VC28 J 03BW	0	0		
VC28 J 04AW	149	177	6.32	19.4
VC28 J 04W	54	65	2.83	23.8
VC33 34B 05E	45	24	3.01	43.7
VC33 H 03AE	92	68	1.42	8.9
VC39 30 01W	33	150	0.96	5.2
VC39 M 01W	47	35	2.80	34.1
VC39 M WRS 2	0	0		
VC39 M WRS2 01W	41	17	0.97	16.7
VC39 L 01E	30	34	2.12	33.1
VC39 L WRS	74	38	3.63	32.4
VC40 30A 02CW	79	107	2.35	12.6
VC40 30A 02D W	24	68	1.33	14.5
VC40 30A 02W	74	61	2.98	22.1
VC40 32 02E	83	32	4.28	37.2
VC40 32 03W	55	0	1.43	26.0
VC40 32 WRS	137	81	6.45	29.6
VC42 30A 03W	118	147	2.22	8.4
VC42 31 02W	61	48	2.32	21.3
	1383	1535	52.42	18.0
Total	2918			