AN ANALYSIS OF THE IMPACT OF POTHOLES AND WASTE OVER-BREAK ON THE ECONOMICS OF A STOPE PANEL ON A PLATINUM MINE.

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A research report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfillment of the requirements for the degree of Master of Science in Engineering (Mining).

Johannesburg, 2007

DECLARATION

I declare that this research report is my own, unaided work. It is being submitted for the Degree of Master of Science in Engineering (Mining) in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

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Kabelo Tlhapi

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ABSTRACT

In the Bushveld Complex, potholes provide challenges that have proven difficult for management to handle. The lack of innovative ways of solving the challenges provided an environment in which value destructive paradigms came into existence. There currently exists as a result, a paradigm in which tonnes, rather than quality tonnes (tonnes against a certain grade) are the main focus of mine management. In this paradigm has long existed a rule of thumb that dictated that a panel can remain economically viable with two-thirds of its facelength being off-reef.

This research employs a simple MS Office Excel-based model to investigate the impact of varying pothole size and primary contamination on the rule of thumb. A practical industry example is then used to show the impact on business, of the current paradigm.

This research found that the amount of off-reef that a stope panel in a platinum mine can tolerate is largely dependent on the operation's overall pay limit and that the off-reef tolerance decreases with increasing pay limit. For the particular mine that this research was carried out on, the findings are that the maximum off-reef that a panel can mine is forty-two percent.

Finally, based on the findings of this research, recommendations and additional areas of research are identified, which could help mine management in the

platinum industry achieve a paradigm shift, as well as enhance the findings in this report.

A dedication to my kids Tshenolo le Bogosi

A dedication to my grandfather,

Ramorwesi Simon Tlhapi for his love for

education and an absolute belief in a

Masters Degree

In loving memory of the best mentor I ever had

Nnenne Rosinah Thage

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I would also like to thank Prof Fred Cawood, University of the Witwatersrand, for his valuable input and guidance when my mind had given up.

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LIST OF SYMBOLS

Centimetre	cm
centimetre gram per tonne	cmg/t
gram	g
gram per tonne	g/t
Metre	m
Ounce	Oz
tonne	t

NOMENCLATURE

4E	4 Element (Pt,Pd,Rh+Aug)
ASG	Advanced Strike Gully
BC	Bushveld Complex
EVA	Economic Value Add
FW	Footwall
HW	Hangingwall
IRUP	Iron Rich Ultramafic Pegmatoid
MR	Merensky Reef
MRM	Mineral Resource Management
PGM	Platinum Group Metals
SAMREC	South African Code for Mineral Reporting
SMU	Smallest Mining Unit
SW	Stope Width

SWAR	Stope Width Analysis Report
UG2	Upper Group 2
USD	United States Dollar

1 INTRODUCTION

1.1 The Bushveld Complex

1.1.1 Location

The Bushveld Complex (BC) was formed more than two billion years ago by an injection of large volumes of magma from the earth's mantle into the earth's crust and includes layered mafic intrusions (the Rustenburg Mafic Suite) and a felsic intrusion (the Lebowa Granite Suite). It exists in three provinces of South Africa, namely: Limpopo, the North West and Mpumalanga. Its geographic centre is located just north of Pretoria at about 25° S and 29° E, covering an area bigger than Ireland at just over 66,000 km². It is shown by the green colour in Figure 1.1.

1.1.2 Economic importance

The combined effect of multiple injections of lava into the magma chamber and the crystallisation of different minerals as the chamber cooled over time created distinct layered rocks including the three PGM bearing horizons referred to as reefs, namely: the Merensky Reef, the UG2 reef and the Plat reef. About eighty percent of the platinum and twenty percent of palladium mined in the world are mined from these reefs, where the Merensky Reef and the UG2 reefs are known to contain over ninety percent of the world's remaining PGM reserves (Viljoen & Schuurman, 1998).

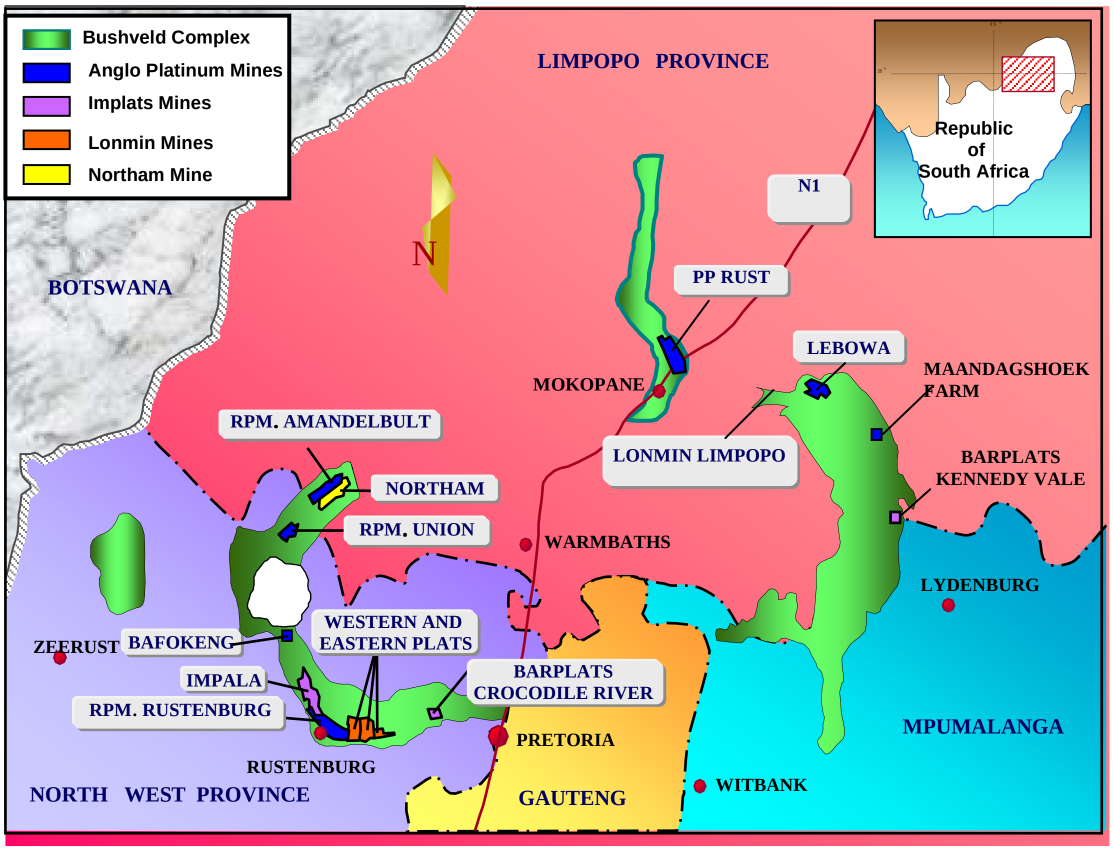


Figure 1.1 The location of the Bushveld Complex (Novy 2006:1)

1.1.3 Geological structures

The mineralised horizons mentioned above are also associated with geological structures like dunite pipes, faults and shear zones, cooling domes (flat-dipping joints), Iron Rich Ultramafic Pegmatoids (IRUP), dykes and sills, reef undulations and potholes. Potholes are almost entirely unique to the Bushveld Complex. These structures cut across the existing strata causing reef losses or reef displacement on the reef horizons.

Potholes and the associated reef type changes encountered in the BC are difficult to predict, in fact, there has been very little technological advancements in the area of resolving potholes to the scale of the smallest mining unit, the stope panel. The inability to predict these potholes ahead of an advancing stope panel in the BC results in inefficient mine planning. The subsequent unexpected intersection of these structures leads to delays in mining with a resultant increase in mining costs followed by down-scaling of operations in some instances, depending on the amount of flexibility (or the lack thereof) that the particular operation enjoyed at the time the pothole is intersected.

Potholes affect operations in both real time and space. Production at local and mine-wide level is likely to be constantly disrupted as re-raising and rectification of the layout is undertaken to compensate for the variability in the morphology of the pothole and most of the reserves in and around the pothole are often rendered sterile. The variability of reef types in the pothole structure exposes a stoping or reef development process to the risk of either missing the correct reef, mining in economically unpaying areas and loss of reef in hanging or footwalls, which results in contamination, resulting in higher mining and milling costs. Over and above this risk, developing and mining into potholed areas puts the safety of that particular process, people and equipment at risk as a result of weakened strata.

1.2 Overall aims of study

When quality (grade) started receiving the attention that it deserves from senior management in as far as the yield of platinum ounces and hence cash flow for platinum mining are concerned, there was a directive issued to the operations with respect to the need to improve the quality of the tonnages being mined. This directive was contradictory to a rule of thumb applied at the time to stope panels that intersected mainly potholes, which suggested that a panel could still be economic even with two thirds of it being off-reef.

From underground trips undertaken by the author to stope panels that were in an off-reef situation, it became quite clear that the “rule” was inappropriate and as a result had to be investigated, more so as no one seemed to know where it originated from.

The “rule” could have been empirically established of course, but the documentation thereof proved too hard to find. For as long as the status quo remained, the rule of thumb remained the accepted norm, which contributed to the problem of dilution control and the destruction of value for an operation. The practical realization of it was that panels could quite often be mined off-reef beyond the two thirds blanket rule.

This research project seeks to test the “two-thirds” hypothesis by scientifically determining how much off-reef a face length of any particular stope panel can afford to mine before it becomes economically unviable, taking into consideration in particular, the impact of off-reef mining due to potholes and contamination as a result of over-breaking in the footwall and hangingwall.

1.2.1 Area of research

This research seeks to assess the economical impacts of potholes pre-mining and during extraction of a block of platinum reserves underground such that decisions can be made quicker as to whether it is economical to continue mining or apply alternative strategies, saving in the process, time and money for the operation.

This will be done by looking at how much waste a particular stoping panel in a particular geo zone with unique over-breaking conditions can tolerate before it becomes economically unpaying, thus challenging the outdated and untraceable rule of thumb wildly used in the platinum mining sector, which states that a panel can mine up to two thirds of its face length off-reef before it becomes unpay.

It becomes therefore possible that by the time the panel encounters a pothole, a quick decision can be made by the relevant parties around how much longer it can mine in the pothole before being stopped and other alternatives looked at. Secondly, an economic case study can then be conducted, comparing the costs of re-establishing a panel that has encountered a pothole to the costs of mining the stope panel through the pothole, essentially, waste. The research is mainly based on a conventional breast stope but the principles can be applied to other mining methods that use a panel as the smallest mining unit.

1.3 Subsequent chapters

Chapter 2: Why is this research important

This chapter looks at the risk applicable to a mining project. The current literature, given the nature of this research as an emerging topic is reviewed in this chapter. The impact of geological structures and dilution are high on the risk rankings.

Chapter 3: Review of current practices

This chapter highlights the difference between contamination and dilution and their impact on a platinum stope panel. The current ore body evaluation practices on an operating mine are reviewed and shortcomings identified in relation to chapter two.

Chapter 4: Mining economics and the pay limit

This chapter highlights the importance of the pay limit as the key factor in the determination of what is an uneconomical stope panel in the presence the risks highlighted in chapter two. Strategic mine planning and the key variables are also discussed.

Chapter 5: Managing a pothole intersection

This chapter looks at the various strategies applied to address mining in pothole affected panels. This chapter effectively emphasises the fact that there is no need to incur unnecessary waste from potholes.

Chapter 6: The study

This chapter describes the methods and the tools employed in conducting this research. A simple, yet powerful excel-based model is introduced and its application in satisfying the research aim set in chapter one explained.

Chapter 7: Results and discussion

The results of the methods discussed in chapter seven are presented in table and graphical formats for simplicity and discussed.

Chapter 8: Conclusions and recommendations

The findings and conclusions reached in this research are summarised in this chapter. Unanswered questions that occurred to me but requiring research beyond the scope of this research are also listed in this chapter.

2 WHY THIS RESEARCH IS IMPORTANT

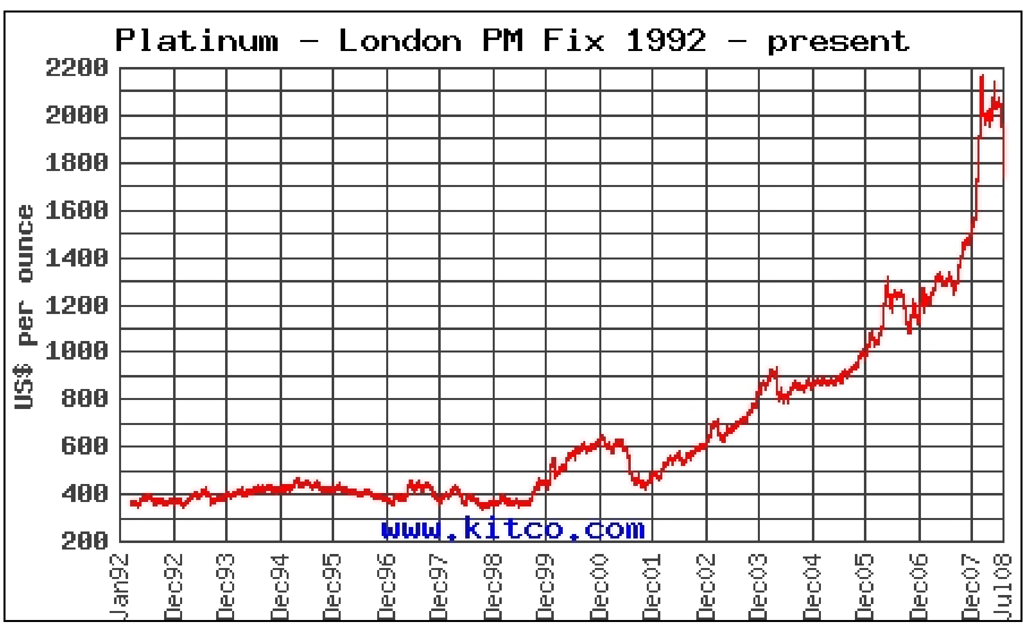
2.1 The dynamic platinum business

Mining is a business purely aimed at separating the valuable content of a mineral deposit in the most effective and efficient way. Despite the investment community's continued investment and all the technical advances that have occurred in the past, the profitability of mining still falls short of that obtained by most other industries. Failure to give attention to the unique economic principles that govern the exploitation of mineral resources and their implications in the management of mines stands out as the crucial component out of various other causes that lead to dismal performances of mining operations (Camus, 2002).

The need for the platinum industry expansion in the recent times highlights the supply pressures that are created by the global demand for an exhaustible resource. This supply deficit calls for an increase in production, which in turn has an associated increase to costs. The strengthening of the rand against the dollar, thus eroding the Rand-based revenue and increasing dollar-denominated borrowings highlights the important role of exchange rates as determined by global markets. Despite good commodity prices (Figure 2.1) the platinum industry is still very much a price taker and the Rand basket price of its products is on a downward trend as a result of the strong Rand to US Dollar exchange rate (Tlhapi, 2004).

(Figure 2.1a) and the only way to maintain acceptable profit margins, is to reduce the upward spiraling costs associated with mining its products.

(a)



(b)

Figure 2.1 A graph of the Rand vs USD (a) and the Platinum price trend (b)

Source: www.kitco.com

It is this dynamic environment that forces platinum miners to better understand their key value drivers, which have an impact on their margins. These include:

- Operating volumes
- Best cut comparison
- 4E optimisation (grade)
- Dilution control
- Quality assurance

An effective understanding of an orebody is based, according to the points discussed above, on the thorough understanding of its fixed geology. This research report will highlight how geological structure impacts on most of the bullet points above on a conventional breast platinum mine.

Viljoen et al (1986) and other authors like Lomberg, Patterson and Venter (1999), Carr, Groves, and Cawthorn (1994a), Carr, Groves, and Cawthorn (1994b), Ballhaus (1988), Viljoen and Hieber (1986), Bumby et al (1999) and Brown (2003) have written quite extensively on the geology of the BC with reference to its Merensky reef as well as its petrology and the geological structures affecting the reef horizons, particularly potholes and their morphology. But very little has been written about the significance of these structures on the mining process.

Brown and Lyons (1996) have written on the alternative ways of mining the UG2 given the pothole disruptions encountered during mining operations. The importance of a geologist on a mine, within the context of mineral resource management lends itself to the management of these structures and a meaningful contribution towards the optimum extraction of the resources from the ground by assisting with meaningful information for the mining process (Brown and Theron, 2003).

2.2 Destroying value

Hall (2005) notes quite relevantly that "tradition and rules of thumb were… and often the number was imposed on the operation from some distant head office. These are often still true today." This research was actually sparked by such a rule of thumb, which stated that panels that became off-reef, mainly through intersecting a pothole, would still be economic even with two thirds of it being off-reef. This of course sounded incorrect and the inappropriateness of the "rule" of thumb was quite apparent from underground trips to panels that had been mined under its guideline.

From legacy, the rule of thumb got acceptable and thus became the norm, which contributed to the problem of dilution control and 4E optimisation. The practical realization of it is that sometimes panels even got mined beyond this two thirds blanket rule (Figure 2.2). This research project seeks to address this by scientifically determining how much off-reef a face length of any particular stope panel can afford to carry before it becomes economically unviable, taking into consideration in particular, the impact of off-reef due to potholes and their negative impact on the key value drivers mentioned earlier on.

Figure 2.2 shows the results of several underground mapping trips made by the author where on the last visit the panel facelength was about ninety percent off-reef and still mining. Though this working place was eventually stopped, it goes without saying that a lot of value was destroyed by the activities that took place in the working area. On the other hand the scenario is actually a good demonstration of how “more is better and less is bad” unfortunately lends itself to the destruction of shareholder value. As panel 2 in Figure 2.2 was mining ahead of panel 1 due to ventilation requirements, the pothole was intersected first in the gully.

For the person mining the panel it is practically impossible to tell what the morphology of the pothole is at this stage and it would as such make no sense for him to stop mining. It is as such vital that the responsible personnel is armed with the knowledge of how much further he/she can still mine before shareholder value gets destroyed. The miner ought to strike a balance between reaching ‘call’ and quality mining and as alluded to earlier on, this is a balance that should be driven by corporate values.

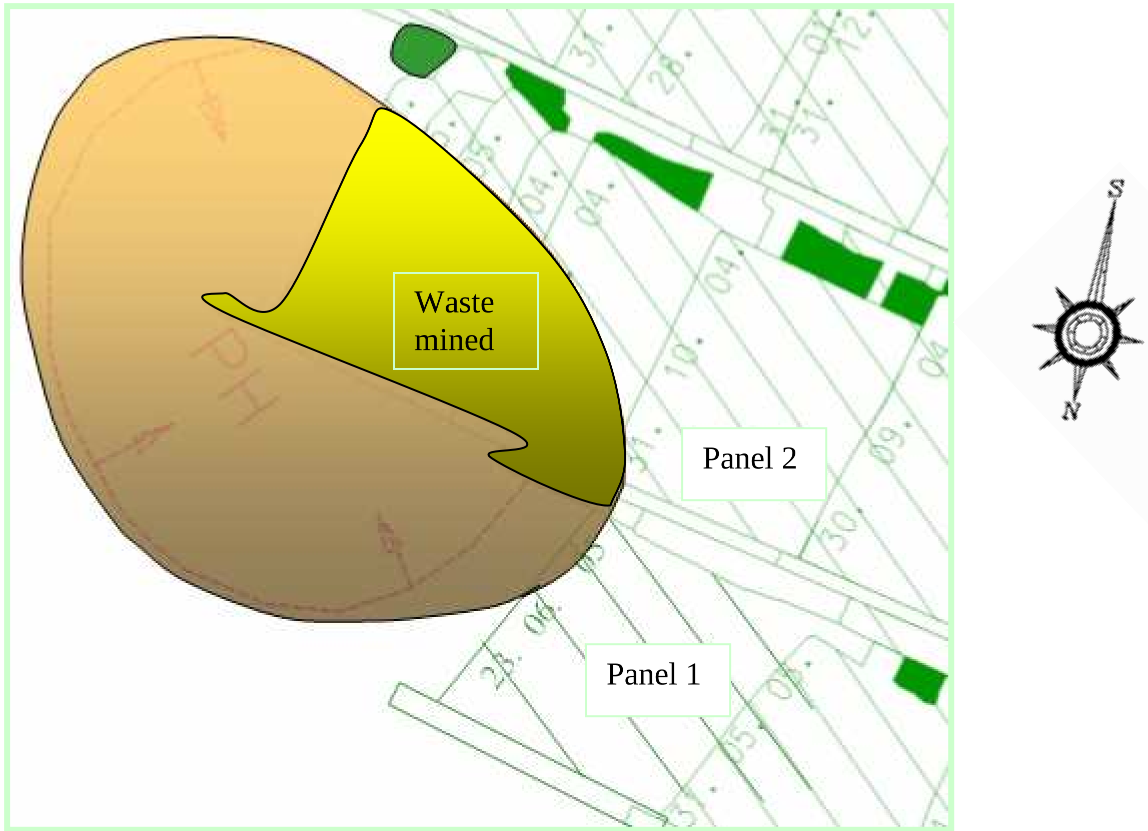


Figure 2.2 A panel affected by a pothole on the down-dip side

2.3 Financing a mining project

To understand the importance of the subject matter discussed in this research project, it is important to take a step back from the mining operation and get into the shoes of a banker who has been approached by a mining house for capital to finance their project. A banker, same as anybody lending money to, be it a friend or a stranger, seeks to take care of the downside, i.e. the fundamental question on their mind is “what are the risks”? Meaning, what are the chances of not being able to recoup the money from the investment, what could possibly enhance these chances? Well, in the business of mining and related project developments, the general areas of risks can be divided into four:

- Bank risk
- Country risk
- Company risk; and
- Project risk

For the purposes of this section, which seeks to inform the reader why out of so many subject matters that could have been discussed under the general topic of mining, was dilution (impact of waste mining on the economics of a stope panel on a platinum mine) chosen, only the last bullet point is discussed.

2.3.1 Project risks

The technical risks of a mining project under consideration by a banker form the primary risk inherent in lending money to the mining project. These risks are made up of geological risks, mining risks, metallurgical or processing risks, market risks and environmental risks. These risks are reflected in ‘The modifying factors’ part of the most significant diagram contained in the

SAMREC code, shown in Figure 2.3. Only two of these risks are discussed, namely: mining risks and geological risks.

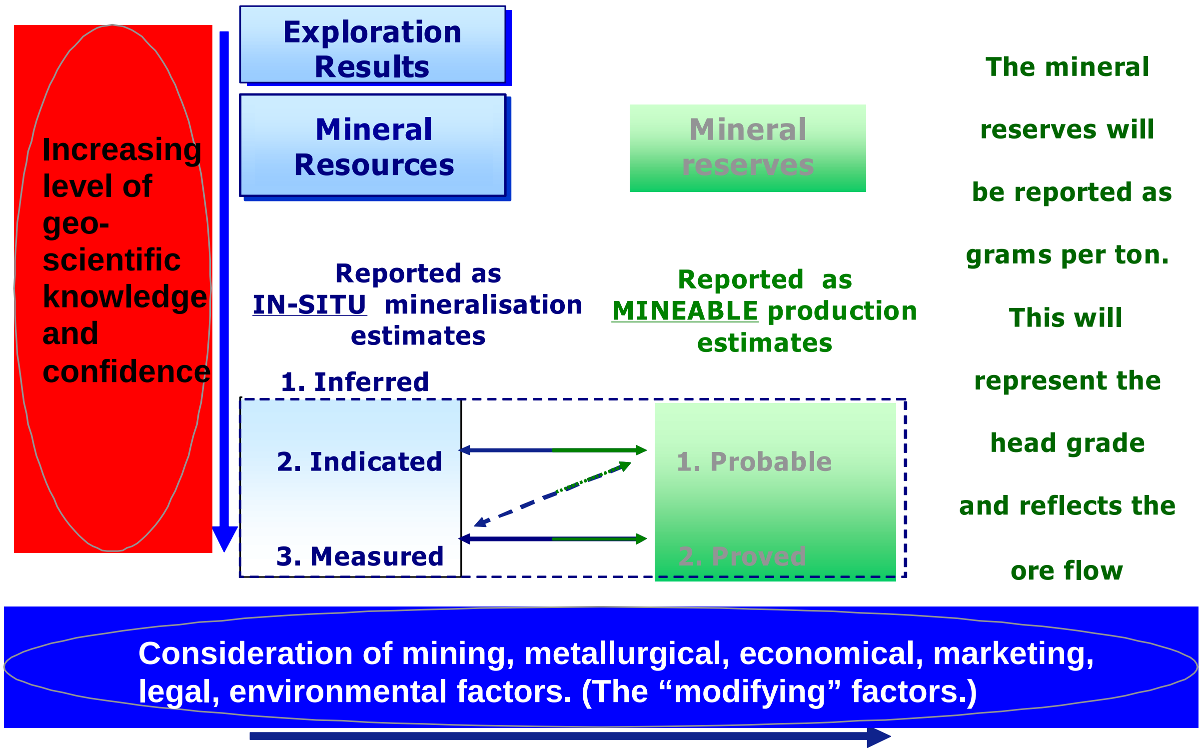


Figure 2.3 The relationship between resources and reserves (SAMREC code, 2000)

2.3.2 Mining risks

Underground mining has far more risks than surface mining, unless if one is in the DRC or Angola, but then again, that would have been discussed under Country Risk, which is deliberately not in the scope of this discussion.

Dilution is the most important factor to consider here. According to Guarnera (1997) it is not uncommon for dilution to be underestimated by as much as fifty percent during planning. It is by now a well known fact that dilution results in the lowering of grade and an increase in the tonnage that has to be handled, processed and crushed, thus increasing costs whilst decreasing unit values at the same time. Another significant downside to underestimating dilution is the resultant inaccurate life-of-mine plan, which specifies the tonnages to be mined over a given period and the grade of material that will be produced over the same period, thus destroying value and some CEOs' reputations as well.

2.3.3 Geological risks

"Geological risk can be summed up in one word: RESERVES" (Guarnera, 1997). Underestimating dilution would be one way of causing a mining project to fail as a result of the reserves turning out not to be what they had originally been estimated to be by a mining company. The basic principle underlying this is that of cut-off grade, which is effectively the grade utilised to determine if a block of material has economic value to actually be considered economically viable.

Any particular block of material would at the very least have to pay for itself, i.e. offset all the mining, milling, processing, transportation, marketing, general overhead expenses, royalties and taxes incurred in extracting it. This lends itself to the SAMREC code definition of reserves as shown in Figure 2.3. In the platinum industry, the term used for this is pay limit.

The greatest risk to mining in the Bushveld Complex, geologically, is posed by the existence of potholes, which obliterate the continuity of mineralised horizons for up to hundreds of metres at times (Figure 2.4). It becomes quite important as a result, that every ore reserve block has a representative number of cross sections demonstrating the continuity of the mineralization between sample points (Figure 2.5). These cross sections can be drawn up by computer but should be verified by the responsible geologist as being representative of the area of the orebody in which the reserve block exists.

It is not within the scope of this paper to define what a pothole is or to discuss the theories behind pothole creation, for this the reader is referred to Boudreau (1992), Campbell (1986) and Viljoen et al (1986). The schematic shown in Figure 2.5 shows a cross section through a regional pothole on the Merensky horizon, demonstrating the importance of drawing cross sections to understand the continuity of a mineralised horizon. The one thing that is a fact about extracting the different reef types shown is that there will be some unavoidable external dilution mined with the reef. The only question that’s important to answer is just how much contamination can a stope panel mining in one of the reef types tolerate before it destroys value?

Figure 2.4 A plan view of a pothole intersection on the Merensky horizon (Novy 2006: 8)

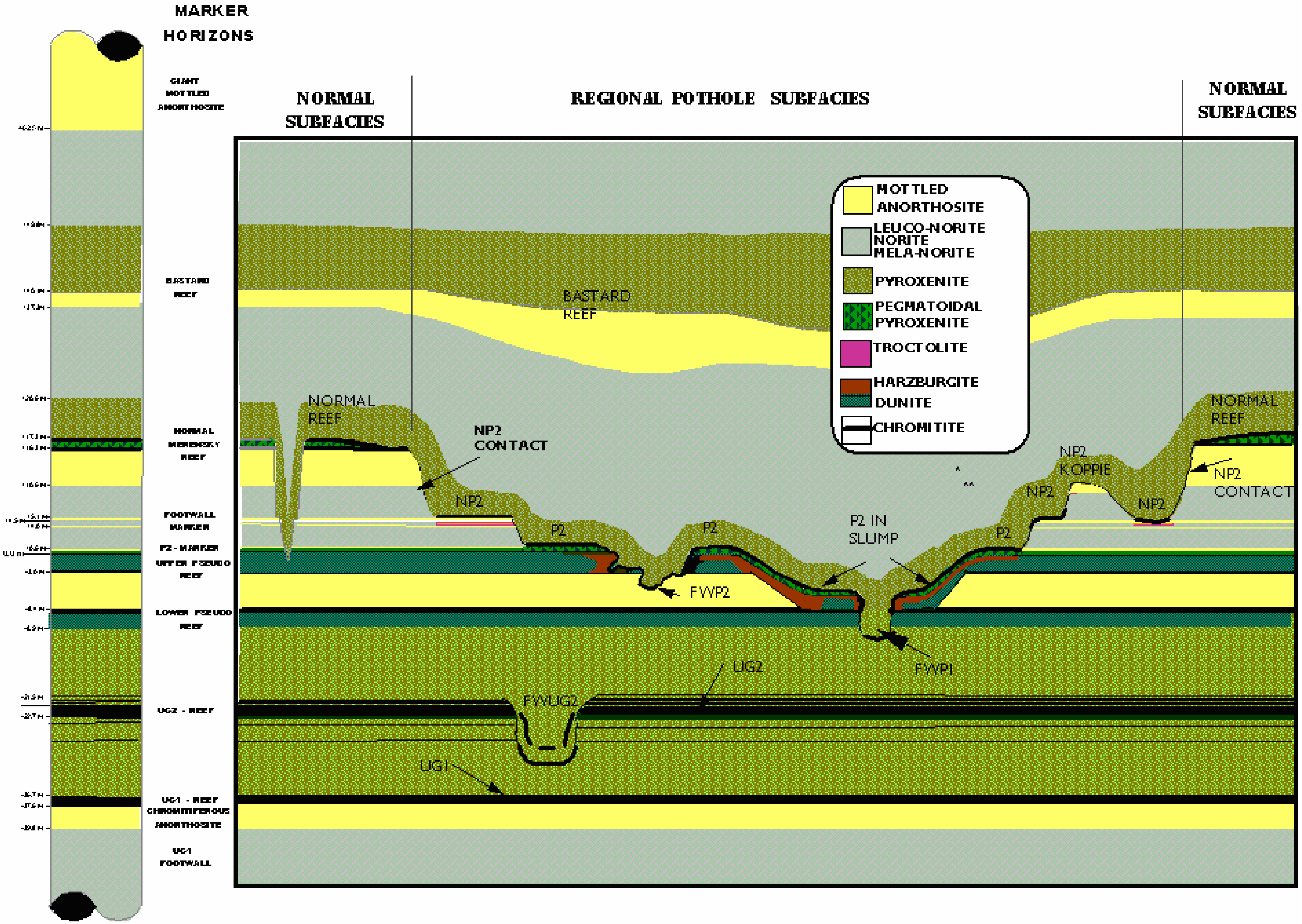


Figure 2.5 A cross section view of a regional MR pothole (Novy 2006: 2)

2.4 Specific aims

This research specifically aims at scientifically proving that stope panel number two shown in Figure 2.2 should have been stopped before two thirds of its facelength or more was mined off-reef. Similar off-reef situations will be simulated using a simple spreadsheet technique and presented in a format that can be used by mining and service personnel to stop an off-reef panel at an optimum point balancing tonnages with revenue and cost by benchmarking against the overall pay limit of the operation.

The research will also put forth alternative ways of treating an off-reef situation in a panel due to a pothole situation by analysing different pothole intersection scenarios in a particular panel. The research will also show how paying more attention to quality rather than quantity can help maintain an ore resource company's market value and uphold its integrity in the market place by using a practical example.

3 REVIEW OF CURRENT PRACTICES

3.1 Contamination and dilution: two different meanings

According to Makgatlha (2005) contamination is the unplanned extraneous waste material mined in addition to the planned mining horizon and differs from dilution in that the latter comprises planned waste material which is included as part of the mining horizon due to constraints imposed by operational requirements, which may include geotechnical considerations. The Upper Group two (UG2) horizon as an example, has a chrome parting that is on average fifty centimetres above the Main Seam, which leads to an additional amount of waste material having to be mined with the Main Chromitite Seam for safety reasons. This does get accounted for as a “modifying factor” in the conversion from mineral resources to mineral reserves and is termed dilution.

Since the Main Seam is itself bottom loaded, a small portion of footwall waste is mined to make sure that no grade is left underground. This waste constitutes dilution, which is planned within the mining ‘best cut’. Any over-breaking that happens in either the hangingwall or the footwall or both, beyond the planned dilution, leads to the unplanned extraneous waste, which is contamination, being mined with the targeted mineralised horizon. As Makgatlha (2005) asserts, both contamination and dilution may have the same source material, but are significantly different and contamination is within this context, a controllable phenomenon. In the platinum mining industry, the term dilution has substituted contamination, leaving the industry in the most hardened paradigm state where contamination is acceptable. It is uncommon to hear a Mine Technical Services manager say "but we have already accounted for it in the modifying factors" when this is not the truth. The following section looks at how this happens.

3.2 Differentiating between face width and stope width

In a conventional mining operation, a stope face is the smallest mining unit of the operation, forming the core business of the operation where the actual process of orebody extraction takes place. Measuring the width of a stoping excavation at the stope face yields the stope's Face Width, which is always less than the total width of the excavation as measured at a certain distance from the face (usually two metres). This distance is generally inclusive of the average face advance of the stope panel from the previous blast. Measuring the stope excavation's width at this distance yields the stope's stope width.

This is the total width of the excavation made during a stoping operation which represents the complete mining cycle of blasting, cleaning and scraping of the ore from the stope. Face width is only inclusive of the first two stages of the mining cycle and excludes the scraping stage. The general shape of this excavation is shown in Figure 3.1. The main difference between the two is the inevitable footwall over-breaking caused mainly by scrapers during ore tramming, effectively leading to secondary contamination. Primary contamination happens on the stope face itself, where unplanned hangingwall or footwall or both is/are mined with the mineralised horizon (reef).

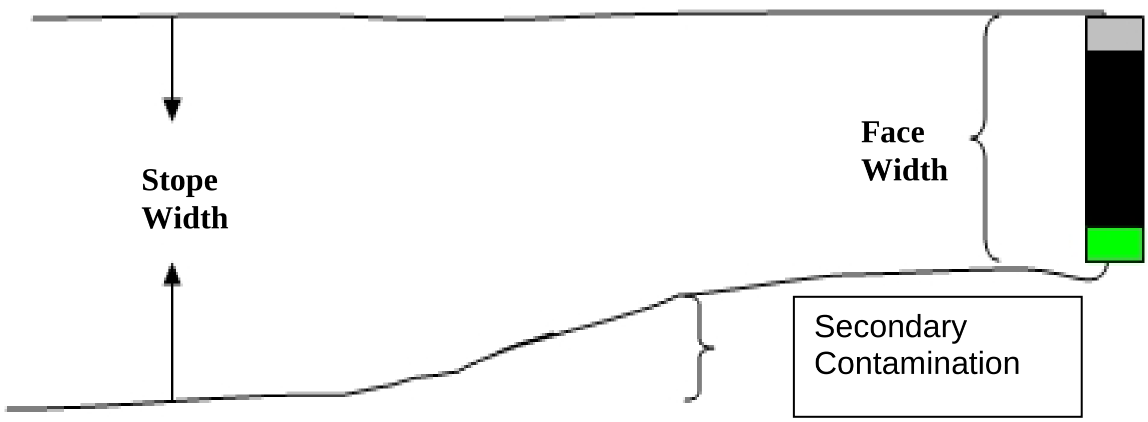


Figure 3.1 The difference between stope width and face width

3.2.1 Contamination defined

In the diagram above, a stope panel's mining cut is shown at the stope face. Black represents the UG2, whereas grey represents the hangingwall and green represents the footwall. A reconciliation of these units' widths with their respective planned widths may show an increased amount of waste as opposed to what was planned for. This waste is referred to as Primary Contamination as it was incurred in the initial advance of the panel and is mostly caused by human behaviour, like drilling ill-discipline. Machine Operator awareness and correct attitude is critical to reducing and avoiding this type of contamination, with a balance between quantity and quality of tonnage produced kept in mind.

The footwall over-breaking caused by the scraping operations as shown in the figure is referred to as secondary contamination. Any rock further broken from the hangingwall or footwall, e.g. roof collapses (fog) is called tertiary contamination. Primary contamination is measured at least once a week per stope panel where possible as a control measure and a management tool. It forms the backbone of stope width measurement by stope width observers. Secondary contamination is usually not measured even though possible.

For a panel with 1m advance, measuring the excavation width some 1,5m from the face is all that's required to measure this contamination. Tertiary contamination is on the other hand very difficult to monitor and is most of the time not even accounted for in the tonnage reconciliation calculations. The ultimate goal in as far as contamination is concerned is that the mining of the economic horizon as cleanly as practically possible becomes the standard operating procedure. Contamination control should therefore not only be seen as a best practise issue but as a business imperative.

3.2.2 Impact on business

The metal accounting that happens currently, aided by software packages, only accounts for the primary contamination and not the more destructive, secondary contamination. In the author's own experience, footwall over-breaking due to tramming operations is usually not less than twenty percent of the face width on average. It is not in the scope of this research to quantify this contamination and as such the study is limited to the impact of the primary contamination, i.e. at the stope face. This points out to the much wide loophole that exists in metal accounting at present because from the stope blasting process, the ore that gets sent into the shaft's orepass system and ultimately to the metallurgical plant, actually comes from the "stope width" area in the figure above and not only from the stope face.

The impact is thus on two important areas of tonnage (varied density and width) and grade. Using the true stope width yields higher tonnages and lesser grade for a particular panel. Using face width, shows better grades but not necessarily lower tonnages as the tonnage gets adjusted for in the ore flow statement by using some survey factors or the density might be higher at the stope face than it is at stope width. This means that it might forever be difficult to reconcile grade as reported from the stope face with the go-belt grade. What this means is if a panel has a planned stoping width of 90cm, it's face width ought to be planned at seventy centimetres in order to accommodate the footwall later ripped out by the scrapers, which is not currently done.

3.3 Current evaluation process

Currently on a platinum mine, an ore reserve block gets sampled at a certain sampling interval in the raise line and in the Advanced Strike Gully such that grade values obtained from all the sampling around the block provide a representative average grade value for that ore reserve block (Figure 3.2) at an optimum mining width or best cut, which takes into cognisance the grade variation over the reef width (Figure 3.3). A value distribution histogram created for this ore reserve block is then assigned (or linked) to all the working places established within the boundaries of this particular ore reserve block (Figure 3.4).

This process effectively removes the need for regular stope face sampling, with the only control on grade being provided by geological logs of the face by stope observers, to monitor the amount of over-breaking in the hangingwall or footwall, effectively contamination, as the stope panel advances. The histograms are compiled for every shaft on a regular three month basis to make sure that all the latest sampling is taken into consideration.

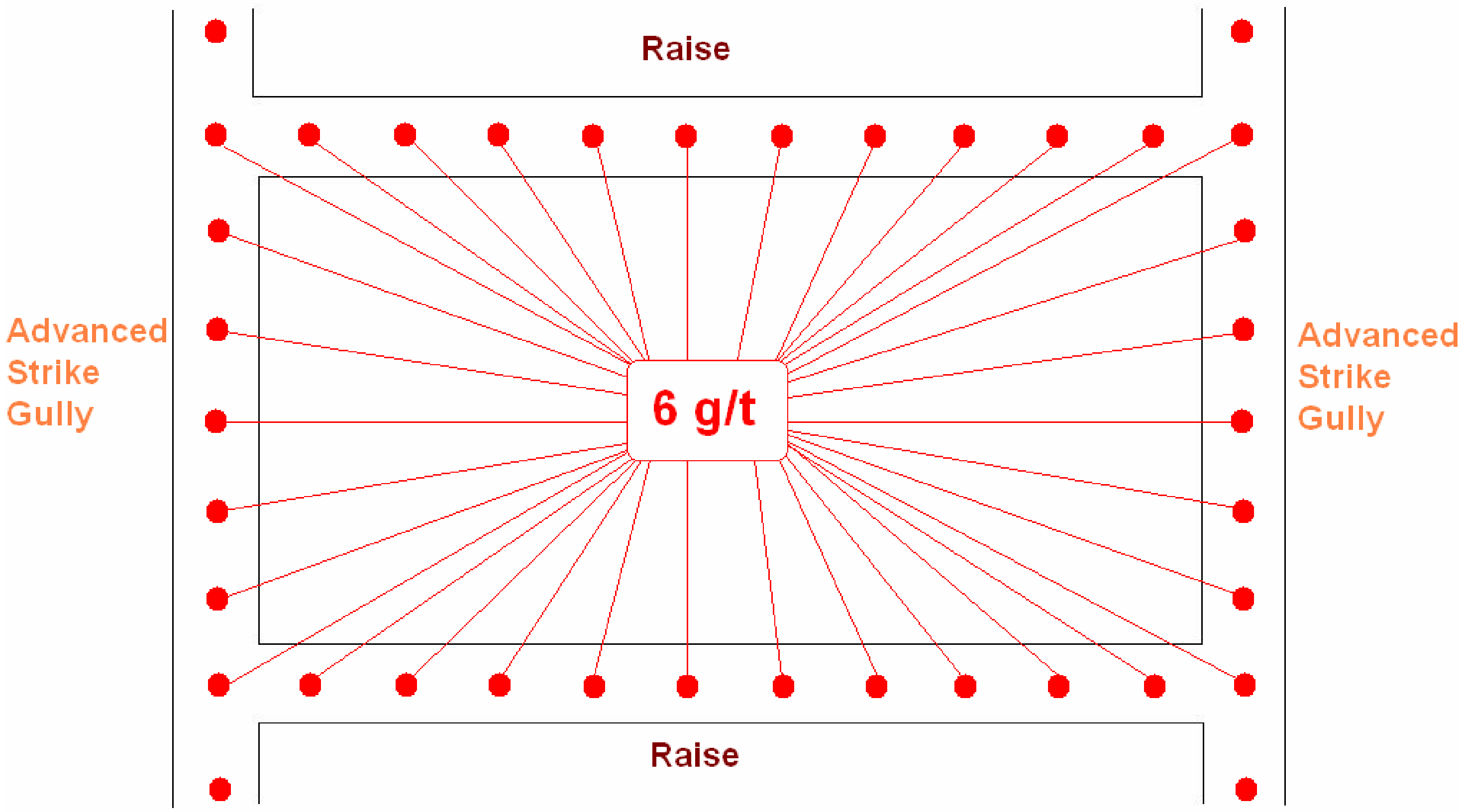


Figure 3.2 Valuation of an ore reserve block

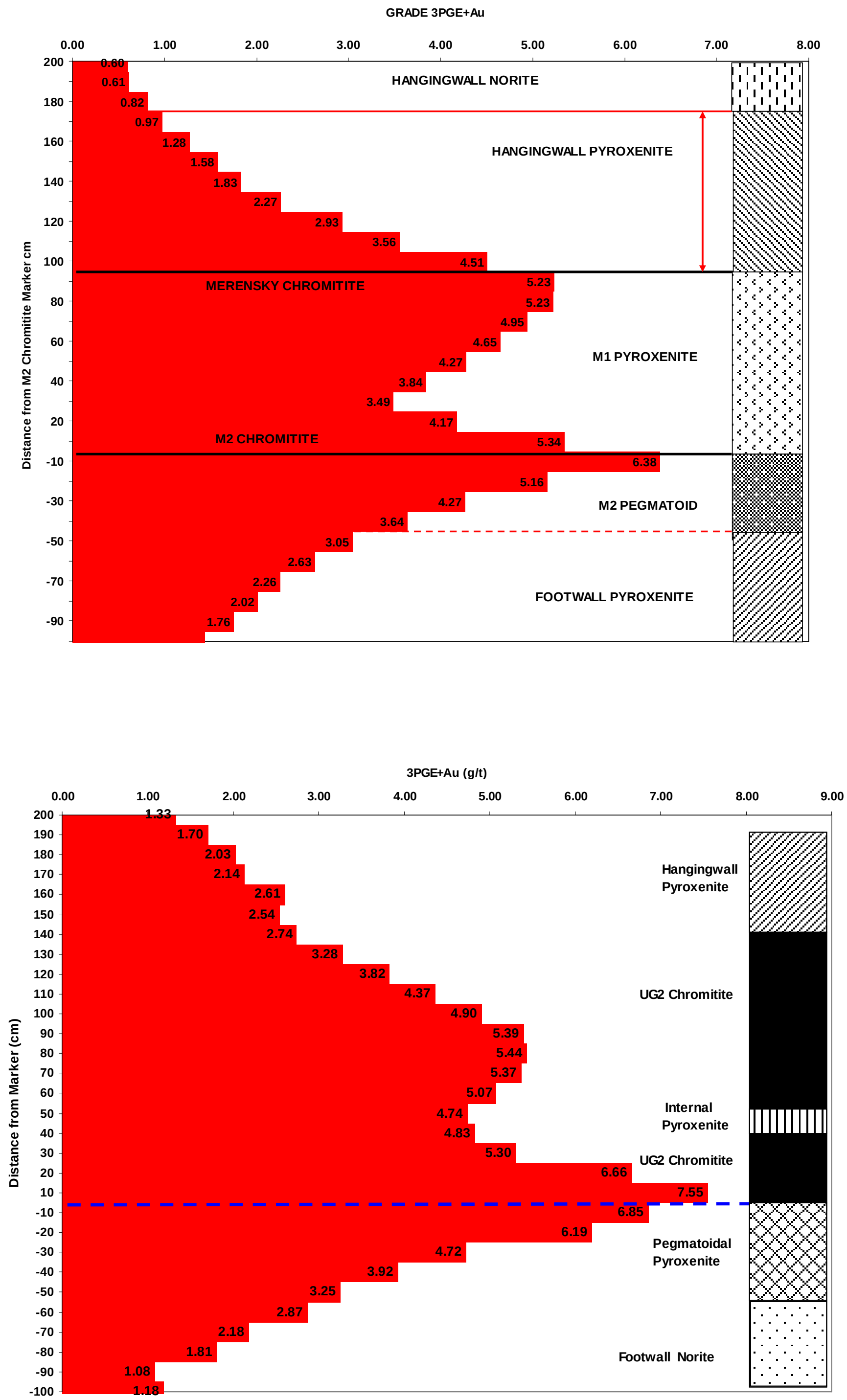


Figure 3.3 Grade variation in the MR (top) and the UG2 (bottom)

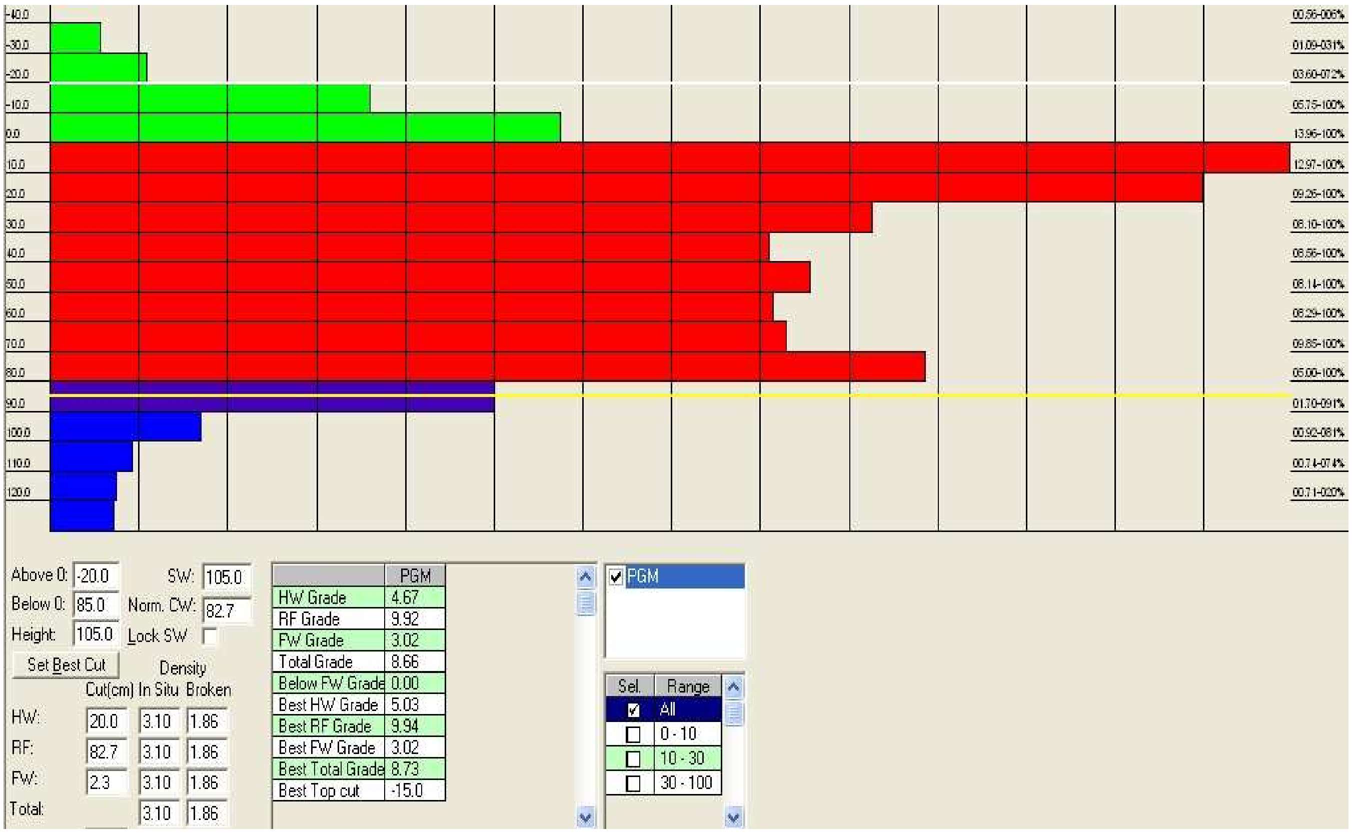


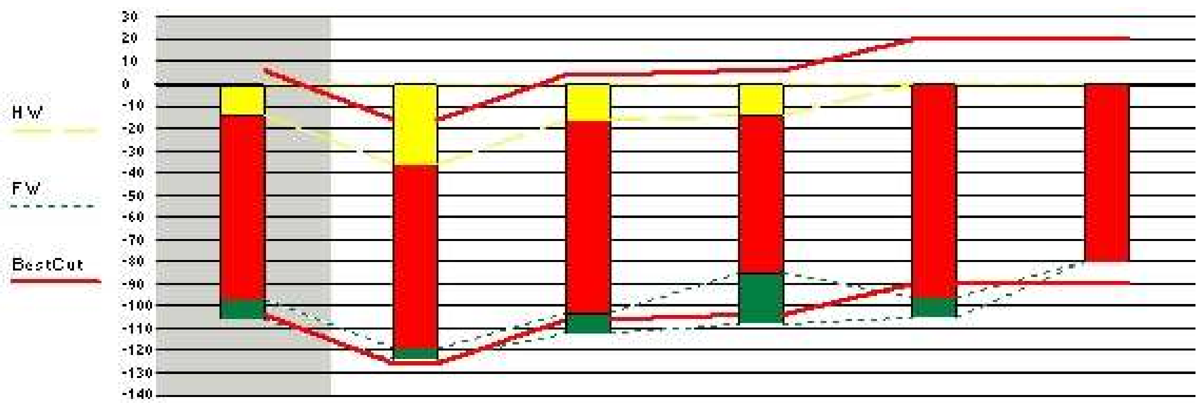
Figure 3.4 A value distribution histogram for a particular ore reserve block

This is done using various off-the-shelf software packages available to the mining industry. Grade variations in any particular working panel established in this ore reserve block are then monitored on a regular bases with the amount of additional waste mined as the controlling factor, meaning, the more waste mined than originally planned for, the more the contamination and hence loss of grade and vice versa.

This is effectively made possible by stope width analysis. Stope width observers employed in the mine technical services department go out to take daily face width measurements, the results of which are captured in the Stope Width Analysis Report (SWAR) module, which then calculates an average grade based on the histogram to which the working area is linked. The face profiles are measured at six metre intervals to check for footwall and hangingwall over-break as well as off-reef situations.

These sheets are then compiled by the evaluation officer for all the working areas visited by the stope width observers the previous day, who then passes them on to the geologist for comments before being sent to the relevant mining personnel for execution. The comments are often along the lines of ‘reduce footwall waste’ or ‘strip against the pothole’ etc. Very little economical data is reflected on the sheet if any at all, which is really the core of the service rendered to the mining personnel.

The actual grade reflected on the sheet is often not correct, detracting further from the quality of the service rendered to a miner. This shouldn’t however, detract from stoping width as one of the key value drivers on an underground platinum stope panel. The process is in itself not a pro-active process but rather re-active as it basically accounts for what happened on the previous round of blasting. In most cases, by the time the report gets to the miner, who ought to implement recommendations from the technical services department based on the day's findings about what happened yesterday, a second round has already been blasted. So, in the case of a pothole intersection, a prior knowledge of how to handle the situation would come in handy to the miner and the overall business.



	1/10/2006	3 (Top)	9	15	21	27 (Bot.)
Planned HW	20	20	20	20	20	20
Planned CH	85	85	85	85	85	85
Planned FW	5	5	5	5	5	5
Planned SW	110	110	110	110	110	110
Planned g/t	8.72	8.72	8.72	8.72	8.72	8.72
Actual HW	13	36	16	14	0	0
Actual CH	83	83	87	71	96	80
Actual FW	9	5	9	23	9	0
Internal W.	0	0	0	0	0	0
SW (Incl OffR.)	106	124	112	108	105	80
-3m Stope W	0	0	0	0	0	0
Actual g/t	8.74	7.83	8.67	8.86	8.70	10.16
% Dilution	0.2	-10.2	-0.6	1.6	-0.2	16.5
RIH / %	40.0	☐	☐	☐	☑	☑
RIF / %	20.0	☐	☐	☐	☐	☑
Off Reef / %	0.0	☐	☐	☐	☐	☐

Figure 3.5 A Stope Width Analysis Report (SWAR) for a working area

4 MINING ECONOMICS AND THE PAY LIMIT

4.1 Mining economics

Mining economics specify the manner in which a mineral deposit should be consumed to maximise the on-going value as well as the long-term economic value of an mining operation. Tonnes (t) in a mining operation is used as a unit of ore reserves and mineral resources and ounces (oz) as a unit of the recoverable revenue-generating metal product, which for a platinum mine is PGM's. Since mine operators or owners cannot spend tonnes or ounces, the real value of an operation lies in the stream of free cash that it can generate.

So, if it was at all possible, operators would seek to spend less on mining just the mineralised portions of an orebody and leaving the waste behind, thus generating more revenues at low costs and hence higher profit margins. However, as rightly pointed out by Hall (2005), increases in reported tonnes are `usually seen as good and any reduction as bad. It is only in an ideal world, however, where all the tonnes reported as reserves would all add value because in the real world of mining as it has come to be known today, reserves tonnages for many operations contain value-destroying ounces.

In the former case, the “more is better and less is worse” slogan would hold true whereas in the latter, the “more is worse and less is better” slogan holds true. This could lead to a shift supervisor blasting an off-reef panel at the originally planned face length when they could abandon it or at the very least reduce the face length mined and report to a geologist to investigate. For this not to happen, the actions taken underground by the same person would need to be aligned to a clearly defined corporate goal.

This official would then need to understand everything about the overall pay limit applicable to the operation, how it affects his working area and the impact of potholes and off-reef situations on it. If it is indeed the company’s corporate goal to use a break even pay limit then the miner should know that every tonne he/she mines ought to cover its cost and they should as such know the maximum amount of off-reef face length they can allow their panel to mine.

The research work contained in this report seeks to address exactly that. This is more so as a lot of mining companies have in the recent times been putting much emphasis on efficiency, productivity, and cost saving and in the process being seen as “doing things right”. In the case of dilutions and off-reef mining, particularly in areas affected by potholes, it is important to “do the right thing” first. The guiding principle here should be “leave waste underground, where it belongs” because not only is it an economic challenge but an environmental challenge too (Makgatlha 2005).

The ultimate aim would be for the operation to “do the right things right” and if the overall strategy is not right, no amount of efficiency in executing a suboptimal plan can maximise value Hall (2005).

4.2 Mining strategy

One of the most important features of a mineral resource is the variability and distribution of the valuable minerals within its confines such that the whole mining process is then basically the business of managing 1) the way and sequence in which the deposit is exploited and 2) the progressive separation of its valuable content.

4.2.1 Mine planning

There are two types of mine plans that are used to deal with the processes discussed above: 1) Strategic mine planning, which deals with the controllable factors that largely determine the value of the mineral resource and 2) Tactical mine planning, which deals with the operational tasks to actually achieve the value dealt with in strategic planning (Camus, 2002). According to Horsley (2002) strategic planning is not only about understanding, monitoring, anticipating and planning for change but also determining the key triggers that would require changes in business or annual plan to be implemented. The planning processes progress simultaneously such that whilst the mining strategy is being set up, the tactical planning transforms it into specific production targets whose realisation creates the feedback to update the strategic plan.

Thus geological reconnaissance of the mineral resource becomes quite a crucial on-going task that needs to be performed with absolute dedication. The fact that these variables get managed in a dynamic environment is a pointer to the fact that strategic mine planning is an ongoing process and as such should be kept alive throughout the life of a mineral deposit. The product is a life-of-mine plan (LOM) that indicates the origin and destination of tonnage and grades to be mined from the deposit.

4.2.2 Technical variables

Five technical variables that have to be dealt with when mining, which affect the life of mine (LOM) and hence the economics of the business are:

1. The mining method
2. The processing method
3. Production rate (rate of extraction)

3a. Replacement factors

4. Mine sequence (schedule)
5. Selective cut-offs (pay-limit)

4.3 Economic value add

Mineral Resource Management (MRM) is an integrated activity, which identifies, evaluates and provides an optimal extraction plan of the mineral resource, which satisfies the business objectives in a dynamic environment. It performs an audit function to ensure compliance to the contracted Business Plan in terms of quality and quantity (MacFarlane 2004). The intended outcome of this research project should thus, in light of the above be only seen through the Economic Value Add (EVA) principle filters as the application of a pay limit on a platinum mine stope panel and the strictest adherence thereto lends itself to the maximisation of shareholder value.

Leaving waste underground where it belongs has a direct impact on the triple bottom line. Costs will be saved, production efficiencies will increase and the less waste the environment has to handle the lesser the negative impact on the environment becomes. Indeed leaving waste where it belongs can lead to the business earning more profit without employing more capital, increasing asset utilisation and seizing real marginal opportunities. Since the pay limit is so key to panel optimisation, it warrants a closer look.

4.4 The pay limit

4.4.1 Introduction

This chapter will briefly discuss the existing pay-limit calculation as currently used by most platinum-mining companies. It is not within the scope of this paper to discuss the determination of cut-off grades as used in the platinum industry or to critique the process. For further reading on the subject the reader is directed to other literature referenced in this paper, like Wood (1997).

What is important to note however, is that the platinum industry is currently using the approach of Storrar (1980) for its pay limit calculation. The Operational pay limit is determined annually at the beginning of every Long Term Planning cycle and the Marginal or Incremental pay limit is determined and subsequently used for purposes of planning to mine in pillar areas, the so-called 'white areas' as the need arises.

4.4.2 Pay limit definitions

Hall (2005) notes that for any given mineral deposit in a given social and economic environment with an existing infrastructure, the major parameters that a mining company can make independent decisions about are typically the mining method(s), production rate and cut-off grade. He further notes that the reason cut-off grade is often the key driver of value of the operation is because possible mining methods and production rates may vary significantly with cut-off grade.

In a practical research as the one carried out in this project report, it is always useful to find out what the general understanding of the relevant mining personnel is of the subject at hand. A chief surveyor at whom the question of what the stoping pay limit actually means in practical terms described it as "... a grade below which the mining of a (stope) panel becomes (economically) useless". (personal conversation, 22 Feb. 06). The following definitions, relevant to this study, were first referenced by Wood (1997):

Nilsson (1982) defines pay limit as "... the assay grade below which an orebody or part of an orebody cannot be profitably exploited".

Storrar (1980) defines a pay limit as "... the minimum value at which (an ore) can be mined and treated without profit or loss i.e. when revenue obtained from the specific mineral product balances expenditure incurred in mining and treating the ore, and possibly, also transporting the product to the delivery point".

Lane (1988) describes a Cut-off grade as "... the boundary that distinguishes which material within a mineralised body is to be extracted and treated from the remainder...which is, in effect the economic definition of ore".

According to Hall (2005), most operations tend to be working with a cut-off definition described in 1950 by Mortimer, which can be summarised as:

1. The average grade of rock must provide a certain minimum profit per tonne milled
2. The lowest grade of rock must pay for itself

As noted by Hall (2005), the platinum industry's and indeed Storrar's pay limit calculation ignores the first leg of Mortimer's definition, although its absence is often lamented when profitability is low. Much of the industry is therefore working with cut-offs that, at best, have been derived using half of a 1950's definition (Hall 2005).

4.4.3 The pay limit procedure

The operational pay limit is determined for every shaft at the beginning of the long term planning cycle in the first quarter of every year. This is locally known as the stoping pay limit but more precisely as the overall pay limit, which includes off-mine costs. This pay limit will always be higher than the incremental pay limit as primary development costs, as an example, fall off the pay limit calculation equation. It is thus quite important to make sure that areas classified as 'white area' are not included in the overall pay limit calculation. White areas have not been considered in the research covered by this report.

The calculation itself leaves flexibility for different shafts mining the same orebody to have a stoping pay limit unique to their operational circumstances due to the internal parameters used in these calculations being obtained from individual mine-based functional departments. As an example, if shaft A manages to keep its on-mine costs under control or even lower them, it will experience a lower stoping pay limit than other shafts in its vicinity.

4.4.4 Pay limit calculation method

Table 4.1 shows the current overall pay limit calculation on a platinum mine. The calculation is performed in an excel spreadsheet, wherein a user, like the chief surveyor or one of the planning department's personnel is required to provide the necessary input parametres. The relative revenue contributions of the refined base metals (Ni, Cu, Co) get added to the revenues obtained from the refined PGM's (Pt, Pd, Rh and Au) to determine the net revenue per kilogram of total PGM's sold (the basket price). The refined metal grade required to cover the costs incurred in obtaining the saleable metal (mill grade) is determined next.

The necessary process efficiencies, grade dilution factors and the mine call factor (MCF) adjustments are applied next to determine the respective insitu grade required from a panel to yield the mill grade. This grade is the stoping pay limit, which effectively refers to that grade below which, an operational stope panel should not be mined if value is to be added to that particular mining operation.

Table 4.1 An example of a pay limit calculation for a UG2 operation, 2006

OVERALL PAYLIMIT (INCLUDING OFF-MINE COSTS)					
Revenue from Precious Metals Sales					
Metals	Metal	Recovery	Recovered	Price	Revenue
	Ratio %	%	Eq. oz.	$/oz	(Rand)
Pt	55.00	84.18	45.988	800.00	251399.84
Pd	34.00	78.90	26.826	176.00	32262.58
Rh	11.00	76.50	8.063	1200.00	66116.28
Au	0.80	65.00	0.540	377.00	1391.12
Ir	0.00	0.00	0.000	0.00	0.00
Ru	0.00	0.00	0.000	0.00	0.00
Os	0.00	0.00	0.000	0.00	0.00
TOTAL	100.80		81.417		351169.82
Revenue from Base Metals Sales					
	Eq. lb	Recovery	Recovered	Price	Revenue
		%	lb	$/lb	(Rand)
Ni	2887.218	18.13	523.453	3.83	13699.57
Cu	288.722	68.21	196.937	0.92	1237.31
Co	0	2.5	0	8.22	0.00
TOTAL					14936.88
Head Grade					
Total Revenue		- Metal Sales			366106.70
		- Basket Price / Pt oz			7960.92
		- Basket Price / gram Pt			255.95
Commission		- % of Total Revenue			29288.54
Refining and smelting		- Rate per dry ton conc. Delivd			8079.79
Total off mine costs					37368.33
Moisture penalty		- Rate per dry ton conc. Delivd			584.97
Chrome penalty		- Rate per dry ton conc. Delivd			441.58
Total penalties					1026.55
Revenue distributed to mine					327711.82
Revenue per Pt ounce					7126.03
Revenue per gram PGM					105.36
On mine costs (R/ton milled)					351.00
Grade required to cover cost - (g/t) - Required mill grade					**3.33**
Pay limit					
SOURCE			Tons	Val. (g/t)	Contents
Milled			1092635	**3.33**	3638475
MCF		95			181924
Tons to mill			1092635	**3.50**	3820399
Reclamation			0		0
Development to mill			149627	3.30	493769.1
From Stoping			943008	3.53	3326629.9
Waste from stopes			137526	0.00	0
Broken on stope face			**805482**	**4.13**	**3326629.9**

4.5 Summary

Mining is a business purely aimed at separating the valuable content of a mineral deposit from the non-valuable portion in the most effective and efficient way. Real value is as suggested however by Lane (1988), only realised when revenues obtained from selling the product exceed all the costs incurred in extracting and beneficiating the mineral. Failure to give attention to the unique economic principles that govern the exploitation of mineral resources and their implications in the management of mines stands out, according to Camus (2002) as the crucial component out of various other causes that lead to dismal performances of mining operations.

A convenient tool developed to assist decision-makers in the minerals industry in this regard is the cut-off grade, or as referred to in the platinum industry, the pay-limit. In the context of Lane's definition, the pay-limit is the breakeven point where the costs incurred in separating the valuables from the non-valuables are at the very least, covered by the revenues obtained from selling the valuable content. Since the overall pay limit is the lowest value at which a specified mining unit (stope panel) may be mined at break even, it should always be used in pothole situations to determine how much off-reef that mining unit should ever be allowed to mine before it starts to destroy value for the operation.

5 MANAGING A POTHOLE INTERSECTION

Figure 5.1 shows a sectional view of a pothole intersection as mapped underground by the author on the UG2 horizon. There are several alternatives to addressing a pothole situation from a geological point of view. As mentioned earlier, corporate goals may dictate that no pothole intersections will be mined through, whereas others may have a maximum amount of off-reef which may be carried and these are sometimes based on some blanket rule of thumb pre-determined by some distant past.

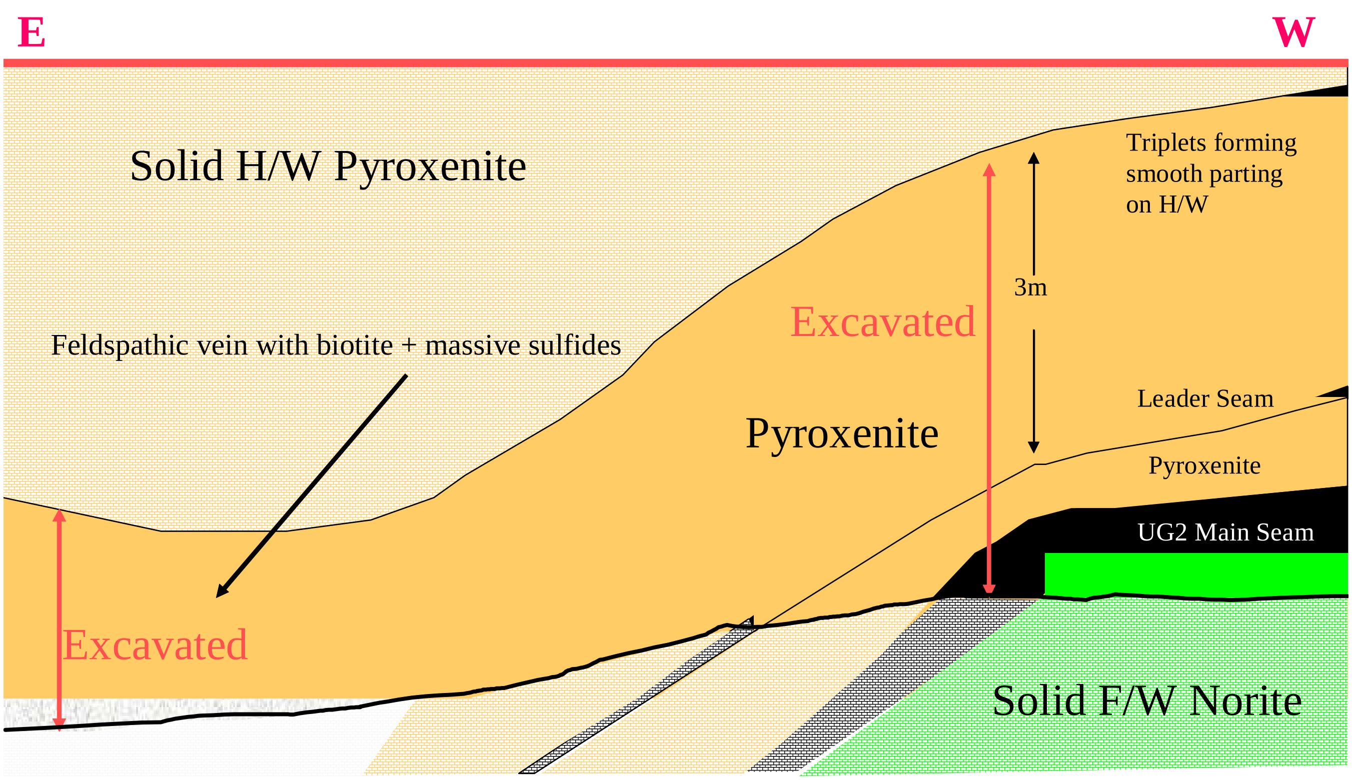


Figure 5.1 A cross-section view through a pothole on the UG2 horizon (Tlhapi 2003)

I have worked on a mine where the rule of thumb was “two thirds of a panel” can be mined off-reef, a rule which in fact led to the conceptualization of this research project and stands to be tested by the research reported upon in this report. It would seem apparent however, that to know how much off-reef a stope panel should mine before it becomes economically unviable one would have to understand that particular panel’s economics. Of particular influence on the panel’s economics would be the estimated morphology of the pothole, its position in the panel, the amount of FW and HW over break already existent in the panel, geotechnical considerations and best mining practice.

Figures 5.2 & 5.3 show various pothole intersection scenarios in a 30m panel that are commonly encountered on an underground platinum mine. Below is a discussion on the amelioration strategies that can be applied to such situations.

5.1 Pothole occurrence on the up dip side of the panel

Panel one in Figure 5.2 has intersected the big pothole on its up dip side. In this case, the panel length could be reduced and the panel stripped against the pothole edge by always making sure that at most one metre of the panel face length is carried in the pothole to make sure that its edge is effectively traced out. The panel could then mine to the point that the face length does not allow for optimal recovery of the ore reserve.

5.1.1 Advantages

In this way the panel is mined around the down dip edge of the pothole and then gradually fanned out on the other side to normal panel length (pothole size allowing), avoiding all the unnecessary waste.

5.1.2 Disadvantages

The shortcomings in this method are amongst others, the creation of a backstope with no second escape, restricted ventilation and the difficulty in restricting the pothole portion to exactly one metre.

5.2 Pothole occurrence in the middle of the panel (fanning past it)

This is a difficult challenge in that in as much as the omission of waste is of priority, so is the optimum extraction of the good ore. The area hatched in red in Figure 6 signifies the amount of ore that cannot be mined and is thus ‘lost’ to the pothole as discussed in the ‘disadvantages’ section below.

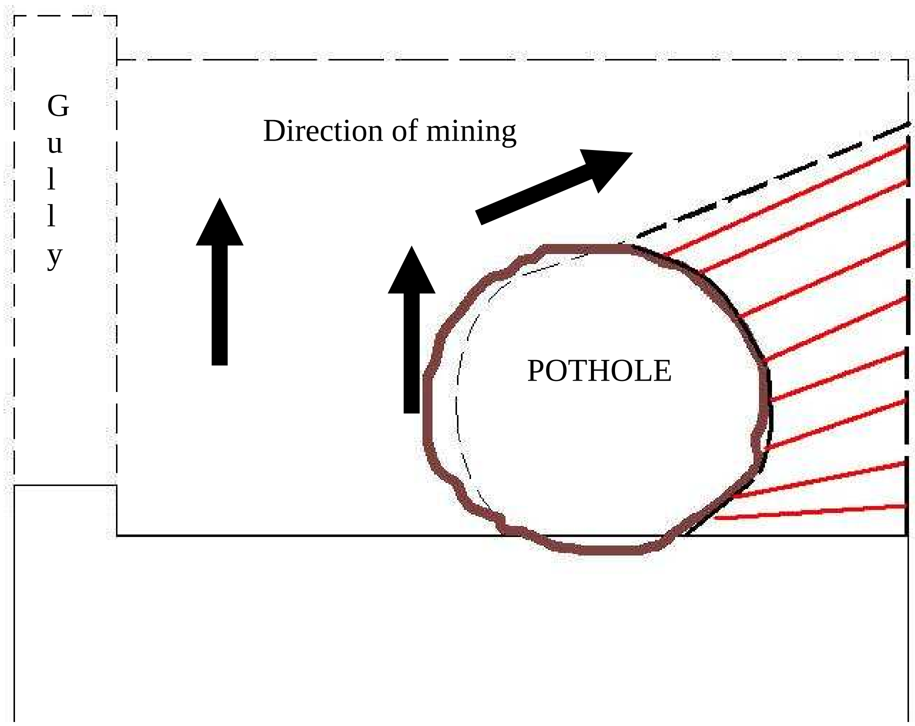


Figure 5.2 Mining around a pothole occurring in the middle of a stope (derived from Brown and Theron: 14)

5.2.1 Advantages

Depending on the proximity of the down dip edge to the gully, the panel could be fanned around the pothole and the full panel length re-established on the other side of it.

5.2.2 Disadvantages

The shortcomings include: the creation of a backstope without a second escape, ventilation is restricted even more than in the previous example and good ore from the up dip side of the panel will be lost. This loss of ground will lead to unwarranted “white areas”.

5.3 Pothole occurrence in the middle of the panel (re-establishing)

In the case where the pothole intersected in the middle of the panel is larger than in the case presented above, re-raising past it might be the only suitable alternative. Figure 5.3 depicts the same panel presented above with a bigger pothole intersected in the middle. The area hatched in red demonstrates quite clearly the bigger impact this pothole has on ore loss.

5.3.1 Advantages

If on-reef, the re-raise would extend to the original panel length planned whilst having avoided the off-reef situation completely by advancing the ASG past an estimated position of the re-raise first, before the actual re-raising. The panel can then be mined back towards the pothole and stop against it to maximize ore extraction. The ground ‘lost’ will act as a stabilizing regional pillar.

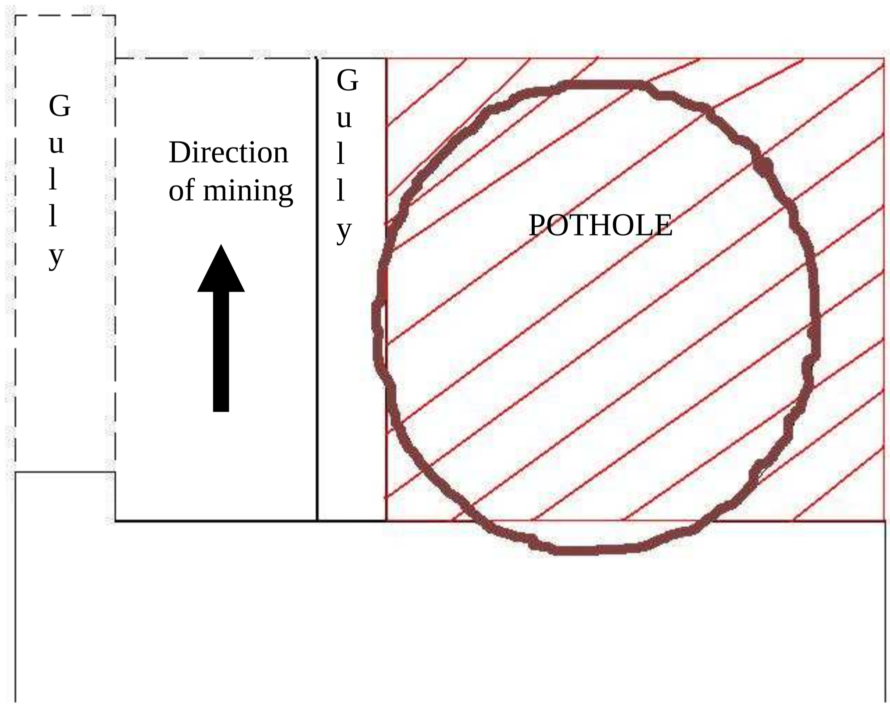


Figure 5.3 A bigger pothole intersected in the middle of a stope

5.3.2 Disadvantages

For cleaning purposes, the re-raise cannot be done at the same stope width as the panel itself, it would always involve some footwall lifting (i.e. excavated at normal raise dimensions). There is always risk that the re-raise can re-intersect the pothole should it happen that the pothole size was incorrectly estimated, which has a high likelihood of happening. There will be more ore lost to the pothole. Secondary development is necessary, which introduces more costs both in money terms and time delays. Ore reconciliation can be duly complicated.

5.4 Pothole occurrence on the down dip side of the panel

Figure 2.2 shows a large pothole occurring on the down dip side of a panel. As is evidenced in this diagram, what would seem quite a straightforward case where the panel would be stopped and the ASG mined through the pothole to a reasonable ‘back-on-reef’ position and then the panel re-established on the other side does not always happen that way. This may primarily be a result of “seeing more as good and less as bad” from a tonnage point of view. Assuming the “right thing” is done in this case, only the ASG would be advanced and a reef position established past the pothole.

5.4.1 Advantages

Improved waste management could result in that the waste from the ASG over the period in which it mined off-reef can be trammed as waste. It would be quicker to mine through and re-establish reef position.

5.4.2 Disadvantages

A lot of good ore would be lost on the up dip side of the panel, creating a white area that may not be retrievable in future. What mostly happens is that the angle of reef elevation is lost inside the pothole, such that reef position is never re-established as soon as it is possible, delaying the restoration of the on-reef mining activity. This loss of elevation usually results in larger than allowed excavations that are a safety hazard as they require extra support re-considerations. Re-raising can be a disruptive, time consuming and expensive process (Brown and Theron, 2003). A ventilation column will need to be carried in the excavation to provide air at the face.

Although there might be a combination of various reasons that lead to a situation shown in Figure 2.2, the challenges discussed in the paragraphs above play a significant role as well. It is a combination of these factors that commonly lead to the responsible miner mining the whole planned face length with disregard to value destruction. The only way that would help avoid such a situation is when the miner is empowered with the knowledge of his panel economics. The miner would be more empowered if he/she knew what the more economical option to pursue was, such that they would know if it's more economical to stop mining, abandoning the panel or re-establishing and the timing thereof.

Potholes that pose a big problem, as per the discussions above, are those that occur in the middle and on the down dip side, including the ASG of a breast-mining panel. According to Brown and Theron (2003) the two options available in these scenarios are to either stop the panel, lose the on-reef up dip section of the panel and face the costs of re-raising or to mine through the pothole, enduring some off-reef whilst avoiding the costs of re-raising.

6 THE STUDY

6.1 Introduction

Reading the paper by Guarnera (1997) inspired the need to disprove the theory that two thirds of a panel could be mined off reef profitably. This ‘rule’ got highlighted just about the time that grade started getting the attention it needed from senior management in the platinum mining company that the author used to work for. The operation itself was making losses month after month whilst the rule of thumb was in operation. A note from the mine manager at the time indicating that the geologist should be called in to investigate only if two thirds of any particular stope panel’s face length was off-reef prompted the author to start investigating the legitimacy of the ‘rule’.

6.2 Methodology

6.2.1 Underground visits

After interviewing a few relevant people from the central main offices, including a chief geologist that had been with the company for many years, attempts to get hold of any documentation that might have supported the ‘two-thirds rule’ drew a blank.

Table 6.1 Results from underground mappings of a stope panel

	Planning					
Date	SW	Reef	HW	FW	Face Length	Grade
2 Nov '04	**85**	68	0	17	30	5.46
9 Nov '04	**85**	64	0	21	30	5.14
24 Nov '04	**85**	61	0	24	30	4.90
9 Dec '04	**85**	55	0	30	30	4.42
4 Jan '05	**85**	59	0	26	30	4.74
17 Jan '05	**85**	63	0	22	30	5.06
14 Jan '05	**85**	51	0	34	30	4.10
12 Jan '05	**85**	54	0	31	30	4.34

		Actual								Overbreak/Underbreak					
Workplace	Date	SW	Reef Width	HW width	FW width	Face Length (m)			Grade (g/t)	SW	Reef Width	HW width	FW width	Face length	Geological observation
						On- reef	Off-reef	Total							
Panel ABC	2 Nov '04	**89**	64	3	22	30	0	30	5.21	**4**	**-4**	**3**	**5**	**0**	On-reef
	9 Nov '04	**92**	61	6	25	30	0	30	4.75	**7**	**-3**	**6**	**4**	**0**	On-reef
	24 Nov '04	**87**	55	8	24	30	0	30	4.79	**2**	**-6**	**8**	**0**	**0**	hw overbreak
	9 Dec '04	**92**	59	11	22	24	0	24	3.68	**7**	**4**	**11**	**-8**	**-6**	hw overbreak
	4 Jan '05	**90**	63	20	7	18	6	24	3.36	**5**	**4**	**20**	**-19**	**-12**	pothole
	12 Jan '05	**96**	54	22	20	11.8	12.2	24	1.89	**11**	**0**	**22**	**-11**	**-18.2**	pothole
	14 Jan '05	**87**	69	9	9	12	18	30	1.60	**2**	**18**	**9**	**-25**	**-18**	pothole
	17 Jan '05	**88**	51	28	9	6	24	30	0.98	**3**	**-12**	**28**	**-13**	**-24**	pothole
	Average	**90**	**60**	**13**	**17**	**20**	**8**	**28**	**3.28**	**5**	**0**	**13**	**-8**	**-10**	

I then decided to undertake an investigation into this subject by collecting information from underground stope panels affected by potholes and checking their resulting economical stature. As can be seen from Table 6.1, panels' geological conditions were monitored over a certain period to monitor the impact of the associated geological conditions on its economics over the same period.

The best cut variables as determined from a histogram drawn up from the sampling information pertaining to this working place are listed at the top of the table. Analysing the results from this table led to the realisation that the results from the underground trips can actually be simulated quite easily for varying panel and pothole sizes, as well as differing degrees of over-breaking. The exercise remained the same, but the approach became smarter.

6.2.2 The panel optimiser model

The discussion in the preceding sections made it imperative to have a tool which can help rid decision makers of the rules of thumb ascribed only to legacy whilst at the same time helping them to be more pro-active when it comes to potholes and off-reef mining situations. Any panel with an optimised best cut selection can be analysed through simulation for any possible future contamination and its impact on that panel's bottom line before that situation actually arises.

The SWAR already contains information from the histogram to which it is linked, through the “planned” section in Figure 3.5.

The panel optimiser model shown in Table 6.2 is developed to run on an excel spreadsheet, which requires a user (e.g. a geologist or evaluation officer) to enter required input parameters from the planned best cut figures to the actual figures as observed underground. The model allows for a range of pothole-affected panel scenarios to be simulated, testing the ‘two-thirds’ theory whilst at the same time allowing a decision maker to choose an optimum way out of a pothole scenario based on economic principles of cost and revenue as dictated to by the overall pay limit. In simple terms, if a panel’s grade is below that of the overall pay limit, it becomes unpay and if it is above the pay limit, it remains economically viable.

Corporate principles that have zero tolerance for waste can however, override the decision to continue mining a panel with considerable waste in it, even if the panel remains economically viable. This analysis can be carried out every time new histograms are generated, allowing every new working panel to have its waste tolerance figures before mining commences, thus helping in quick decision making should the panel intersect a pothole.

The blue areas of the table contain formulae and should not be altered. What makes this tool easy is that once the observation are punched into their respective cells, the panel grade is automatically calculated and compared to the pay limit and from that a recommendation is made out to the user in the 'Decision Section'. The model is divided into four simple and self-explanatory sections:

6.2.3 Stoping width section

In this section, the planned stoping width and the actual stoping width as observed underground are supplied as input parameters for the comparison that happens in section three of the model. The main output in this section is the actual grade, which will differ from the planned one should there be over-breaking experienced in either the hangingwall or the footwall of the stoping panel. This grade is a reflection of the influence that the actual stoping width has on the planned content (cmg/t's) of the panel before any geological conditions are taken into consideration. An ideal situation at this point would be a situation where the actual cut equals or is less than the planned cut for a given channel width.

Table 6.2 The stope panel optimizer model (derived from Brown and Theron 2003:19)

Best Cut (As determined from the histogram):						
	HW	Ch W	FW	Face Width	HW/FW Overbreak	Actual Stoping Width
Enter Best Cut (cm):	20	70	5	95.00		
Best Cut Grade(g/t):	5.58	Best Cut Content (cmg/t):		530.10		
Actual Cut (As determined from u/grnd mapping)						
Enter Actual Cut (cm):	20	70	5	95.00	11	106.00
Actual Cut Grade(g/t):	5.00	Actual Cut Content (cmg/t):		530.10		
Geological Conditions (off-reef face length)						
Total Face Length (m):	Off-reef (m)	On-reef (m)	% On-reef	% Off-reef	Off-reef grade (g/t):	
25	5	20	80	20	0	

Summary sheet for: (WORKING PLACE)					Date:
	Planned	Actuals	Variance		
HW (cm)	20	20	-	*(negative values indicate underbreak)	
Fw (cm)	5	5	-		
FaceW (cm)	95	95	-		
Content	530.10	530.10	-	*negative means loss	
Grade	5.58	4.00	-1.58		

The Decision, based on panel conditions summarised above			
Overall Pay limit (g/t):	4.00	Mortimer cut-off grade:?	
Best Cut Adherence?	Poor Stoping Width Control, adhere to the set best cut!!		
Is the panel economically viable?	YES		
Action:	Continue mining the panel with care!		

6.2.4 Geological section

This section takes cognisant of any geological disturbance that may result in a portion of the panel becoming off-reef, which effectively dilutes the panel grade, thus destroying value. A grade of 0 g/t is assumed for off reef situations defined by reef absence, or else a kriged value could be applied. The total panel face length (in m) and the total off-reef panel facelength (in m) are recorded and the latter expressed as a percentage of the former.

6.2.5 The panel summary section

In this section, the actual panel conditions are compared to the planned panel parametres in terms of stoping width and off-reef conditions. The main output at this point is the actual panel grade after taking the geological conditions into consideration. In the basic formula used for this calculation, the section grade is factored to the on-reef portion of the panel then added to the off-reef grade, which is itself factored to the off-reef portion of the panel. Thus, if the off-reef grade is assumed to be zero, the second part of the equation is cancelled out. In this section, the general economic condition of the panel is summarised in the way of an actual grade vs. planned grade comparison.

6.2.6 The decision section

This section helps the decision maker in deciding whether to continue mining the panel or not, or seek alternative remedies for the panel comparison by comparing the stope panel grade to the overall pay limit. In the most basic definition of pay limit as discussed in chapter 4, an overall panel grade lower than the stoping pay limit renders the panel uneconomical and hence value destroying. It may still be necessary to mine material below the minimum cut-off grade in order to access higher grade material.

That does not detract however, from the fact that a decision still ought to be taken in order to do so, unlike where value is arbitrarily destroyed simply because of a lack of decision-making. A situation often occurs where little or no flexibility exists to bypass or avoid the mining of low grade material as it often happens in pothole situations. The situation, can however, be better managed and value destroying tonnages kept to a minimum.

6.3 Easy application

The panel optimiser's flexibility allows for any length of off-reef in either metres or percentage to be input into the spreadsheet and record the changes in the panel grade as the amount of off-reef is increased or decreased. This effectively allows for the amount of off-reef that any particular panel can tolerate in order for it to remain economically payable to be checked. The model achieves this by comparing the planned panel parameters like SW to the actual panel parameters measured underground and compares the resultant actual grade obtained through this comparison to the calculated overall pay limit for that particular reef type.

It calculates panel grade, content, mining cut and over-break and percentage off-reef/on-reef. It also advises on whether the panel can be mined through a pothole or any off-reef situation based on the planned best cut, planned face length, off-reef length, the actual HW/FW/SW measured on the face, the assay data profile associated with that specific panel and the overall pay limit applicable at the time. The results are then recorded in Table 6.3 and this immediately helps identify problems that may warrant further attention. If the grade is more than this pay limit, the panel is payable and the reverse is unpay.

A decision to stop this panel from mining would then be made based on its payable or sub-economical status. The exercise is obviously dependent on the pay limit applicable at the time it is carried out, hence the economic analysis should be carried out regularly depending on the frequency of change of external inputs like the exchange rate.

Table 6.3 Determination of tolerable off-reef metres at various best-cut

face advance (m):		1			
UG2 Density (t/m^3)		3.8			
Face length (m):		30			
at sw (m):		85	90	95	100

Grade variance in a pothole-affected panel with 30m facelength

@ Best cut (85cm)				@ 6% o/break(90cm)				@ 12% o/break(95cm)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.46	0	0	0	5.16	0	0	0	4.89	0	0
10	4.91	3	10	10	4.64	3	10	10	4.40	3	11
20	4.37	6	19	20	4.13	6	21	20	3.91	6	22
30	3.82	9	29	30	3.61	9	31	30	3.42	9	32
33	3.64	10	32	33	3.44	10	34	33	3.26	10	36
37	3.46	11	36	37	3.27	11	38	35	3.18	11	38
40	3.28	12	39	38	3.18	12	39	37	3.09	11	40
42	3.18	13	40	40	3.09	12	41	40	2.93	12	43
50	2.73	15	48	50	[illegible]	[illegible]	[illegible]	50	2.44	15	54
60	2.18	18	58	60				60	1.95	18	65
70	1.60	21	68	70				70	1.47	21	76
80	1.09	24	78	80				80	0.98	24	87
90	0.55	27	87	90				90	0.49	27	97
100	0.00	30	97	100				100	0.00	30	108
at no geological loss, tonnage due to o/breaking is (t):							6				11

Increasing off-reef intolerance with increasing over-break

7 RESULTS AND DISCUSSION

7.1 Underground mapping

The importance of stoping width and the intersection of geological structures on the economics of a stope panel is easily reflected by it's significant influence on tonnage and grade return calculations, where its misrepresentation often leads to "survey excesses" and "survey shortfalls". It is therefore quite clear that without the necessary improvements needed in a pothole affected panel or a panel affected by poor mining practices, its off-reef tolerance is exceeded. This renders it uneconomical to mine but by merely controlling HW/FW over-break or SW, which is essentially a principle of best mining practice, the future of the panel can be extended and as such the LOM improved.

The observations presented in Table 6.1 were input into the panel optimizer model to evaluate the economic viability under the circumstances prevailing in the panel at the time. The results of the underground investigations are summarized in Tables A1 to A8 in Appendix A and these are then summarized in Table 7.1. For this particular panel for the given circumstances, the verdict is that the panel was uneconomical to continue mining from the time it was fifty percent off-reef. Two thirds equates to sixty-seven percent, therefore the first real conclusion that the two thirds blanket rule is incorrect.

Table 7.1 A summary of the results of underground observations on panel ABC

		Underground Observation											Panel Optimiser
Workplace	Date	Face Width	Reef Width	HW width	FW width	Face Length (m)				% Over-break	Grade (g/t)	Economically Viable?
						On-reef	Off-reef	Total	% Off-reef			
Panel ABC	2 Nov '04	**89**	64	3	22	30	0	30	0%	5%	5.21	**Yes**
	9 Nov '04	**92**	61	6	25	30	0	30	0%	8%	4.75	**Yes**
	24 Nov '04	**87**	55	8	24	30	0	30	0%	2%	4.79	**Yes**
	9 Dec '04	**92**	59	11	22	24	0	24	0%	8%	3.68	**Yes**
	4 Jan '05	**90**	63	20	7	18	6	24	25%	6%	3.36	**Yes**
	12 Jan '05	**96**	54	22	20	11.8	12.2	24	51%	13%	1.89	**No**
	14 Jan '05	**87**	69	9	9	12	18	30	60%	2%	1.60	**No**
	17 Jan '05	**88**	51	28	9	6	24	30	80%	4%	0.98	**No**

It also becomes quite clear from the table above that the off-reef tolerance for this panel is actually much lower than fifty percent and that the only stumbling block in establishing what it is exactly is the fact that the panel was only mapped when it had twelve metres off-reef and not at eight or ten metres off-reef. So what would the verdict have been at these unmapped off-reef metres? The answer to this question makes it quite clear that off-reef situations warrant pro-active decision making where a panel would not have to mine fifty percent before a decision is made whether it is paying or not, rather a decision to be made well before the panel commences to mine.

7.2 Impact of extraneous waste

A certain panel XYZ mining the UG2 reef was reported to have intersected a pothole by a shift supervisor. An underground trip was undertaken by the author to investigate and the actual observations are listed in table 7.2a. The best cut variables as determined from a histogram drawn up from the sampling information pertaining to this working place are listed in table 7.2b.

Table 7.2 Panel results showing (a) Geological observations and (b) best cut summary

(a)

U/g observations	
Total (m)	24.00
Off-reef (m)	4.40
On-reef (m)	19.60
HW (cm)	22.00
CH (cm)	56.00
FW (cm)	18.00

(b)

Best cut information:	
Hw (cm)	0.00
Ch W (cm)	56.00
Fw (cm)	29.00
SW (cm)	85.00
Grade (g/t)	4.40
Pay limit	3.18

These observations were then input into the panel optimiser model to evaluate the economic viability under the prevailing circumstances. The results of the underground investigation summarized in table A9 in Appendix one indicate that under the given circumstances, the panel was uneconomical to continue mining and hence the miner was given an alternative to either apply the best mining practice or stop the panel (as can be seen in the ‘decision’ area of the model).

Having a closer look at the challenges this panel is facing, it can be seen that it was more a best mining practice issue than it was a “waste due to pothole-intersection” issue that made the panel uneconomic to mine. Just reducing the HW over-break to the recommended width, increases the panel grade by twenty one percent, from 2.85 g/t to 3.59 g/t, which is more than the set pay limit, thus improving the economic status of the panel from unpay to pay (Table A10).

The difference between the two tables mentioned above is a good demonstration of the importance of stoping width in the economics of a panel, where its misrepresentation often has a significant and irreversible impact on grade and tonnage return calculations leading to “survey excess” and/or “survey shortfall”. Controlling HW over-break or SW, would be a “prevention is better than cure” reality, which basically lends itself to the principle of best mining practice: “doing the right things right”.

7.3 Scenario analysis

In the example discussed above, the influence of the HW over-break on the economics of a stope panel on a platinum mine is clear. The question that arises is “what if there was no HW over-break, i.e. best cut was being adhered to and what would the grade have been at various off-reef face length situations with or without the extraneous waste?” This is effectively, the part where the panel optimiser model can be turned into a proactive tool, where a miner can know before-hand what his limit of tolerance is.

To satisfy this, an analysis of a changing panel grade with an increasing off-reef portion was conducted at best cut and at the existing dilution levels of twenty six percent over-break. The results thereof are presented in Table 7.3. Without the observed over-break, the panel’s off-reef tolerance only gets exceeded above 28%, an equivalent of just under seven metres, whereas with the over-break, this is lowered down to only 9%, an equivalent of just over two metres of off-reef. The amount of value-destroying tonnages increases significantly with non-adherence to best mining practice. This unnecessary waste material will increase milling costs whilst decreasing the recovery of metals at the plant, decreasing the LOM in the process.

Over-breaking is most often caused by a lack of discipline when it comes to drilling the mining face before it gets charged up. Best mining practice dictates that a miner be accountable for this and exercises best supervision over the rock drill operator crews. Quality takes precedence over quantity in this case and the ability to tolerate waste created by geological structures, which lies totally outside of the control of the mining crew, is enhanced.

Table 7.3 An increase in off-reef tolerance with decreasing contamination

face length (m)	24.00	
face advance (m):	1	
UG2 Density (t/m^3):	3.8	
at sw (m):	0.85	1.07
overbreak (m):		0.22

@ Best cut				@ actual sw(107cm) =26% o/break				
Off-reef %	Grade	Off-reeef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	o/break tonnage
0	4.40	0.0	0	0	3.50	0.0	0	20
10	3.96	2.4	8	9	3.18	2.2	9	18
20	3.52	4.8	16	20	2.80	4.8	20	16
28	3.18	6.7	21	30	2.45	7.2	29	14
40	2.64	9.6	31	40	[illegible]	9.6	39	12
50	2.20	12.0	39	[illegible]	1.75	12.0	49	10
60	1.76	[illegible]	[illegible]	60	1.40	14.4	59	8
70	1.32	[illegible]	54	70	1.05	16.8	68	6
80	0.88	[illegible]	62	80	0.70	19.2	78	4
90	0.44	21.6	70	90	0.35	21.6	88	2
100	0.00	24.0	78	100	0.00	24.0	98	0

This is clearly demonstrated by Figure 7.1. The difference between the '@ best cut' graph and 'actual sw' graphs is the impact of stope width over-break on a pothole affected panel. The red dotted line signifies the cut-off grade applied for the simulation.

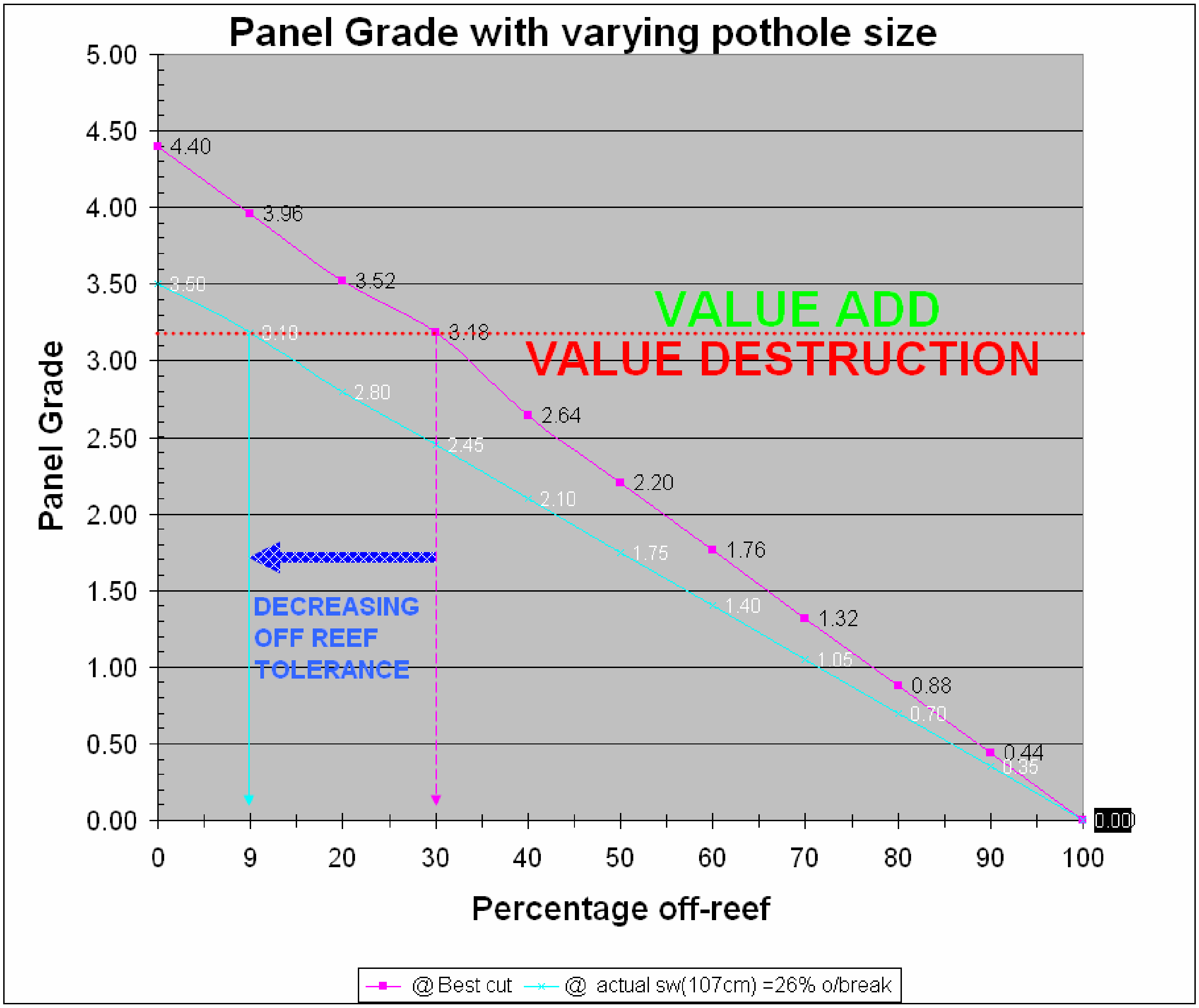


Figure7.1 A graph showing panel grade with varying pothole size

The ‘@ Best cut’ graph in the diagram above proves once again that a stope panel cannot be mined with more than thirty percent of its facelength off-reef without destroying value for the company and its shareholders. An increase in the amount of contamination (the difference between the ‘@ best’ and ‘@ actual cut’ graphs) brings with it a decrease in off-reef tolerance.

A simple grade tonnage curve was also plotted and the relationship between the destructive tonnage, panel grade and the off-reef percentage plotted both at best cut and at the existent over-break situation recorded at the time of the investigation. The results are shown in Figure 7.2 for the best cut scenario and in Figure 7.3 for the over-break scenario.

Both diagrams point quite clearly to the fact that stope width over-break increases tonnages that destroy value, whilst at the same time rendering the panel grade unpay. Keeping to best mining practice is the only way that this can be eliminated and here lies the issue of integrity on the part of the responsible person and the issue of corporate values on the part of the business unit. A much higher off-reef tolerance exists where ‘best mining practice’ is applied.

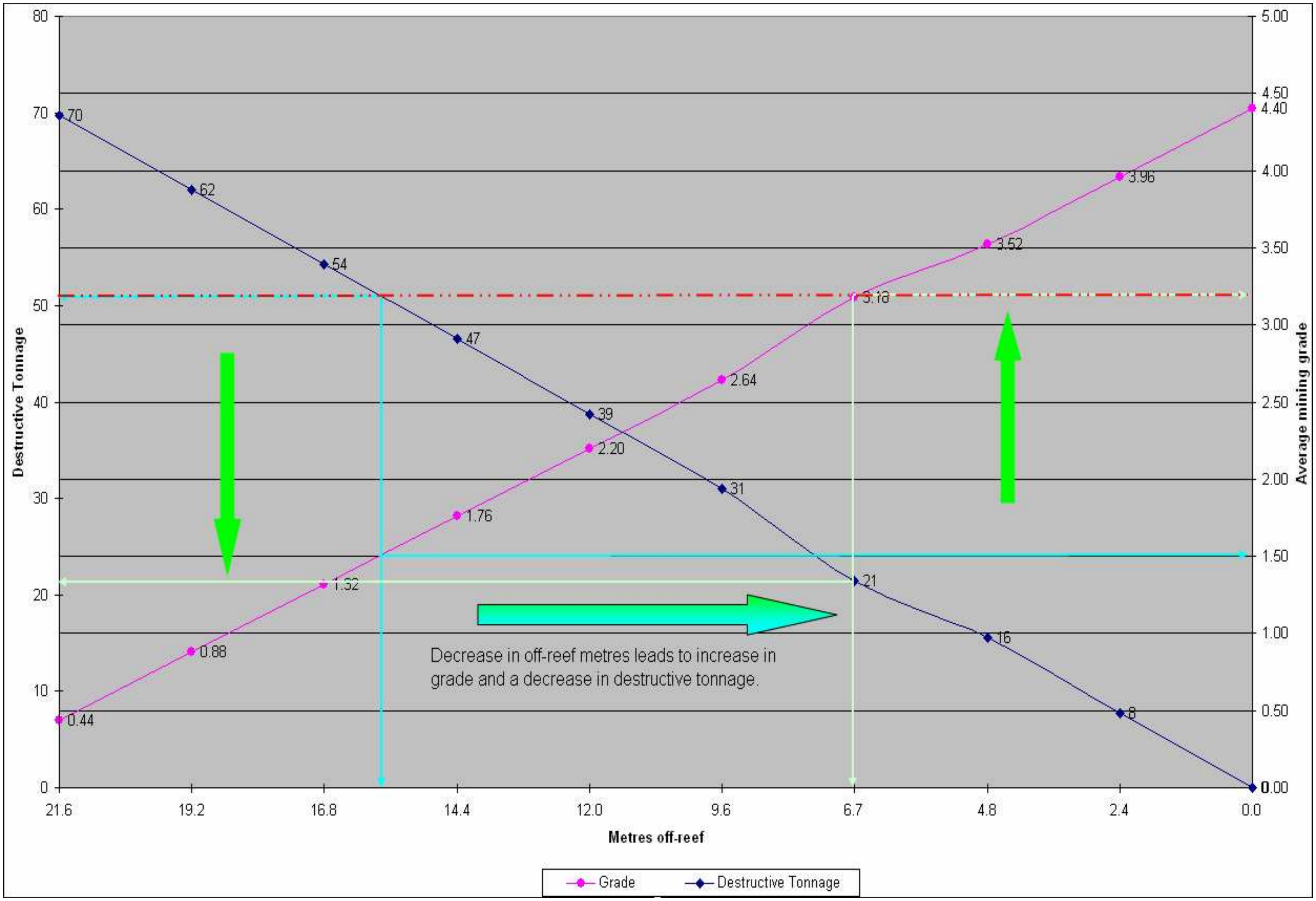


Figure 7.2 A graph of varying pothole size vs panel grade and value-destroying tonnages at best cut

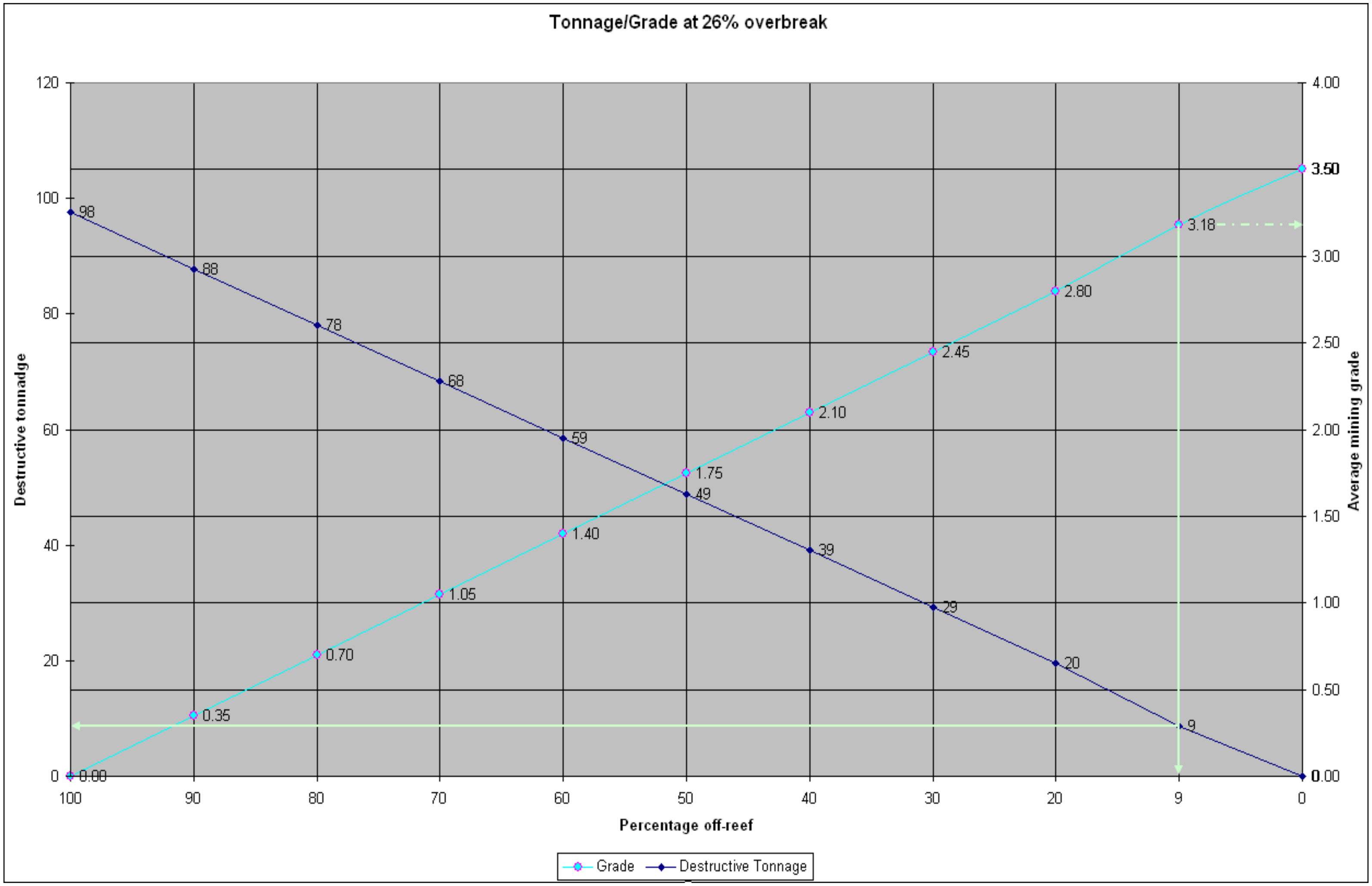


Figure 7.3 A graph showing how over-breaking leads to lower off-reef tolerance

7.3.1 The ‘two-thirds’ rule of thumb

Two thirds of the panel on waste? As quite relevantly noted by Hall (2005), “tradition and rules of thumb were… often imposed on the operation from some distant head office”. In the case of the two-thirds rule however, the number could not be traced back to some distant head office, but to a distant past.

What is clear however, is that this rule of thumb got accepted as the norm, as observed from a personal conversation the author had with a senior mine manager when discussing this project. He said “I just know that for as long as it (the off-reef face length) is below two thirds, it (the panel) is mineable”.

7.3.2 The main objective

The main aim of this research was to determine the validity of the ‘two-thirds’ blanket rule of thumb still dictated to the operations by some distant past, to finally have a scientifically researched figure, which can be generally used in off-reef situations created in the workings, mainly by potholes, thereby improving grade control and reducing the costs of production.

This at the same time needed to help highlight the importance of treating each panel face as a business entity, a field where the mine geologist could be utilised more meaningfully in financial analysis of these business entities by applying his/her knowledge of the structural behaviour of the orebody to the optimal extraction of the resource.

The changing face length conditions due to a pothole intersected in a panel was researched using the excel tool described in 6.2.2. The grades for each off-reef situation was compared to the overall pay limit of the relevant mine. The point at which the grade equals the pay limit indicates the break-even grade for that particular panel and any grade below the pay limit renders the panel uneconomic.

7.3.3 Assumptions

A pay limit of 3.18 was used in the 2005 financial year at the shaft that the author was working at the time, which is what got used for this research. The results do however, allow for anyone to determine off-reef tolerance for any pay limit, given a specific face length. It is assumed for this research that there is no correlation between reef thickness and the in-situ grade, thus eliminating any anticipation of grade variation due to reef thickness. As such, a panel planned to mine a reef package of 68cm in thickness at 6.68 g/t in-situ grade can expect the same in-situ grade even though the reef thickness varies slightly from the anticipated width. All that needs to happen is that a new grade be obtained for that channel width by re-adjusting the content over the new channel width.

Main assumptions:

UG2 density: 3.8 t/m^3

Overall Pay limit: 3.18 g/t

Face advance: 1m

Waste: FW/HW: 0 g/t

The off-reef tolerance model presented in Table 6.2 was used to investigate the impact of a pothole of varying size on a panel of varying face length (30 m, 25m and 20m) at four different stoping widths (best cut, 6% dilution, 12% dilution and 18% dilution). The ‘best cut’ stoping width represents the resource as stated at a ‘practical mining cut’ or the reserve without any external dilution. The other stoping widths allow for the investigation of the impact of dilution on the panel economics given the pothole situation.

7.3.4 The findings

It is only logical to expect panel grade to diminish with increasing off-reef and/or contamination. Practical realization is however, despite the logical argument, that panels are often mined beyond the two-thirds blanket rule, as borne witness by Figure 2.2. The only logical explanation for this is perhaps the lack of understanding of the impact of such a practice or as Hall (2005) puts it, the "more is good" philosophy. With increased pressures for production as a result of high and sometimes unreasonable expectations from the markets, there really is hardly any incentive for separating waste from ore, as tonnages are the ultimate target, not valuable tonnes. Table 7.4 presents the results of the research described above, which are then presented in a graphical format in Figure 7.4.

Two-thirds of a thirty metre face length is twenty metres. If the blanket rule were true, twenty metres of a thirty metre long panel could be mined off-reef at a profit or at the very least, at break-even. The best economic conditions for a stope panel on a platinum conventional breast mine are at best cut. Table 7.4 shows that the maximum amount of off-reef metres that a panel with a thirty metre face length can tolerate is thirteen metres, an equivalent of fourty-two percent of the face length and this percentage diminishes with an increase in the amount of extraneous contamination mined. Nonetheless, the thirteen metres is twenty five percent lower than the figure of twenty metres suggested by the mythical two-thirds rule.

It can be seen from the table that thirty percent or less than a third of a panel can be mined off-reef at a profit provided the business unit enjoys the economy of scale that allows for an overall pay limit of 3.18 g/t. This is the primary reason for the many years of complaint from the markets that mining companies deliver poor returns and that is the undermining of the influence that a pay limit has on value. This is quite clearly, where the ‘two-thirds’ rule came from as well.

The simulation exercise allows for a plot of the value envelope which demonstrates why the pay limit is important to the determination of when a stope panel should stop mining waste. Figure 7.4 graphs the off-reef tolerance at the four different stoping widths to illustrate the thin line between adding value and destroying value.

Table 7.4 Grade variation in a pothole-affected panel with 30m face length

Inputs

Face length (m):	30			
face advance (m):	1			
UG2 Density (t/m^3):	3.8			
sw (m):	85	90	95	100

@ Best cut (85cm)				@ 6% o/break(90cm)				@ 12% o/break(95cm)				@ 18% o/break(100cm)			
Off-reef %	Grade	Off-reef (m)	Off-reef Tonnage	Off-reef %	Grade	Off-reef (m)	Off-reef Tonnage	Off-reef %	Grade	Off-reef (m)	Off-reef Tonnage	Off-reef %	Grade	Off-reef (m)	Off-reef Tonnage
0	5.46	0	0	0	5.16	0	0	0	4.89	0	0	0	4.64	0	0
10	4.91	3	10	10	4.64	3	10	10	4.40	3	11	10	4.18	3	11
20	4.37	6	19	20	4.13	6	21	20	3.91	6	22	20	3.71	6	23
30	3.82	9	29	30	3.61	9	31	30	3.42	9	32	30	3.25	9	34
33	3.64	10	32	33	3.44	10	34	33	3.26	10	36	32	3.18	9	36
37	3.46	11	36	37	3.27	11	38	35	3.18	11	38	40	2.78	12	46
40	3.28	12	39	38	3.18	12	39	37	3.09	11	40	50	2.32	15	57
42	3.18	13	40	40	3.09	12	41	40	2.93	12	43	60	1.86	18	68
50	2.73	15	48	50	2.58	15	51	50	2.44	15	54	70	1.39	21	80
60	2.18	18	58	60	2.06	18	62	60	1.95	18	65	80	0.93	24	91
70	1.60	21	68	70	1.55	21	72	70	1.47	21	76	90	0.46	27	103
80	1.09	24	78	80	1.03	24	82	80	0.98	24	87	100	0.00	30	114
90	0.55	27	87	90	0.52	27	92	90	0.49	27	97				
100	0.00	30	97	100	0.00	30	103	100	0.00	30	108				

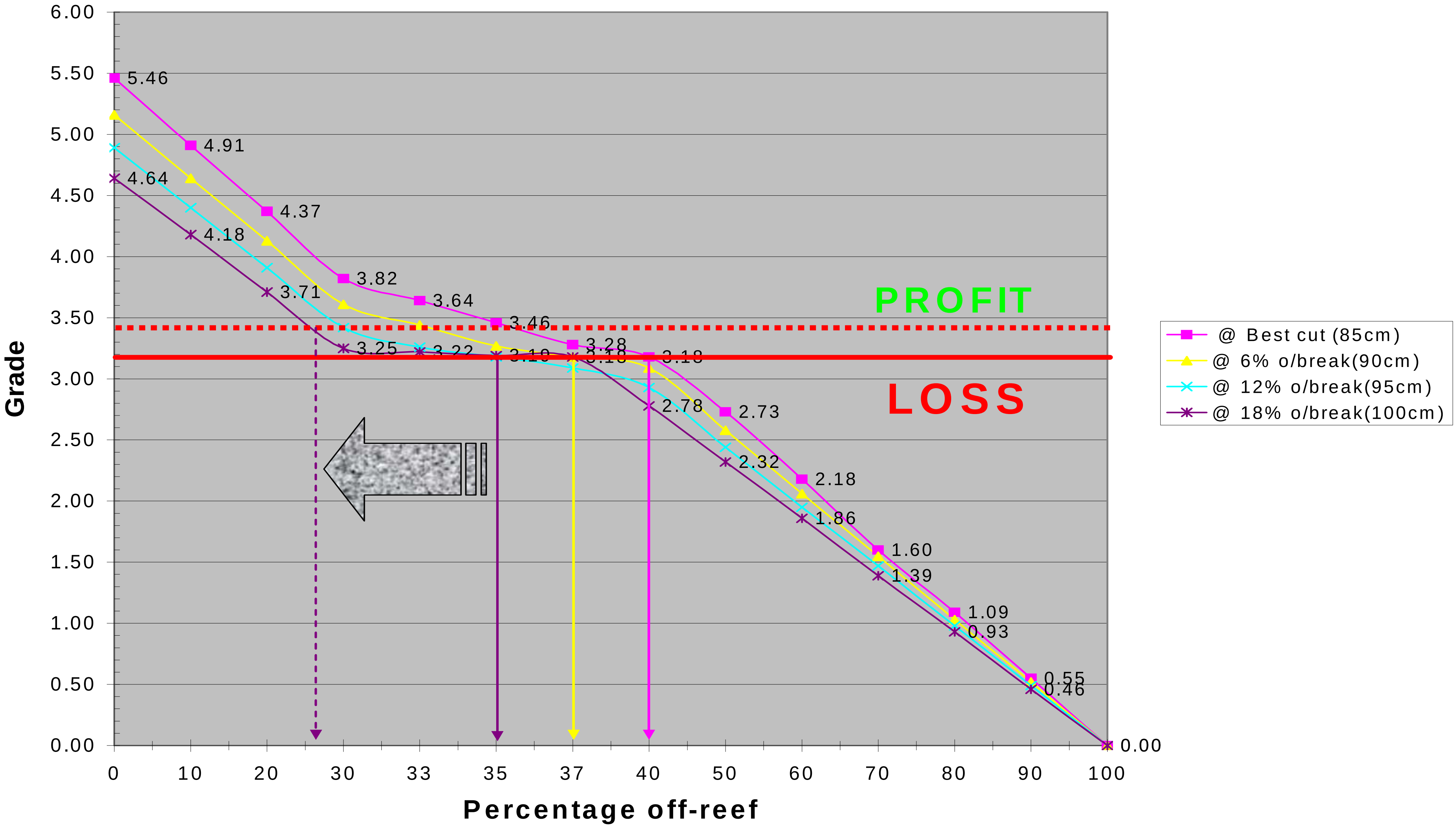


Figure 7.4 Off-reef tolerance at varying stoping width for a panel on a platinum mine

The red solid line marks the overall pay limit value of 3.18 g/t below which a stope panel mining on the business unit would not be adding value to the overall business. This line effectively serves as the break-even point, where a stope panel plotting anywhere on it is neither making a loss nor a profit. An operational stope panel would under its prevailing circumstances, seek to plot on the purple graph, at which potholes are tolerated much easier than it is along the other graphs, i.e. have no extraneous contamination other than the waste caused by the geological structure.

To check what effect an increase in the pay limit, which is driven by variables like costs and external factors like metal prices would have on a panel's off-reef tolerance, the red line can be moved up to the particular pay limit grade (red dotted line) and the corresponding off-reef percentage read off on the x axis. As shown by the grey arrow in Figure 7.4, there is a substantial decrease in a panel's ability to tolerate an off-reef situation as the pay limit increases, which can happen quite easy as for one, commodity prices take a knock or the Rand becomes stronger against the US$. This puts emphasis on the usage of the panel optimiser model to track the economic status of panels with changing internal and external conditions.

7.4 Proactive application

Appendix B contains tables derived using the panel optimiser model to produce off-reef tolerance figures up-front as per each planned half level on a mine such that every miner/shift supervisor/mine overseer or mine manager can have full knowledge of what would be acceptable or not in as far as off-reef panels due to potholes are concerned. In the wake of facies/domain appreciation and their impact on planning, the proactive provision and application of this information to the current operation becomes invaluable. Ultimately, the panel optimizer model could be made available in a palm format, enabling a miner/shift boss or mine overseer to make a quick decision in a case where his/her panel has encountered an off-reef situation underground.

The tables not only provide this information up-front, but also do affirm the fact that not more than a third of a panel's face length can be mined off-reef whilst adding value to the business. Three face lengths were investigated, each at various pay limit grades and four different mining cuts to dispel the two-thirds myth with the strictest measure of finality. Data covering twelve half levels was used to produce the summary results presented in Tables 7.5 to 7.7.

This data was analysed for three different face lengths (20m, 25m and 30m) with varying over-breaking in the footwall and hangingwall averaged out to 6%, 12% and 18% dilution. The graphs presented in Figures 7.5 to 7.7 show that a linear relationship exists between the pay limit grade and the amount of off-reef a panel can tolerate across the face lengths. Figures 7.5 to 7.7 show that there is a maximum pay limit that a panel can mine at given poor mining conditions existent in it. This is shown in the diagrams by the thick, broken green line which indicates the ceiling of off-reef tolerance at best cut of fourty two percent of a panel.

Assuming that a ‘best cut’ scenario was assumed in the ‘two-thirds’ blanket rule, this figure is thirty three percent less than the sixty seven percent postulated by the outdated rule. The figure deteriorates by a further ten percent to fourty-three percent below the postulated mark when eighteen percent contamination is experienced at the stope face. This deterioration is depicted by the vertical distance between the ‘@ best cut’ graph and ‘@ 18% dilution graphs. This vertical difference increases with an increase in the pay limit indicating that at a higher pay limit, stope panels are highly sensitive to extraneous waste, which is mostly avoidable.

In most instances this underpins at best, the ill discipline of the mining personnel or at worst, incompetence of the relevant mining personnel in identifying the orebody. Key to the debacle is the case of “more is good and less is bad” and the culture of mining has at times been encapsulated in rewarding bad behaviour, for example, awarding incentives based on the amount of tonnages mined rather than on the tonnages at a certain grade (valuable tonnages). The culture of “us against them” when it comes to the mining personnel and the rest of the personnel on the mine, particularly those from mine technical services or mineral resource management departments is also still rampant and fortifies un-maximised returns for the shareholder.

Table 7.5 Off-reef tolerance for a panel of 20m face length with varying stope width

@ Best cut			@ 6% dilution			@ 12% dilution			@ 18% dilution		
Off-reef (%)	Grade (g/t)	Off-reef (m)	Off-reef (%)	Grade (g/t)	Off-reef (m)	Off-reef (%)	Grade (g/t)	Off-reef (m)	Off-reef (%)	Grade (g/t)	Off-reef (m)
100	0.0	20.0	100	0.0	20.0	100	0.0	20.0	-	-	-
83	0.9	16.6	81	1.0	16.1	79	1.0	15.9	100	0.0	20.0
74	1.4	14.8	71	1.5	14.2	69	1.5	13.9	78	1.0	15.7
65	1.9	12.9	61	2.0	12.2	59	2.0	11.8	68	1.5	13.5
55	2.4	11.1	51	2.5	10.3	49	2.5	9.8	57	2.0	11.4
45	3.0	8.9	42	3.0	8.3	39	3.0	7.7	46	2.5	9.2
35	3.5	7.1	32	3.5	6.4	28	3.5	5.7	35	3.0	7.1
26	4.0	5.2	22	4.0	4.4	18	4.0	3.6	25	3.5	4.9
17	4.5	3.4	12	4.5	2.5	8	4.5	1.6	14	4.0	2.8
8	5.0	1.5	4	5.0	0.8				4	4.5	0.9

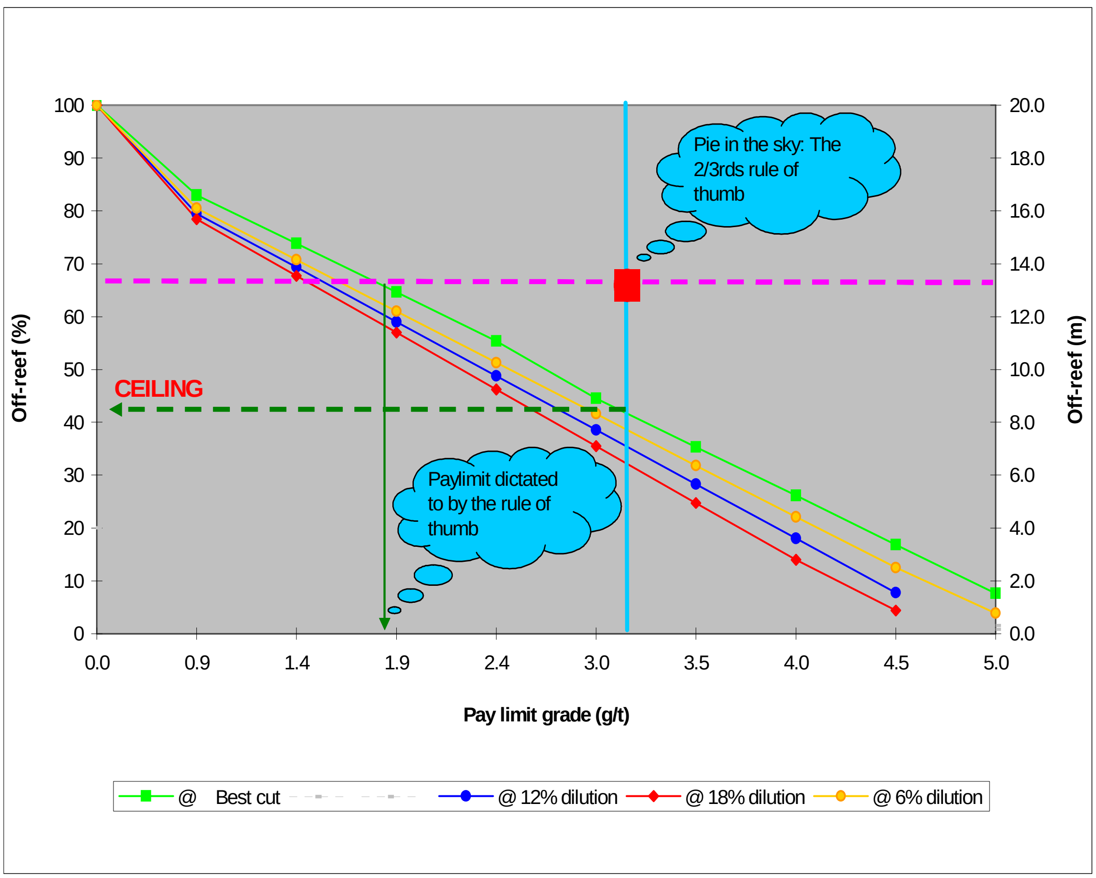


Figure 7.5 A graph of varying off-reef tolerance with varying pothole size for a 20m long panel

Table 7.6 Off-reef tolerance for a panel of 25m face length with varying stope width

@ Best Cut			@ 6% Dilution			@ 12% Dilution			@ 18% Dilution		
Off-reef %	grade	off-reef metres	Off-reef %	grade	off-reef metres	Off-reef %	grade	off-reef metres	Off-reef %	grade	off-reef metres
100.00	0.00	25.00	100.00	0.00	25.00	100.00	0.00	25.00	100.00	0.00	25.00
81.54	1.00	20.39	80.55	1.00	20.14	79.52	1.00	19.88	78.52	1.00	19.63
72.29	1.50	18.07	70.77	1.50	17.69	69.25	1.50	17.31	67.73	1.50	16.93
63.03	2.00	15.76	61.02	2.00	15.25	59.05	2.00	14.76	56.98	2.00	14.25
53.83	2.50	13.46	51.27	2.50	12.82	48.73	2.50	12.18	46.25	2.50	11.56
44.57	3.00	11.14	41.57	3.00	10.39	38.52	3.00	9.63	35.50	3.00	8.88
35.36	3.50	8.84	31.83	3.50	7.96	28.25	3.50	7.06	24.73	3.50	6.18
26.13	4.00	6.53	22.07	4.00	5.52	18.05	4.00	4.51	13.98	4.00	3.50
16.88	4.50	4.22	12.32	4.50	3.08	7.77	4.50	1.94	4.37	4.50	1.09
7.64	5.00	1.91	3.93	5.00	0.98						

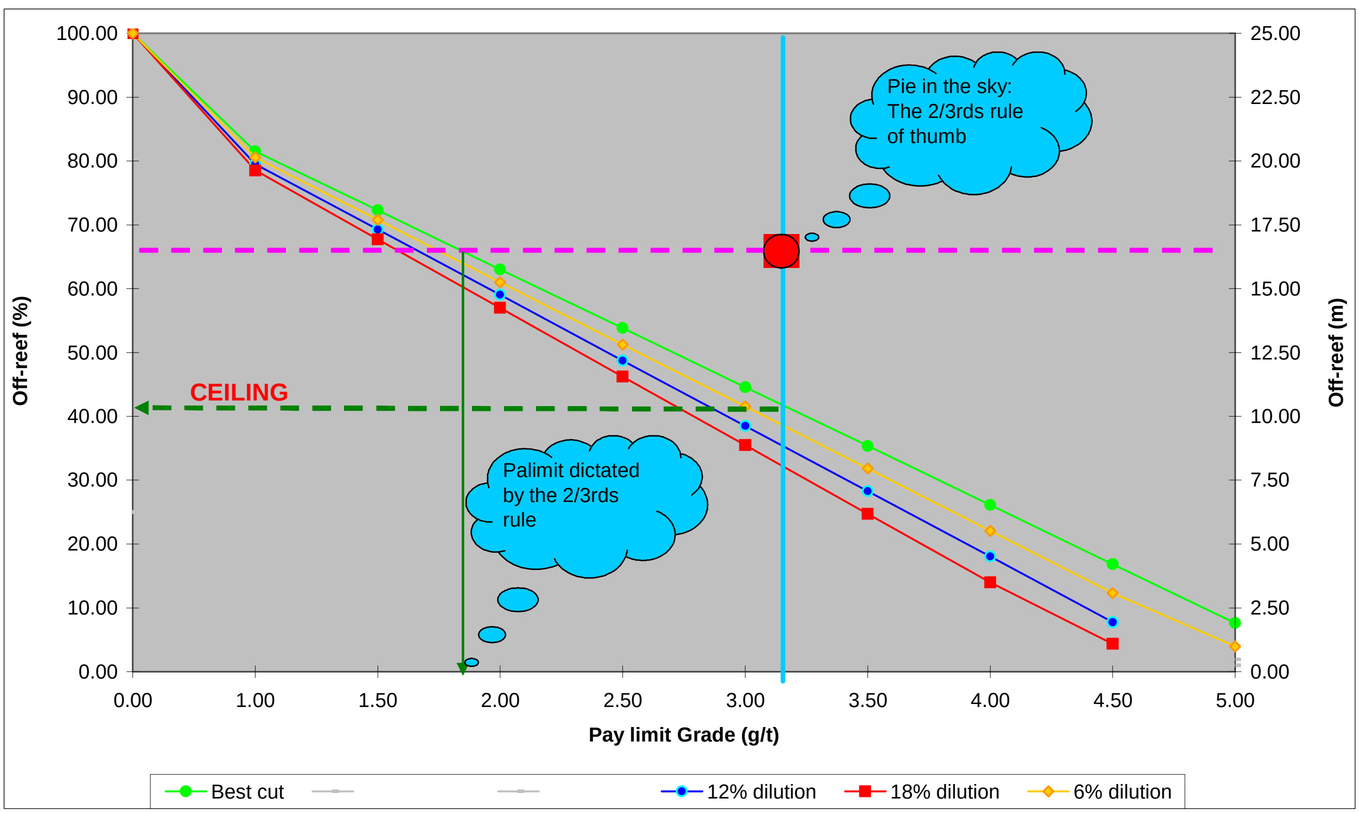


Figure 7.6 A graph of varying off-reef tolerance with varying pothole size for a 25m long panel

Table 7.7 Off-reef tolerance for a panel of 30m face length with varying stope width

@ Best cut			@ 6% dilution			@ 12% dilution			@ 18% dilution		
Off-reef (%)	grade (g/t)	Off-reef (m)	Off-reef (%)	grade (g/t)	Off-reef (m)	Off-reef (%)	grade (g/t)	Off-reef (m)	Off-reef (%)	grade (g/t)	Off-reef (m)
100	0.0	30.0	100	0.0	30.0	100	0.0	30.0	100	0.0	30.0
82	1.0	24.5	81	1.0	24.2	80	1.0	23.9	78	1.0	23.5
72	1.5	21.7	71	1.5	21.3	69	1.5	20.8	68	1.5	20.3
63	2.0	18.9	61	2.0	18.4	59	2.0	17.8	57	2.0	17.1
53	2.5	15.9	52	2.5	15.5	49	2.5	14.7	46	2.5	13.9
44	3.0	13.1	42	3.0	12.6	39	3.0	11.7	35	3.0	10.6
35	3.5	10.4	32	3.5	9.7	29	3.5	8.6	25	3.5	7.4
25	4.0	7.6	23	4.0	6.8	18	4.0	5.5	14	4.0	4.2
17	4.5	5.1	13	4.5	3.9	8	4.5	2.5	4	4.5	1.2
8	5.0	2.3	4	5.0	1.2						

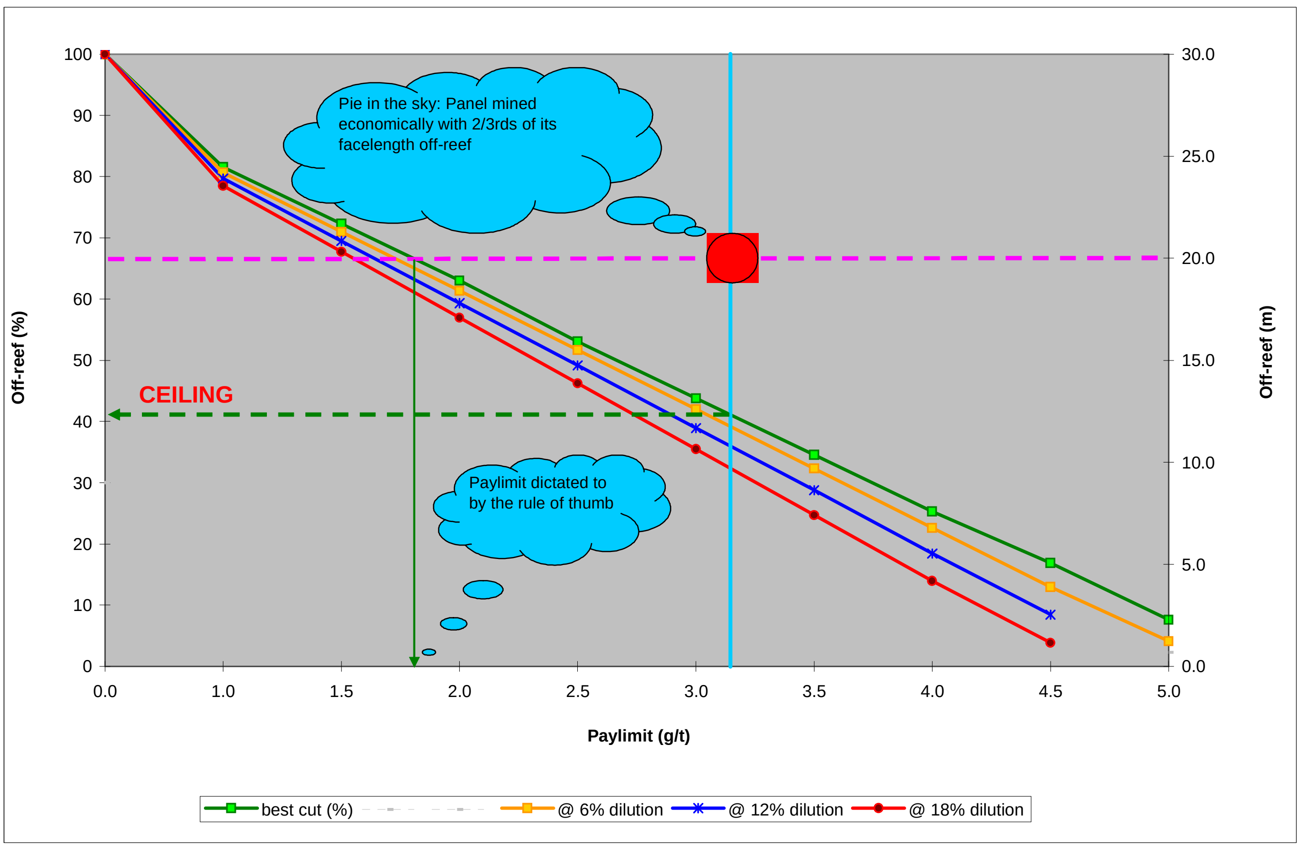


Figure 7.7 A graph of varying off-reef tolerance with varying pothole size for a 30m long panel

8 CONCLUSIONS AND RECCOMMENDATIONS

The specific aims and the importance of the work carried out in this report were highlighted in chapter two from a mining project financier's point of view. In chapter three, the differentiation between dilution and contamination was made and the role of potholes (briefly discussed in chapter one) in contamination and ultimately grade dilution, was discussed. The pay limit, procedures of determining it and its importance to this research were discussed in chapter four.

Chapter five highlighted the amelioration strategies currently used in mining panels that have intersected potholes such that minimal contamination occurs. Chapter six carried out the aims discussed in chapter two by researching the legitimacy of the outdated “two-thirds” rule in detail, making use of the concepts discussed in chapters one to five. Chapter seven presented the results of the research carried out in chapter six and this chapter makes conclusions and offers recommendations and insight into areas of possible future research.

8.1 Summary and conclusions

It is very clear from evidence presented above that the two-thirds off-reef blanket rule has no scientific support, further than that it is safe to conclude that off-reef tolerance depends on various variables like, panel stope width, contamination from extraneous waste and the business unit's overall pay limit, which incorporates in it external factors which are beyond the mine's control. It is hence the appreciation of the impact of the amount of off-reef on the overall economics of the mine that is more important than some baseless rule imposed on the current by some distant past.

The results presented in Tables 7.5 to 7.7 show that for this blanket rule to hold, a pay limit of about 1.8 g/t would have to be realised for the operation on which the research was conducted, an impossible feat in deed. The rule would thus have only been a pie in the sky and would have only served to destroy shareholder value. This research has proven, based on the 2005/2006 UG2 pay limit that no stope panel can mine, at best cut, with more than fourty-two percent of its facelength off-reef. A question that springs to mind in the wake of these results is: how did this rule manage to slip into a system dictated to by profit margins?

8.1.1 Consequences of getting it wrong: Lonmin, a case in point

On Monday 16th July Lonmin, the world's third largest platinum producer announced to the market for the third quarter a substantial downgrade to their full year sales guidance from 980,000 to 1 million ounces of Platinum to 820,000 to 840,000 ounces of Platinum. The market was surprised and disappointed by the results and the Lonmin share price fell some £2.93 or 6.85% on the day to close at £39.85 per share, wiping some US$750 million off the value of Lonmin. The result was that Lonmin had lost some credibility among analysts and its shareholders. How did this happen?

Brad Mills, the Lonmin CE ascribed much of the company's production problems to its operational staff focusing on "mining more tons, but falling short of achieving favourable grades and ore mixes". Hill (2007) quoted Brad Mills as saying: "They've mined more tons, and did a good job on that. We've been shifting away from that thinking, and it is a painful paradigm shift." According to Hill (2007), Mills had said in a conference call that each percentage change in concentrator recoveries could have a $25-million, or about R174-million, impact on earnings before tax and interest.

8.1.2 Optimisation of the strategic plan

For any mining company with underground operations, it all starts in the smallest mining unit, the stope panel, and rules of thumb that overlook value can lead to a disaster like the one discussed in the preceding paragraphs. In this story lies the answer to the author's earlier question: "They've mined more tons, and did a good job on that". Hall (2005) also says the same thing in that increases in tonnages are seen as "good" and any reduction is seen as "bad". It is this philosophy that leads to panels mined with two-thirds of their facelength off-reef, leading to lower recoveries in the concentrators and the ultimate reduction in a company's value, leaving it susceptible to take-over bids.

Having discussed in chapter four the importance of a life-of-mine plan (LOM) as an indicator of the origin and destination of tonnage and grades to be mined from the deposit, it becomes clear in the light of the Lonmin case that understanding an operation's pay limit and the impact of potholes on the economics of a stope panel (the smu) can optimise the Strategic Mine Plan. All it takes is "doing the right things right" and having focus in the right areas of the business. This would stand any miner in good stature with the market as there wont be any "over-promising and under-delivering" as in the case of Lonmin. The following are recommendations based on the conclusions summarised above.

8.1.3 Pay attention to quality

The biggest lesson out of the Lonmin case study is "Pay attention to grade and costs". Grade is a reflection of ore mixes, and waste mixed with ore leads to contamination, which leads to dilution of the grade. This dilution of grade as seen from the Lonmin case study can lead to 'not-so-good' consequences like loss of credibility through over-promising and under-achieving, reduction in company value (drop in share price) and as a result, susceptibility to hostile take-overs.

8.1.4 Reward value-add

One question that still bothers the author to this day is: in the wake of all the attention given to operating costs, efficiencies and new technology, which all in all point to mining in the modern world, why haven't management in the platinum industry changed the production bonus schemes to reflect the company's corporate values of the modern day?

As highlighted by MacFarlane (2004) Mineral Resource Management (MRM) is an integrated activity, which identifies, evaluates and provides an optimal extraction plan of the mineral resource, which satisfies the business objectives in a dynamic environment. It performs an audit function to ensure compliance to the contracted business plan in terms of quality and quantity.

This definition puts an immediate conflict between the 'auditors' and those who are tasked with carrying out the task of executing the business plan because of incentive schemes built on rewarding value destroying behaviour. New mining contracts for miners should be milestone based and should include terminology such as stope width, grade and waste mining and penalties, not just tonnes.

8.2 Further research

8.2.1 Mortimer pay limit for platinum industry

The importance of a pay limit calculation in the determination of the amount of waste a stope panel in a pothole situation on a platinum mine was discussed in chapter four. Storrar (1980) defines a pay limit as "... the minimum value at which (an ore) can be mined and treated without profit or loss. The question that comes

to the author's mind here is: "who wants to get into business not to make profit, there has to be profit right? As noted by Hall (2005), the platinum industry's and indeed Storrar's pay limit calculation ignores the first leg of Mortimer's definition, although its absence is often lamented when profitability is low. It is as such important that research be conducted into the optimised pay limit that takes into consideration a profit-related corporate goal for the platinum industry and its correct application.

8.2.2 Optimized metal accounting

Chapter three discussed the difference between face width and stope width (primary contamination vs secondary contamination) and their respective impact on metal accounting. The research contained in this report was primarily based on the stope face (face width and primary contamination). The importance of the real stope width and its associated secondary contamination and its real impact on concentrator recoveries and operating costs warrant further research.

8.2.3 Cost-benefit analysis

The costs attributable to the options presented in chapter five, which dealt with the various options of mining through or re-establishing around a pothole need to be researched. It is my experience that the accounting system on a mine does not make the determination of the costs of mining an individual smu easy. This research might at the same time help identify the current ‘bottle necks’.

8.2.4 Influence of a mine layout

There needs to be a comprehensive assessment of the influence of mine layouts on the ability of a mining operation to deal with the complexity of varying geological orebody signature.

APPENDIX A

RESULTS OF THE OBSERVATIONS ON A POTHOLE-AFFECTED UNDERGROUND STOPE PANEL

Table A1 Panel evaluation for the 2nd November 2004

Best Cut (As determined from the histogram):

	HW	Ch W	FW	Face Width	HW/FW Overbreak	Actual Stoping Width
Enter Best Cut (cm):	0	68	17	85.00		
Best Cut Grade(g/t):	5.46	Best Cut Content (cmg/t):		464.10		

Actual Cut (As determined from u/grnd mapping)

	HW	Ch W	FW	Face Width	HW/FW Overbreak	Actual Stoping Width
Enter Actual Cut (cm):	3	64	22	89.00	0	89.00
Actual Cut Grade(g/t):	5.21	Actual Cut Content (cmg/t):		464.10		

Geological Conditions (off-reef face length)

Total Face Length (m):	Off-reef (m)	On-reef (m)	% On-reef	% Off-reef	Off-reef grade (g/t):
30	0.0	30.0	100.0	0.0	0

Summary sheet for: (WORKING PLACE) **Date: 2 November 2004**

	Planned	Actuals	Variance	
HW (cm)	0	3	3.00	*(negative values indicate underbreak)
Fw (cm)	17	22	5.00	
FaceW (cm)	85	89	4.00	
Content	464.10	464.10	-	*negative means loss
Grade	5.46	5.21	**-0.25**	

The Decision, based on panel conditions summarised above

Overall Pay limit (g/t):	**3.18**	**Mortimer cut-off grade:**	**?**

Best Cut Adherence?	**Poor Stoping Width Control, adhere to the set best cut!!**
Is the panel economically viable?	**YES**
Action:	**Continue mining the panel with care!**

Table A2 Panel evaluation for the 9th November 2004

Best Cut (As determined from the histogram):						
	HW	Ch W	FW	Face Width	HW/FW Overbreak	Actual Stoping Width
Enter Best Cut (cm):	0	61	24	85.00		
Best Cut Grade(g/t):	5.14	Best Cut Content (cmg/t):		436.90		
Actual Cut (As determined from u/grnd mapping)						
Enter Actual Cut (cm):	6	61	25	92.00		92.00
Actual Cut Grade(g/t):	4.75	Actual Cut Content (cmg/t):		436.90		
Geological Conditions (off-reef face length)						
Total Face Length (m):	Off-reef (m)	On-reef (m)	% On-reef	% Off-reef	Off-reef grade (g/t):	
30	0.0	30.0	100.0	0.0	0	

Summary sheet for: (WORKING PLACE) — **Date: 9 November 2004**

	Planned	Actuals	Variance	
HW (cm)	0	6	6.00	*(negative values indicate underbreak)
Fw (cm)	24	25	1.00	
FaceW (cm)	85	92	7.00	
Content	436.90	436.90	-	*negative means loss
Grade	5.14	4.75	**-0.39**	

The Decision, based on panel conditions summarised above

Overall Pay limit (g/t):	**3.18**	**Mortimer cut-off grade:**	**?**
Best Cut Adherence?	**Poor Stoping Width Control, adhere to the set best cut!!**		
Is the panel economically viable?	**YES**		
Action:	**Continue mining the panel with care!**		

Table A3 Panel evaluation for the 24th November 2004

Best Cut (As determined from the histogram):

	HW	Ch W	FW	Face Width	HW/FW Overbreak	Actual Stoping Width
Enter Best Cut (cm):	0	61	24	85.00		
Best Cut Grade(g/t):	4.90	Best Cut Content (cmg/t):		416.50		
Actual Cut (As determined from u/grnd mapping)						
Enter Actual Cut (cm):	8	55	24	87.00	0	87.00
Actual Cut Grade(g/t):	4.79	Actual Cut Content (cmg/t):		416.50		

Geological Conditions (off-reef face length)

Total Face Length (m):	Off-reef (m)	On-reef (m)	% On-reef	% Off-reef	Off-reef grade (g/t):
30	0.0	30.0	100.0	0.0	0

Summary sheet for: (WORKING PLACE) — **Date: 24 November 2004**

	Planned	Actuals	Variance	
HW (cm)	0	8	8.00	*(negative values indicate underbreak)
Fw (cm)	24	24	0.00	
FaceW (cm)	85	87	2.00	
Content	416.50	416.50	-	*negative means loss
Grade	**4.90**	**4.79**	**-0.11**	

The Decision, based on panel conditions summarised above

Overall Pay limit (g/t):	**3.18**	**Mortimer cut-off grade:**	**?**

Best Cut Adherence?	**Poor Stoping Width Control, adhere to the set best cut!!**
Is the panel economically viable?	**YES**
Action:	**Continue mining the panel with care!**

Table A4 Panel evaluation for the 9th December 2004

Best Cut (As determined from the histogram):						
	HW	**Ch W**	**FW**	**Face Width**	**HW/FW Overbreak**	**Actual Stoping Width**
Enter Best Cut (cm):	0	55	30	85.00		
Best Cut Grade(g/t):	4.42	Best Cut Content (cmg/t):		375.70		
Actual Cut (As determined from u/grnd mapping)						
Enter Actual Cut (cm):	11	59	22	92.00	10	102.00
Actual Cut Grade(g/t):	3.68	Actual Cut Content (cmg/t):		375.70		
Geological Conditions (off-reef face length)						
Total Face Length (m):	Off-reef (m)	On-reef (m)	% On-reef	% Off-reef	Off-reef grade (g/t):	
24	0.0	24.0	100.0	0.0	0	

Summary sheet for: (WORKING PLACE) **Date: 9 December 2004**

	Planned	Actuals	Variance	
HW (cm)	0	11	11.00	*(negative values indicate underbreak)
Fw (cm)	30	22	-8.00	
FaceW (cm)	85	92	7.00	
Content	375.70	375.70	-	*negative means loss
Grade	**4.42**	**3.68**	**-0.74**	

The Decision, based on panel conditions summarised above

Overall Pay limit (g/t):	**3.18**	**Mortimer cut-off grade:**	**?**
Best Cut Adherence?	**Poor Stoping Width Control, adhere to the set best cut!!**		
Is the panel economically viable?	**YES**		
Action:	**Continue mining the panel with care!**		

Table A5 Panel evaluation for the 4th January 2005

Best Cut (As determined from the histogram):						
	HW	**Ch W**	**FW**	**Face Width**	**HW/FW Overbreak**	**Actual Stoping Width**
Enter Best Cut (cm):	0	59	26	85.00		
Best Cut Grade(g/t):	4.74	Best Cut Content (cmg/t):		402.90		
Actual Cut (As determined from u/grnd mapping)						
Enter Actual Cut (cm):	20	63	7	90.00	0	90.00
Actual Cut Grade(g/t):	4.48	Actual Cut Content (cmg/t):		402.90		
Geological Conditions (off-reef face length)						
Total Face Length (m):	Off-reef (m)	On-reef (m)	% On-reef	% Off-reef	Off-reef grade (g/t):	
24	6.0	18.0	75.0	25.0	0	

Summary sheet for: (WORKING PLACE) **Date: 4 January 2005**

	Planned	Actuals	Variance	
HW (cm)	0	20	20.00	*(negative values indicate underbreak)
Fw (cm)	26	7	-19.00	
FaceW (cm)	85	90	5.00	
Content	402.90	402.90	-	*negative means loss
Grade	**4.74**	**3.36**	**-1.38**	

The Decision, based on panel conditions summarised above

Overall Pay limit (g/t):	**3.18**	**Mortimer cut-off grade:**	**?**

Best Cut Adherence?	**Poor Stoping Width Control, adhere to the set best cut!!**
Is the panel economically viable?	**YES**
Action:	**Continue mining the panel with care!**

Table A6 Panel evaluation for the 12th January 2005

Best Cut (As determined from the histogram):	HW	Ch W	FW	Face Width	HW/FW Overbreak	Actual Stoping Width
Enter Best Cut (cm):	0	54	31	85.00		
Best Cut Grade(g/t):	4.34	Best Cut Content (cmg/t):		368.90		
Actual Cut (As determined from u/grnd mapping)						
Enter Actual Cut (cm):	22	54	20	96.00	0	96.00
Actual Cut Grade(g/t):	3.84	Actual Cut Content (cmg/t):		368.90		

Geological Conditions (off-reef face length)

Total Face Length (m):	Off-reef (m)	On-reef (m)	% On-reef	% Off-reef	Off-reef grade (g/t):
24	12.2	11.8	49.2	50.8	0

Summary sheet for: (WORKING PLACE) **Date: 12 January 2005**

	Planned	Actuals	Variance	
HW (cm)	0	22	22.00	*(negative values indicate underbreak)
Fw (cm)	31	20	-11.00	
FaceW (cm)	85	96	11.00	
Content	368.90	368.90	-	*negative means loss
Grade	**4.34**	**1.89**	**-2.45**	

The Decision, based on panel conditions summarised above

Overall Pay limit (g/t):	**3.18**	**Mortimer cut-off grade:**	**?**

Best Cut Adherence?	**Poor Stoping Width Control, adhere to the set best cut/stop!!**
Is the panel economically viable?	**NO!**
Action:	**Cut face length to on-reef portion and reduce overbreaking OR STOP the panel!**

Table A7 Panel evaluation for the 14th January 2005

Best Cut (As determined from the histogram):

	HW	Ch W	FW	Face Width	HW/FW Overbreak	Actual Stoping Width
Enter Best Cut (cm):	0	51	34	85.00		
Best Cut Grade(g/t):	4.10	Best Cut Content (cmg/t):		348.50		
Actual Cut (As determined from u/grnd mapping)						
Enter Actual Cut (cm):	9	69	9	87.00	0	87.00
Actual Cut Grade(g/t):	4.01	Actual Cut Content (cmg/t):		348.50		

Geological Conditions (off-reef face length)

Total Face Length (m):	Off-reef (m)	On-reef (m)	% On-reef	% Off-reef	Off-reef grade (g/t):
30	18.0	12.0	40.0	60.0	0

Summary sheet for: (WORKING PLACE) — **Date: 14 January 2005**

	Planned	Actuals	Variance	
HW (cm)	0	9	9.00	*(negative values indicate underbreak)
Fw (cm)	34	9	-25.00	
FaceW (cm)	85	87	2.00	
Content	348.50	348.50	-	*negative means loss
Grade	**4.10**	**1.60**	**-2.50**	

The Decision, based on panel conditions summarised above

Overall Pay limit (g/t):	**3.18**	**Mortimer cut-off grade:**	**?**

Best Cut Adherence?	**Poor Stoping Width Control, adhere to the set best cut/stop!!**
Is the panel economically viable?	**NO!**
Action:	**Cut face length to on-reef portion and reduce overbreaking OR STOP the panel!**

Table A8 Panel ABC evaluation for the 17th January 2005

Best Cut (As determined from the histogram):						
	HW	Ch W	FW	Face Width	HW/FW Overbreak	Actual Stoping Width
Enter Best Cut (cm):	0	63	22	85.00		
Best Cut Grade(g/t):	5.06	Best Cut Content (cmg/t):		430.10		
Actual Cut (As determined from u/grnd mapping)						
Enter Actual Cut (cm):	28	51	9	88.00	0	88.00
Actual Cut Grade(g/t):	4.89	Actual Cut Content (cmg/t):		430.10		
Geological Conditions (off-reef face length)						
Total Face Length (m):	Off-reef (m)	On-reef (m)	% On-reef	% Off-reef	Off-reef grade (g/t):	
30	24.0	6.0	20.0	80.0	0	

Summary sheet for: (WORKING PLACE) **Date: 17 January 2005**

	Planned	Actuals	Variance	
HW (cm)	0	28	28.00	*(negative values indicate underbreak)
Fw (cm)	22	9	-13.00	
FaceW (cm)	85	88	3.00	
Content	430.10	430.10	-	*negative means loss
Grade	**5.06**	**0.98**	**-4.08**	

The Decision, based on panel conditions summarised above

Overall Pay limit (g/t):	**3.18**	**Mortimer cut-off grade:**	**?**

Best Cut Adherence?	**Poor Stoping Width Control, adhere to the set best cut/stop!!**
Is the panel economically viable?	**NO!**
Action:	**Cut face length to on-reef portion and reduce overbreaking OR STOP the panel!!**

Table A9 Off-reef panel tolarence for panel XYZ with excessive HW waste

Best Cut (As determined from the histogram):						
	HW	Ch W	FW	Face Width	HW/FW Overbreak	Actual Stoping Width
Enter Best Cut (cm):	0	56	29	85.00		
Best Cut Grade(g/t):	4.40	Best Cut Content (cmg/t):		374.00		
Actual Cut (As determined from u/grnd mapping)						
Enter Actual Cut (cm):	22	56	18	96.00	11	107.00
Actual Cut Grade(g/t):	3.50	Actual Cut Content (cmg/t):		374.00		
Geological Conditions (off-reef face length)						
Total Face Length (m):	Off-reef (m)	On-reef (m)	% On-reef	% Off-reef	Off-reef grade (g/t):	
24	4.4	19.6	81.7	18.3	0	

Summary sheet for: (WORKING PLACE) — **Date: 12 January 2005**

	Planned	Actuals	Variance	
HW (cm)	0	22	22.00	*(negative values indicate underbreak)
Fw (cm)	29	18	-11.00	
FaceW (cm)	85	96	11.00	
Content	374.00	374.00	-	*negative means loss
Grade	**4.40**	**2.85**	**-1.55**	

The Decision, based on panel conditions summarised above

Overall Pay limit (g/t):	**3.18**	**Mortimer cut-off grade:**	**?**
Best Cut Adherence?	**Poor Stoping Width Control, adhere to the set best cut!!**		
Is the panel economically viable?	**NO!**		
Action:	**Cut face length to on-reef portion and reduce overbreaking OR STOP the panel!!**		

Table A10 Adhering to best mining principles improves the LOM

Best Cut (As determined from the histogram):

	HW	Ch W	FW	Face Width	HW/FW Overbreak	Actual Stoping Width
Enter Best Cut (cm):	0	56	29	85.00		
Best Cut Grade(g/t):	4.40	Best Cut Content (cmg/t):		374.00		

Actual Cut (As determined from u/grnd mapping)

	HW	Ch W	FW	Face Width	HW/FW Overbreak	Actual Stoping Width
Enter Actual Cut (cm):	0	56	18	74.00	11	85.00
Actual Cut Grade(g/t):	4.40	Actual Cut Content (cmg/t):		374.00		

Geological Conditions (off-reef face length)

Total Face Length (m):	Off-reef (m)	On-reef (m)	% On-reef	% Off-reef	Off-reef grade (g/t):
24	4.4	19.6	81.7	18.3	0

Summary sheet for: (WORKING PLACE) **Date: 12 January 2005**

	Planned	Actuals	Variance	
HW (cm)	0	0	-	*(negative values indicate underbreak)
Fw (cm)	29	18	-11.00	
FaceW (cm)	85	74	(11.00)	
Content	374.00	374.00	-	*negative means loss
Grade	**4.40**	**3.59**	**-0.81**	

The Decision, based on panel conditions summarised above

Overall Pay limit (g/t):	**3.18**	**Mortimer cut-off grade:**	**?**

Best Cut Adherence?	**Good stoping width control**
Is the panel economically viable?	**YES**
Action:	**Continue mining the panel with care!**

APPENDIX B

OFF-REEF TOLERANCE AT VARYING FACE LENGTHS WITH VARYING CONTAMINATION AT VARYING PAY LIMIT GRADES

Table B1 Grade variation in a pothole-affected 20m long panel on Half Level 1

face advance (m):	1			
UG2 Density (t/m^3):	3.8			
Face length (m):	20			
at sw (m):	90	95	100	105

1W Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.36	0.0	0	0	5.08	0.0	0	0	4.82	0.0	0	0	4.59	0.0	0
10	4.82	2.0	7	10	4.57	2.0	7	10	4.34	2.0	8	13	4.00	2.6	10
20	4.29	4.0	14	21	4.00	4.3	15	17	4.00	3.4	13	24	3.50	4.8	19
25	4.00	5.1	17	31	3.50	6.2	22	27	3.50	5.5	21	35	3.00	6.9	28
35	3.50	7.0	24	41	3.00	8.2	30	38	3.00	7.6	29	40	2.75	8.0	32
44	3.00	8.8	30	50	2.54	10.0	36	50	2.41	10.0	38	50	2.30	10.0	40
50	2.68	10.0	34	60	2.03	12.0	43	60	1.93	12.0	46	60	1.84	12.0	48
60	2.14	12.0	41	70	1.52	14.0	51	70	1.45	14.0	53	70	1.38	14.0	56
70	1.61	14.0	48	80	1.02	16.0	58	80	0.96	16.0	61	80	0.92	16.0	64
80	1.07	16.0	55	90	0.51	18.0	65	90	0.48	18.0	68	90	0.46	18.0	72
90	0.54	18.0	62	100	0.00	20.0	72	100	0.00	20.0	76	100	0.00	20.0	80
100	0.00	20.0	68												

1E Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef	Destructive Tonnage
0	5.27	0.0	0	0	4.99	0.0	0	0	4.74	0.0	0	0	4.52	0.0	0
10	4.74	2.0	7	10	4.49	2.0	7	16	4.00	3.1	12	12	4.00	2.3	9
24	4.00	4.8	16	20	4.00	4.0	14	26	3.50	5.2	20	23	3.50	4.5	18
34	3.50	6.7	23	30	3.50	6.0	22	37	3.00	7.3	28	34	3.00	6.7	27
43	3.00	8.6	29	40	3.00	8.0	29	40	2.84	8.0	30	40	2.71	8.0	32
50	2.64	10.0	34	50	2.50	10.0	36	50	2.37	10.0	38	50	2.26	10.0	40
60	2.11	12.0	41	60	2.00	12.0	43	60	1.90	12.0	46	60	1.81	12.0	48
70	1.58	14.0	48	70	1.50	14.0	51	70	1.42	14.0	53	70	1.36	14.0	56
80	1.05	16.0	55	80	1.00	16.0	58	80	0.95	16.0	61	80	0.90	16.0	64
90	0.53	18.0	62	90	0.50	18.0	65	90	0.47	18.0	68	90	0.45	18.0	72
100	0.00	20.0	68	100	0.00	20.0	72	100	0.00	20.0	76	100	0.00	20.0	80

Table B2 Grade variation in a pothole-affected 20m long panel on Half Level 2

face advance (m):		1			
UG2 Density (t/m^3):		3.8			
Face length (m):		20			
at sw (m):		90	95	100	105

2W Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.29	0.0	0	0	5.01	0.0	0	0	4.76	0.0	0	0	4.53	0.0	0
10	4.76	2.0	7	10	4.51	2.0	7	10	4.28	2.0	8	12	4.00	2.4	9
24	4.00	4.9	17	20	4.00	4.1	15	16	4.00	3.2	12	23	3.50	4.6	18
34	3.50	6.8	23	30	3.50	6.0	22	27	3.50	5.3	20	34	3.00	6.8	27
43	3.00	8.6	30	40	3.00	8.0	29	37	3.00	7.4	28	40	2.72	8.0	32
50	2.65	10.0	34	50	2.51	10.0	36	50	2.38	10.0	38	50	2.27	10.0	40
60	2.12	12.0	41	60	2.00	12.0	43	60	1.90	12.0	46	60	1.81	12.0	48
70	1.59	14.0	48	70	1.50	14.0	51	70	1.43	14.0	53	70	1.36	14.0	56
80	1.06	16.0	55	80	1.00	16.0	58	80	0.95	16.0	61	80	0.91	16.0	64
90	0.53	18.0	62	90	0.50	18.0	65	90	0.48	18.0	68	90	0.45	18.0	72
100	0.00	20.0	68	100	0.00	20.0	72	100	0.00	20.0	76	100	0.00	20.0	80

2E Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef	Destructive Tonnage
0	5.31	0.0	0	0	5.03	0.0	0	0	4.78	0.0	0	0	4.55	0.0	0
10	4.78	2.0	7	10	4.53	2.0	7	10	4.30	2.0	8	12	4.00	2.4	10
25	4.00	5.0	17	20	4.00	4.1	15	16	4.00	3.3	12	23	3.50	4.6	18
34	3.50	6.8	23	30	3.50	6.1	22	27	3.50	5.4	20	34	3.00	6.8	27
43	3.00	8.7	30	40	3.00	8.1	29	37	3.00	7.5	28	40	2.73	8.0	32
50	2.66	10.0	34	50	2.52	10.0	36	50	2.39	10.0	38	50	2.28	10.0	40
60	2.12	12.0	41	60	2.01	12.0	43	60	1.91	12.0	46	60	1.82	12.0	48
70	1.59	14.0	48	70	1.51	14.0	51	70	1.43	14.0	53	70	1.37	14.0	56
80	1.06	16.0	55	80	1.01	16.0	58	80	0.96	16.0	61	80	0.91	16.0	64
90	0.53	18.0	62	90	0.50	18.0	65	90	0.48	18.0	68	90	0.46	18.0	72
100	0.00	20.0	68	100	0.00	20.0	72	100	0.00	20.0	76	100	0.00	20.0	80

Table B3 Grade variation in a pothole-affected 20m long panel on Half Level 3

face advance (m):		1			
UG2 Density (t/m^3):		3.8			
Face length (m):		20			
at sw (m):		95	100	105	110

3W Half Level															
@ Best cut (95cm)				@ 6% o/break(100cm)				@ 12% o/break(105cm)				@ 18% o/break(110cm)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.41	0.0	0	0	5.14	0.0	0	0	4.89	0.0	0	0	4.67	0.0	0
10	4.87	2.0	7	10	4.63	2.0	8	10	4.40	2.0	8	14	4.00	2.9	12
20	4.33	4.0	14	22	4.00	4.5	17	18	4.00	3.7	15	25	3.50	5.0	21
26	4.00	5.2	19	32	3.50	6.4	24	28	3.50	5.7	23	36	3.00	7.2	30
35	3.50	7.1	25	42	3.00	8.3	32	39	3.00	7.8	31	50	2.34	10.0	42
45	3.00	8.9	32	50	2.57	10.0	38	50	2.45	10.0	40	60	1.87	12.0	50
50	2.71	10.0	36	60	2.06	12.0	46	60	1.96	12.0	48	70	1.40	14.0	59
60	2.16	12.0	43	70	1.54	14.0	38	70	1.47	14.0	56	80	0.93	16.0	67
70	1.62	14.0	51	80	1.03	16.0	46	80	0.98	16.0	64	90	0.47	18.0	75
80	1.08	16.0	58	90	0.51	18.0	53	90	0.49	18.0	72	100	0.00	20.0	84
90	0.54	18.0	65	100	0.00	20.0	61	100	0.00	20.0	80				
100	0.00	20.0	72												
3E Half Level															
@ Best cut (95cm)				@ 6% o/break(100cm)				@ 12% o/break(105cm)				@ 18% o/break(110cm)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef	Destructive Tonnage
0	5.58	0.0	0	0	5.30	0.0	0	0	5.05	0.0	0	0	4.82	0.0	0
10	5.02	2.0	7	10	4.77	2.0	8	10	4.55	2.0	8	17	4.00	3.4	14
20	4.46	4.0	14	25	4.00	4.9	19	21	4.00	4.2	17	27	3.50	5.5	23
28	4.00	5.7	20	34	3.50	6.8	26	31	3.50	6.2	25	38	3.00	7.6	32
37	3.50	7.5	27	43	3.00	8.7	33	41	3.00	8.1	32	50	2.41	10.0	42
46	3.00	9.3	33	50	2.65	10.0	38	50	2.53	10.0	40	60	1.93	12.0	50
50	2.79	10.0	36	60	2.12	12.0	46	60	2.02	12.0	48	70	1.45	14.0	59
60	2.23	12.0	43	70	1.59	14.0	53	70	1.52	14.0	56	80	0.96	16.0	67
70	1.67	14.0	51	80	1.06	16.0	61	80	1.01	16.0	64	90	0.48	18.0	75
80	1.12	16.0	58	90	0.53	18.0	68	90	0.51	18.0	72	100	0.00	20.0	84

Table B4 Grade variation in a pothole-affected 20m long panel on Half Level 4

face advance (m):	1			
UG2 Density (t/m^3):	3.8			
Face length (m):	20			
at sw (m):	95	100	105	110

4W Half Level

@ Best cut (95cm)				@ 6% o/break(100cm)				@ 12% o/break(105cm)				@ 18% o/break(110cm)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.41	0.0	0	0	5.14	0.0	0	0	4.89	0.0	0	0	4.67	0.0	0
10	4.87	2.0	7	10	4.63	2.0	8	10	4.40	2.0	8	14	4.00	2.9	12
20	4.33	4.0	14	22	4.00	4.5	17	18	4.00	3.7	15	25	3.50	5.0	21
26	4.00	5.2	19	32	3.50	6.4	24	29	3.50	5.7	23	36	3.00	7.2	30
35	3.50	7.1	25	42	3.00	8.3	32	39	3.00	7.8	31	40	2.80	8.0	33
45	3.00	8.9	32	50	2.57	10.0	38	50	2.45	10.0	40	50	2.34	10.0	42
50	2.71	10.0	36	60	2.06	12.0	46	60	1.96	12.0	48	60	1.87	12.0	50
60	2.16	12.0	43	70	1.54	14.0	38	70	1.47	14.0	56	70	1.40	14.0	59
70	1.62	14.0	51	80	1.03	16.0	46	80	0.98	16.0	64	80	0.93	16.0	67
80	1.08	16.0	58	90	0.51	18.0	53	90	0.49	18.0	72	90	0.47	18.0	75
90	0.54	18.0	65	100	0.00	20.0	61	100	0.00	20.0	80	100	0.00	20.0	84
100	0.00	20.0	72												

4E Half Level

@ Best cut (95cm)				@ 6% o/break(100cm)				@ 12% o/break(105cm)				@ 18% o/break(110cm)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef	Destructive Tonnage
0	5.11	0.0	0	0	4.85	0.0	0	0	4.62	0.0	0	0	4.41	0.0	0
10	4.60	2.0	7	10	4.37	2.0	8	10	4.16	2.0	8	9	4.00	1.9	8
22	4.00	4.4	16	18	4.00	3.5	13	14	4.00	2.7	11	21	3.50	4.1	17
32	3.50	6.3	23	28	3.50	5.6	21	24	3.50	4.9	19	32	3.00	6.4	27
41	3.00	8.3	30	38	3.00	7.6	29	35	3.00	7.0	28	40	2.65	8.0	33
50	2.56	10.0	36	50	2.43	10.0	38	50	2.31	10.0	40	50	2.21	10.0	42
60	2.04	12.0	43	60	1.94	12.0	46	60	1.85	12.0	48	60	1.76	12.0	50
70	1.53	14.0	51	70	1.46	14.0	53	70	1.39	14.0	56	70	1.32	14.0	59
80	1.02	16.0	58	80	0.97	16.0	61	80	0.92	16.0	64	80	0.88	16.0	67
90	0.51	18.0	65	90	0.49	18.0	68	90	0.46	18.0	72	90	0.44	18.0	75

Table B5 Grade variation in a pothole-affected 25m long panel on Half Level 5

face advance (m):		1			
UG2 Density (t/m^3)		3.8			
Face length (m):		25			
at sw (m):		90	95	100	105

5W

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.75	0.0	0	0	5.45	0.0	0	0	5.18	0.0	0	0	4.93	0.0	0
10	5.18	2.5	9	10	4.91	2.5	9	10	4.66	2.5	10	10	4.44	2.5	10
30	4.00	7.6	26	27	4.00	6.7	24	23	4.00	5.7	22	19	4.00	4.7	19
39	3.50	9.8	34	36	3.50	9.0	32	32	3.50	8.1	31	29	3.50	7.3	29
48	3.00	12.0	41	45	3.00	11.3	41	42	3.00	10.5	40	39	3.00	9.8	39
50	2.88	12.5	43	50	2.73	12.5	45	50	2.59	12.5	48	50	2.47	12.5	50
60	2.30	15.0	51	60	2.18	15.0	54	60	2.07	15.0	57	60	1.97	15.0	60
70	1.73	17.5	60	70	1.64	17.5	63	70	1.55	17.5	67	70	1.48	17.5	70
80	1.15	20.0	68	80	1.09	20.0	72	80	1.04	20.0	76	80	0.99	20.0	80
90	0.58	22.5	77	90	0.55	22.5	81	90	0.52	22.5	86	90	0.49	22.5	90
100	0.00	25.0	86	100	0.00	25.0	90	100	0.00	25.0	95	100	0.00	25.0	100

5E

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.72	0.0	0	0	5.42	0.0	0	0	5.15	0.0	0	0	4.90	0.0	0
10	5.15	2.5	9	10	4.88	2.5	9	10	4.64	2.5	10	10	4.41	2.5	10
30	4.00	7.5	26	26	4.00	6.6	24	22	4.00	5.6	21	18	4.00	4.6	18
39	3.50	9.7	33	35	3.50	8.9	32	32	3.50	8.0	30	29	3.50	7.2	29
48	3.00	11.9	41	43	3.11	10.7	38	42	3.00	10.5	40	39	3.00	9.7	39
50	2.86	12.5	43	50	2.71	12.5	45	50	2.58	12.5	48	60	1.96	15.0	60
60	2.29	15.0	51	60	2.17	15.0	54	60	2.06	15.0	57	72	1.37	18.0	72
70	1.72	17.5	60	70	1.63	17.5	63	70	1.55	17.5	67	84	0.78	21.0	84
80	1.14	20.0	68	80	1.08	20.0	72	80	1.03	20.0	76	96	0.20	24.0	96
90	0.57	22.5	77	90	0.54	22.5	81	90	0.52	22.5	86	108	-0.39	27.0	108
100	0.00	25.0	86	100	0.00	25.0	90	100	0.00	25.0	95	120	-0.98	30.0	120

Table B6 Grade variation in a pothole-affected 25m long panel on Half Level 6

face advance (m):		1			
UG2 Density (t/m^3):		3.8			
Face length (m):		25			
at sw (m):		90	95	100	105

6W Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.65	0.0	0	0	5.35	0.0	0	0	5.09	0.0	0	0	4.84	0.0	0
10	5.09	2.5	9	10	4.82	2.5	9	10	4.58	2.5	10	10	4.36	2.5	10
29	4.00	7.3	25	25	4.00	6.3	23	21	4.00	5.4	20	17	4.00	4.4	17
38	3.50	9.5	32	35	3.50	8.7	31	31	3.50	7.8	30	28	3.50	6.9	28
47	3.00	11.7	40	44	3.00	11.0	40	41	3.00	10.3	39	38	3.00	9.5	38
50	2.83	12.5	43	50	2.68	12.5	45	50	2.55	12.5	48	50	2.42	12.5	50
60	2.26	15.0	51	60	2.14	15.0	54	60	2.04	15.0	57	60	1.94	15.0	60
70	1.70	17.5	60	70	1.61	17.5	63	70	1.53	17.5	67	70	1.45	17.5	70
80	1.13	20.0	68	80	1.07	20.0	72	80	1.02	20.0	76	80	0.97	20.0	80
90	0.57	22.5	77	90	0.54	22.5	81	90	0.51	22.5	86	90	0.48	22.5	90
100	0.00	25.0	86	100	0.00	25.0	90	100	0.00	25.0	95	100	0.00	25.0	100

6E Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.19	0.0	0	0	4.92	0.0	0	0	4.67	0.0	0	0	4.45	0.0	0
10	4.67	2.5	9	10	4.43	2.5	9	14	4.00	3.6	14	10	4.00	2.6	10
23	4.00	5.8	20	19	4.00	4.7	17	25	3.50	6.3	24	21	3.50	5.4	21
33	3.50	8.2	28	29	3.50	7.2	26	36	3.00	9.0	34	33	3.00	8.2	33
42	3.00	10.6	36	39	3.00	9.8	35	40	2.80	10.0	38	40	2.67	10.0	40
50	2.60	12.5	43	50	2.46	12.5	45	50	2.34	12.5	48	50	2.23	12.5	50
60	2.08	15.0	51	60	1.97	15.0	54	60	1.87	15.0	57	60	1.78	15.0	60
70	1.56	17.5	60	70	1.48	17.5	63	70	1.40	17.5	67	70	1.34	17.5	70
80	1.04	20.0	68	80	0.98	20.0	72	80	0.93	20.0	76	80	0.89	20.0	80
90	0.52	22.5	77	90	0.49	22.5	81	90	0.47	22.5	86	90	0.45	22.5	90
100	0.00	25.0	86	100	0.00	25.0	90	100	0.00	25.0	95	100	0.00	25.0	100

Table B7 Grade variation in a pothole-affected 25m long panel on Half Level 7

face advance (m):	1			
UG2 Density (t/m^3)	3.8			
Face length (m):	25			
at sw (m):	90	95	100	105

7W Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.36	0.0	0	0	5.08	0.0	0	0	4.82	0.0	0	0	4.59	0.0	0
10	4.82	2.5	9	10	4.57	2.5	9	10	4.34	2.5	10	13	4.00	3.2	13
25	4.00	6.4	22	21	4.00	5.3	19	17	4.00	4.3	16	24	3.50	6.0	24
35	3.50	8.7	30	31	3.50	7.8	28	27	3.50	6.9	26	35	3.00	8.7	35
44	3.00	11.0	38	41	3.00	10.3	37	38	3.00	9.5	36	40	2.75	10.0	40
50	2.68	12.5	43	50	2.54	12.5	45	50	2.41	12.5	48	50	2.30	12.5	50
60	2.14	15.0	51	60	2.03	15.0	54	60	1.93	15.0	57	60	1.84	15.0	60
70	1.61	17.5	60	70	1.52	17.5	63	70	1.45	17.5	67	70	1.38	17.5	70
80	1.07	20.0	68	80	1.02	20.0	72	80	0.96	20.0	76	80	0.92	20.0	80
90	0.54	22.5	77	90	0.51	22.5	81	90	0.48	22.5	86	90	0.46	22.5	90
100	0.00	25.0	86	100	0.00	25.0	90	100	0.00	25.0	95	100	0.00	25.0	100

7E Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.27	0.0	0	0	4.99	0.0	0	0	4.74	0.0	0	0	4.52	0.0	0
10	4.74	2.5	9	10	4.49	2.5	9	10	4.27	2.5	10	12	4.00	2.9	12
24	4.00	6.0	21	20	4.00	5.0	18	16	4.00	3.9	15	23	3.49	5.7	23
34	3.50	8.4	29	30	3.50	7.5	27	26	3.50	6.6	25	34	2.99	8.5	34
43	3.00	10.8	37	40	3.00	10.0	36	37	3.00	9.2	35	40	2.71	10.0	40
50	2.64	12.5	43	60	2.00	15.0	54	50	2.37	12.5	48	50	2.26	12.5	50
60	2.11	15.0	51	72	1.40	18.0	65	60	1.90	15.0	57	60	1.81	15.0	60
70	1.58	17.5	60	84	0.80	21.0	76	70	1.42	17.5	67	70	1.36	17.5	70
80	1.05	20.0	68	96	0.20	24.0	87	80	0.95	20.0	76	80	0.90	20.0	80
90	0.53	22.5	77	108	-0.40	27.0	97	90	0.47	22.5	86	90	0.45	22.5	90
100	0.00	25.0	86	120	-1.00	30.0	108	100	0.00	25.0	95	100	0.00	25.0	100

Table B8 Grade variation in a pothole-affected 25m long panel on Half Level 8

face advance (m):		1			
UG2 Density (t/m^3):		3.8			
Face length (m):		25			
at sw (m):		90	95	100	105

8W Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.29	0.0	0	0	5.01	0.0	0	0	4.76	0.0	0	0	4.53	0.0	0
10	4.76	2.5	9	12	4.41	3.0	11	10	4.28	2.5	10	12	4.00	2.9	12
25	4.00	6.2	21	20	4.00	5.1	18	16	4.00	4.0	15	23	3.50	5.7	23
34	3.50	8.5	29	30	3.50	7.6	27	26	3.50	6.6	25	34	3.00	8.5	34
43	3.00	10.8	37	40	3.00	10.1	36	37	3.00	9.3	35	40	2.72	10.0	40
50	2.65	12.5	43	50	2.51	12.5	45	50	2.38	12.5	48	50	2.27	12.5	50
60	2.12	15.0	51	60	2.00	15.0	54	60	1.90	15.0	57	60	1.81	15.0	60
70	1.59	17.5	60	70	1.50	17.5	63	70	1.43	17.5	67	70	1.36	17.5	70
80	1.06	20.0	68	80	1.00	20.0	72	80	0.95	20.0	76	80	0.91	20.0	80
90	0.53	22.5	77	90	0.50	22.5	81	90	0.48	22.5	86	90	0.45	22.5	90
100	0.00	25.0	86	100	0.00	25.0	90	100	0.00	25.0	95	100	0.00	25.0	100

8E Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.31	0.0	0	0	5.03	0.0	0	0	4.78	0.0	0	0	4.55	0.0	0
10	4.78	2.5	9	10	4.53	2.5	9	10	4.30	2.5	10	12	4.00	3.0	12
25	4.00	6.2	21	20	4.00	5.1	18	16	4.00	4.1	16	23	3.50	5.8	23
34	3.50	8.5	29	30	3.50	7.6	27	27	3.50	6.7	25	34	3.00	8.5	34
43	3.00	10.9	37	40	3.00	10.1	36	37	3.00	9.3	35	40	2.73	10.0	40
50	2.66	12.5	43	50	2.52	12.5	45	50	2.39	12.5	48	50	2.28	12.5	50
60	2.12	15.0	51	60	2.01	15.0	54	60	1.91	15.0	57	60	1.82	15.0	60
70	1.59	17.5	60	70	1.51	17.5	63	70	1.43	17.5	67	70	1.37	17.5	70
80	1.06	20.0	68	80	1.01	20.0	72	80	0.96	20.0	76	80	0.91	20.0	80
90	0.53	22.5	77	90	0.50	22.5	81	90	0.48	22.5	86	90	0.46	22.5	90
100	0.00	25.0	86	100	0.00	25.0	90	100	0.00	25.0	95	100	0.00	25.0	100

Table B9 Grade variation in a pothole-affected 25m long panel on Half Level 9

face advance (m):		1													
UG2 Density (t/m^3):		3.8													
Face length (m):		25													
at sw (m):		95	100	105	110										
9W Half Level															
@ Best cut (95cm)				@ 6% o/break(100cm)				@ 12% o/break(105cm)				@ 18% o/break(110cm)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.41	0.0	0	0	5.14	0.0	0	0	4.89	0.0	0	0	4.67	0.0	0
10	4.87	2.5	9	10	4.63	2.5	10	10	4.40	2.5	10	14	4.00	3.6	15
26	4.00	6.5	23	22	4.00	5.6	21	18	4.00	4.6	18	25	3.50	6.3	26
35	3.50	8.8	32	32	3.50	8.0	30	28	3.50	7.1	28	36	3.00	9.0	37
45	3.00	11.2	40	42	3.00	10.4	40	39	3.00	9.7	39	40	2.80	10.0	42
50	2.71	12.5	45	50	2.57	12.5	48	50	2.45	12.5	50	50	2.34	12.5	52
60	2.16	15.0	54	60	2.06	15.0	57	60	1.96	15.0	60	60	1.87	15.0	63
70	1.62	17.5	63	70	1.54	17.5	48	70	1.47	17.5	70	70	1.40	17.5	73
80	1.08	20.0	72	80	1.03	20.0	57	80	0.98	20.0	80	80	0.93	20.0	84
90	0.54	22.5	81	90	0.51	22.5	67	90	0.49	22.5	90	90	0.47	22.5	94
100	0.00	25.0	90	100	0.00	25.0	76	100	0.00	25.0	100	100	0.00	25.0	105
9E Half Level															
@ Best cut (95cm)				@ 6% o/break(100cm)				@ 12% o/break(105cm)				@ 18% o/break(110cm)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.58	0.0	0	0	5.30	0.0	0	0	5.05	0.0	0	0	4.82	0.0	0
10	5.02	2.5	9	10	4.77	2.5	10	10	4.55	2.5	10	10	4.34	2.5	10
28	4.00	7.1	26	25	4.00	6.2	23	21	4.00	5.2	21	17	4.00	4.3	18
37	3.50	9.3	34	34	3.50	8.5	32	31	3.50	7.7	31	27	3.50	6.9	29
46	3.00	11.6	42	43	3.00	10.9	41	41	3.00	10.2	40	38	3.00	9.5	40
50	2.79	12.5	45	50	2.65	12.5	48	50	2.53	12.5	50	50	2.41	12.5	52
60	2.23	15.0	54	60	2.12	15.0	57	60	2.02	15.0	60	60	1.93	15.0	63
70	1.67	17.5	63	70	1.59	17.5	67	70	1.52	17.5	70	70	1.45	17.5	73
80	1.12	20.0	72	80	1.06	20.0	76	80	1.01	20.0	80	80	0.96	20.0	84
90	0.56	22.5	81	90	0.53	22.5	86	90	0.51	22.5	90	90	0.48	22.5	94
100	0.00	25.0	90	100	0.00	25.0	95	100	0.00	25.0	100	100	0.00	25.0	105

Table B10 Grade variation in a pothole-affected 25m long panel on Half Level 10

face advance (m):		1			
UG2 Density (t/m^3)		3.8			
Face length (m):		25			
at sw (m):		95	100	105	110

10W Half Level															
@ Best cut (95cm)				@ 6% o/break(100cm)				@ 12% o/break(105cm)				@ 18% o/break(110cm)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.41	0.0	0	0	5.14	0.0	0	0	4.89	0.0	0	0	4.67	0.0	0
10	4.87	2.5	9	10	4.63	2.5	10	10	4.40	2.5	10	14	4.00	3.6	15
26	4.00	6.5	23	22	4.00	5.6	21	18	4.00	4.6	18	25	3.50	6.3	26
35	3.50	8.8	32	32	3.50	8.0	30	28	3.50	7.1	28	36	3.00	9.0	37
45	3.00	11.2	40	42	3.00	10.4	40	39	3.00	9.7	39	40	2.80	10.0	42
50	2.71	12.5	45	50	2.57	12.5	48	50	2.45	12.5	50	50	2.34	12.5	52
60	2.16	15.0	54	60	2.06	15.0	57	60	1.96	15.0	60	60	1.87	15.0	63
70	1.62	17.5	63	70	1.54	17.5	48	70	1.47	17.5	70	70	1.40	17.5	73
80	1.08	20.0	72	80	1.03	20.0	57	80	0.98	20.0	80	80	0.93	20.0	84
90	0.54	22.5	81	90	0.51	22.5	67	90	0.49	22.5	90	90	0.47	22.5	94
100	0.00	25.0	90	100	0.00	25.0	76	100	0.00	25.0	100	100	0.00	25.0	105
10E Half Level															
@ Best cut (95cm)				@ 6% o/break(100cm)				@ 12% o/break(105cm)				@ 18% o/break(110cm)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.11	0.0	0	0	4.85	0.0	0	0	4.62	0.0	0	0	4.41	0.0	0
10	4.60	2.5	9	10	4.37	2.5	10	10	4.16	2.5	10	9	4.00	2.3	10
22	4.00	5.5	20	18	4.00	4.4	17	13	4.00	3.4	13	21	3.50	5.2	22
32	3.50	7.9	29	28	3.50	7.0	26	24	3.50	6.1	24	32	3.00	8.0	33
41	3.00	10.3	37	38	3.00	9.6	36	35	3.00	8.8	35	40	2.65	10.0	42
50	2.56	12.5	45	50	2.43	12.5	48	50	2.31	12.5	50	50	2.21	12.5	52
60	2.04	15.0	54	60	1.94	15.0	57	60	1.85	15.0	60	60	1.76	15.0	63
70	1.53	17.5	63	70	1.46	17.5	67	70	1.39	17.5	70	70	1.32	17.5	73
80	1.02	20.0	72	80	0.97	20.0	76	80	0.92	20.0	80	80	0.88	20.0	84
90	0.51	22.5	81	90	0.49	22.5	86	90	0.46	22.5	90	90	0.44	22.5	94
100	0.00	25.0	90	100	0.00	25.0	95	100	0.00	25.0	100	100	0.00	25.0	105

Table B11 Grade variation in a pothole-affected 30m long panel on Half Level 11

face advance (m):		1			
UG2 Density (t/m^3)		3.8			
Face length (m):		30			
at sw (m):		90	95	100	105

11W

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.75	0.0	0	0	5.45	0.0	0	0	5.18	0.0	0	0	4.93	0.0	0
10	5.18	3.0	10	10	4.91	3.0	11	10	4.66	3.0	11	10	4.44	3.0	12
22	4.00	6.5	22	20	4.36	6.0	22	23	4.00	6.9	26	19	4.00	5.7	23
32	3.50	9.5	32	27	4.00	8.0	29	33	3.50	9.8	37	29	3.50	8.7	35
42	3.35	12.5	43	36	3.50	10.8	39	42	3.00	12.6	48	39	3.00	11.8	47
46	3.00	13.9	47	45	3.00	13.5	49	50	2.59	15.0	57	50	2.47	15.0	60
50	2.88	15.0	51	50	2.73	15.0	54	60	2.07	18.0	68	60	1.97	18.0	72
60	2.30	18.0	62	60	2.18	18.0	65	70	1.55	21.0	80	70	1.48	21.0	84
70	1.73	21.0	72	70	1.64	21.0	76	80	1.04	24.0	91	80	0.99	24.0	96
80	1.15	24.0	82	80	1.09	24.0	87	90	0.52	27.0	103	90	0.49	27.0	108
90	0.58	27.0	92	90	0.58	27.0	97	100	0.00	30.0	114	100	0.00	30.0	120
100	0.00	30.0	103	100	0.00	30.0	108								

11E

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef	Destructive Tonnage
0	5.72	0.0	0	0	5.42	0.0	0	0	5.15	0.0	0	0	4.90	0.0	0
10	5.15	3.0	10	10	4.88	3.0	11	10	4.64	3.0	11	10	4.41	3.0	12
20	4.58	6.0	21	20	4.34	6.0	22	22	4.00	6.7	25	18	4.00	5.5	22
30	4.00	9.0	31	26	4.00	7.9	28	32	3.50	9.6	36	29	3.50	8.6	34
39	3.50	11.7	40	36	3.50	10.7	38	42	3.00	12.5	48	39	3.00	11.7	46
48	3.00	14.3	49	45	3.00	13.4	48	50	2.58	15.0	57	50	2.45	15.0	60
50	2.86	15.0	51	50	2.71	15.0	54	60	2.06	18.0	68	60	1.96	18.0	72
60	2.29	18.0	62	60	2.17	18.0	65	70	1.55	21.0	80	70	1.47	21.0	84
70	1.72	21.0	72	70	1.63	21.0	76	80	1.03	24.0	91	80	0.98	24.0	96
80	1.14	24.0	82	80	1.08	24.0	87	90	0.52	27.0	103	90	0.49	27.0	108
90	0.57	27.0	92	90	0.54	27.0	97	100	0.00	30.0	114	100	0.00	30.0	120
100	0.00	30.0	103	100	0.00	30.0	108								

Table B12 Grade variation in a pothole-affected 30m long panel on Half Level 12

face advance (m):	1			
UG2 Density (t/m^3)	3.8			
Face length (m):	30			
at sw (m):	90	95	100	105

12W Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.65	0.0	0	0	5.35	0.0	0	0	5.09	0.0	0	0	4.84	0.0	0
10	5.09	3.0	10	10	4.82	3.0	11	10	4.58	3.0	11	10	4.36	3.0	12
22	4.00	6.5	22	20	4.28	6.0	22	22	4.00	6.5	25	17	4.00	5.2	21
32	3.50	9.5	32	25	4.00	7.6	27	31	3.50	9.4	36	28	3.50	8.3	33
42	3.30	12.5	43	35	3.50	10.4	38	41	3.00	12.3	47	38	3.00	11.4	45
46	3.00	13.9	47	44	3.00	13.2	48	43	2.88	13.0	49	50	2.42	15.0	60
50	2.83	15.0	51	60	2.14	18.0	65	50	2.55	15.0	57	60	1.94	18.0	72
60	2.26	18.0	62	70	1.61	21.0	76	60	2.04	18.0	68	70	1.45	21.0	84
70	1.70	21.0	72	80	1.07	24.0	87	70	1.53	21.0	80	80	0.97	24.0	96
80	1.13	24.0	82	90	0.54	27.0	97	80	1.02	24.0	91	90	0.48	27.0	108
90	0.57	27.0	92	100	0.00	30.0	108	90	0.51	27.0	103	100	0.00	30.0	120
100	0.00	30.0	103					100	0.00	30.0	114				

12E Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef	Destructive Tonnage
0	5.19	0.0	0	0	4.92	0.0	0	0	4.67	0.0	0	0	4.45	0.0	0
10	4.67	3.0	10	10	4.43	3.0	11	10	4.20	3.0	11	10	4.00	3.1	12
23	4.00	6.9	24	19	4.00	5.6	20	14	4.00	4.3	16	21	3.50	6.4	26
33	3.50	9.8	33	29	3.50	8.7	31	25	3.50	7.5	29	33	3.00	9.8	39
42	3.00	12.7	43	39	3.00	11.7	42	36	3.00	10.7	41	43	2.52	13.0	52
46	2.79	13.9	47	50	2.46	15.0	54	43	2.65	13.0	49	50	2.23	15.0	60
50	2.60	15.0	51	60	1.97	18.0	65	50	2.34	15.0	57	60	1.78	18.0	72
60	2.08	18.0	62	70	1.48	21.0	76	60	1.87	18.0	68	70	1.34	21.0	84
70	1.56	21.0	72	80	0.98	24.0	87	70	1.40	21.0	80	80	0.89	24.0	96
80	1.04	24.0	82	90	0.49	27.0	97	80	0.93	24.0	91	90	0.45	27.0	108
90	0.52	27.0	92	100	0.00	30.0	108	90	0.47	27.0	103	100	0.00	30.0	120
100	0.00	30.0	103					100	0.00	30.0	114				

Table B13 Grade variation in a pothole-affected 30m long panel on Half Level 13

face advance (m):	1			
UG2 Density (t/m^3)	3.8			
Face length (m):	30			
at sw (m):	90	95	100	105

13W Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.36	0.0	0	0	5.08	0.0	0	0	4.82	0.0	0	0	4.59	0.0	0
10	4.82	3.0	10	10	4.57	3.0	11	10	4.34	3.0	11	13	4.00	3.9	15
22	4.00	6.5	22	21	4.00	6.4	23	17	4.00	5.1	19	24	3.50	7.1	28
32	3.50	9.5	32	31	3.50	9.4	34	27	3.50	8.2	31	35	3.00	10.4	41
42	3.13	12.5	43	41	3.00	12.3	44	38	3.00	11.3	43	43	2.60	13.0	52
46	3.00	13.9	47	50	2.54	15.0	54	43	2.73	13.0	49	50	2.30	15.0	60
50	2.68	15.0	51	60	2.03	18.0	65	50	2.41	15.0	57	60	1.84	18.0	72
60	2.14	18.0	62	70	1.52	21.0	76	60	1.93	18.0	68	70	1.38	21.0	84
70	1.61	21.0	72	80	1.02	24.0	87	70	1.45	21.0	80	80	0.92	24.0	96
80	1.07	24.0	82	90	0.51	27.0	97	80	0.96	24.0	91	90	0.46	27.0	108
90	0.54	27.0	92	100	0.00	30.0	108	90	0.48	27.0	103	100	0.00	30.0	120
100	0.00	30.0	103					100	0.00	30.0	114				

13E Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef	Destructive Tonnage
0	5.27	0.0	0	0	4.99	0.0	0	0	4.74	0.0	0	0	4.52	0.0	0
10	4.74	3.0	10	10	4.49	3.0	11	10	4.27	3.0	11	12	4.00	3.5	14
20	4.22	6.0	21	20	4.00	6.0	21	16	4.00	4.7	18	23	3.50	6.8	27
24	4.00	7.3	25	30	3.50	9.0	32	26	3.50	7.8	30	34	3.00	10.1	40
34	3.50	10.1	34	40	3.00	12.0	43	37	3.00	11.0	42	43	2.56	13.0	52
43	3.00	13.0	44	50	2.50	15.0	54	43	2.69	13.0	49	50	2.26	15.0	60
50	2.64	15.0	51	60	2.00	18.0	65	50	2.37	15.0	57	60	1.81	18.0	72
60	2.11	18.0	62	70	1.50	21.0	76	60	1.90	18.0	68	70	1.36	21.0	84
70	1.58	21.0	72	80	1.00	24.0	87	70	1.42	21.0	80	80	0.90	24.0	96
80	1.05	24.0	82	90	0.50	27.0	97	80	0.95	24.0	91	90	0.45	27.0	108
90	0.53	27.0	92	100	0.00	30.0	108	90	0.47	27.0	103	100	0.00	30.0	120
100	0.00	30.0	103					100	0.00	30.0	114				

Table B14 Grade variation in a pothole-affected 30m long panel on Half Level 14

face advance (m):	1			
UG2 Density (t/m^3):	3.8			
Face length (m):	30			
at sw (m):	90	95	100	105

14W Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.29	0.0	0	0	5.01	0.0	0	0	4.76	0.0	0	0	4.53	0.0	0
10	4.76	3.0	10	10	4.51	3.0	11	10	4.28	3.0	11	12	4.00	3.5	14
22	4.00	6.5	22	20	4.0	6.0	22	17	4.0	5.1	19	23	3.50	6.9	27
32	3.50	9.5	32	30	3.5	9.1	33	27	3.5	8.0	30	34	3.00	10.1	40
42	3.09	12.5	43	40	3.0	12.0	43	37	3.0	11.1	42	43	2.57	13.0	52
46	3.00	13.9	47	50	2.51	15.0	54	43	2.70	13.0	49	50	2.27	15.0	60
50	2.65	15.0	51	60	2.00	18.0	65	50	2.38	15.0	57	60	1.81	18.0	72
60	2.12	18.0	62	70	1.50	21.0	76	60	1.90	18.0	68	70	1.36	21.0	84
70	1.59	21.0	72	80	1.00	24.0	87	70	1.43	21.0	80	80	0.91	24.0	96
80	1.06	24.0	82	90	0.50	27.0	97	80	0.95	24.0	91	90	0.45	27.0	108
90	0.53	27.0	92	100	0.00	30.0	108	90	0.48	27.0	103	100	0.00	30.0	120
100	0.00	30.0	103					100	0.00	30.0	114				

14E Half Level

@ Best cut (90cm SW)				@ 6% o/break(95cm SW)				@ 12% o/break(100cm SW)				@ 18% o/break(105cm SW)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef	Destructive Tonnage
0	5.31	0.0	0	0	5.01	0.0	0	0	4.76	0.0	0	0	4.53	0.0	0
10	4.78	3.0	10	10	4.51	3.0	11	10	4.28	3.0	11	12	4.00	3.5	14
20	4.25	6.0	21	20	4.00	6.1	22	16	4.00	4.8	18	23	3.50	6.8	27
25	4.00	7.4	25	30	3.50	9.1	33	27	3.50	8.0	30	34	3.00	10.1	40
34	3.50	10.2	35	40	3.00	12.1	44	37	3.00	11.1	42	40	2.71	12.1	48
44	3.00	13.1	45	50	2.51	15.0	54	43	2.70	13.0	49	50	2.27	15.0	60
50	2.66	15.0	51	60	2.00	18.0	65	50	2.38	15.0	57	60	1.81	18.0	72
60	2.12	18.0	62	70	1.50	21.0	76	60	1.90	18.0	68	70	1.36	21.0	84
70	1.59	21.0	72	80	1.00	24.0	87	70	1.43	21.0	80	80	0.91	24.0	96
80	1.06	24.0	82	90	0.50	27.0	97	80	0.95	24.0	91	90	0.45	27.0	108
90	0.53	27.0	92	100	0.00	30.0	108	90	0.48	27.0	103	100	0.00	30.0	120
100	0.00	30.0	103					100	0.00	30.0	114				

Table B15 Grade variation in a pothole-affected 30m long panel on Half Level 15

face advance (m):		1			
UG2 Density (t/m^3):		3.8			
Face length (m):		30			
at sw (m):		95	100	105	110

15W Half Level															
@ Best cut (95cm)				@ 6% o/break(100cm)				@ 12% o/break(105cm)				@ 18% o/break(110cm)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.41	0.0	0	0	5.14	0.0	0	0	4.89	0.0	0	0	4.67	0.0	0
10	4.87	3.0	11	10	4.63	3.0	11	10	4.40	3.0	12	10	4.20	3.0	13
20	4.33	6.0	22	20	4.11	6.0	23	18	4.00	5.5	22	14	4.00	4.3	18
26	4.00	7.8	28	22	4.00	6.7	25	29	3.50	8.6	34	25	3.50	7.5	31
35	3.50	10.6	38	32	3.50	9.6	36	39	3.00	11.6	46	36	3.00	10.8	45
45	3.00	13.4	48	42	3.00	12.5	48	40	2.93	12.0	48	40	2.80	12.0	50
50	2.71	15.0	54	50	2.57	15.0	57	50	2.45	15.0	60	50	2.34	15.0	63
60	2.16	18.0	65	60	2.06	18.0	48	60	1.96	18.0	72	60	1.87	18.0	75
70	1.62	21.0	76	70	1.54	21.0	57	70	1.47	21.0	84	70	1.40	21.0	88
80	1.08	24.0	87	80	1.03	24.0	68	80	0.98	24.0	96	80	0.93	24.0	100
90	0.54	27.0	97	90	0.51	27.0	80	90	0.49	27.0	108	90	0.47	27.0	113
100	0.00	30.0	108	100	0.00	30.0	91	100	0.00	30.0	120	100	0.00	30.0	125

15E Half Level															
@ Best cut (95cm)				@ 6% o/break(100cm)				@ 12% o/break(105cm)				@ 18% o/break(110cm)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef	Destructive Tonnage
0	5.58	0.0	0	0	5.30	0.0	0	0	5.05	0.0	0	0	4.82	0.0	0
10	5.02	3.0	11	10	4.77	3.0	11	10	4.55	3.0	12	10	4.34	3.0	13
20	4.46	6.0	22	20	4.24	6.0	23	18	4.12	5.5	22	17	4.00	5.1	21
28	4.00	8.5	31	25	4.00	7.4	28	31	3.50	9.2	37	27	3.50	8.2	34
37	3.50	11.2	40	34	3.50	10.2	39	41	3.00	12.2	49	38	3.00	11.4	47
46	3.00	13.9	50	43	3.00	13.0	49	43	2.86	13.0	52	43	2.73	13.0	54
50	2.79	15.0	54	50	2.65	15.0	57	50	2.53	15.0	60	50	2.41	15.0	63
60	2.23	18.0	65	60	2.12	18.0	68	60	2.02	18.0	72	60	1.93	18.0	75
70	1.67	21.0	76	70	1.59	21.0	80	70	1.52	21.0	84	70	1.45	21.0	88
80	1.12	24.0	87	80	1.06	24.0	91	80	1.01	24.0	96	80	0.96	24.0	100
90	0.56	27.0	97	90	0.53	27.0	103	90	0.51	27.0	108	90	0.48	27.0	113
100	0.00	30.0	108	100	0.00	30.0	114	100	0.00	30.0	120	100	0.00	30.0	125

Table B16 Grade variation in a pothole-affected 30m long panel on Half Level 16

face advance (m):		1			
UG2 Density (t/m^3):		3.8			
Face length (m):		30			
at sw (m):		95	100	105	110

16W Half Level

@ Best cut (95cm)				@ 6% o/break(100cm)				@ 12% o/break(105cm)				@ 18% o/break(110cm)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage
0	5.41	0.0	0	0	5.14	0.0	0	0	4.89	0.0	0	0	4.67	0.0	0
10	4.87	3.0	11	10	4.63	3.0	11	10	4.40	3.0	12	10	4.20	3.0	13
20	4.33	6.0	22	20	4.11	6.0	23	18	4.00	5.5	22	14	4.00	4.3	18
26	4.00	7.8	28	22	4.00	6.7	25	29	3.50	8.6	34	25	3.50	7.5	31
35	3.50	10.6	38	32	3.50	9.6	36	39	3.00	11.6	46	36	3.00	10.8	45
45	3.00	13.4	48	42	3.00	12.5	48	40	2.93	12.0	48	40	2.80	12.0	50
50	2.71	15.0	54	50	2.57	15.0	57	50	2.45	15.0	60	50	2.34	15.0	63
60	2.16	18.0	65	60	2.06	18.0	48	60	1.96	18.0	72	60	1.87	18.0	75
70	1.62	21.0	76	70	1.54	21.0	57	70	1.47	21.0	84	70	1.40	21.0	88
80	1.08	24.0	87	80	1.03	24.0	68	80	0.98	24.0	96	80	0.93	24.0	100
90	0.54	27.0	97	90	0.51	27.0	80	90	0.49	27.0	108	90	0.47	27.0	113
100	0.00	30.0	108	100	0.00	30.0	91	100	0.00	30.0	120	100	0.00	30.0	125

16E Half Level

@ Best cut (95cm)				@ 6% o/break(100cm)				@ 12% o/break(105cm)				@ 18% o/break(110cm)			
Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef (m)	Destructive Tonnage	Off-reef %	Grade	Off-reef	Destructive Tonnage
0	5.11	0.0	0	0	5.30	0.0	0	0	5.05	0.0	0	0	4.41	0.0	0
10	4.60	3.0	11	10	4.77	3.0	11	10	4.55	3.0	12	10	3.97	3.0	13
22	4.00	6.5	23	20	4.24	6.0	23	18	4.12	5.5	22	17	3.66	5.1	21
32	3.50	9.5	34	25	4.00	7.4	28	31	3.50	9.2	37	27	3.20	8.2	34
41	3.00	12.4	45	34	3.50	10.2	39	41	3.00	12.2	49	38	2.74	11.4	47
46	2.75	13.9	50	43	3.00	13.0	49	43	2.86	13.0	52	43	2.50	13.0	54
50	2.56	15.0	54	50	2.65	15.0	57	50	2.53	15.0	60	50	2.21	15.0	63
60	2.04	18.0	65	60	2.12	18.0	68	60	2.02	18.0	72	60	1.76	18.0	75
70	1.53	21.0	76	70	1.59	21.0	80	70	1.52	21.0	84	70	1.32	21.0	88
80	1.02	24.0	87	80	1.06	24.0	91	80	1.01	24.0	96	80	0.88	24.0	100
90	0.51	27.0	97	90	0.53	27.0	103	90	0.51	27.0	108	90	0.44	27.0	113
100	0.00	30.0	108	100	0.00	30.0	114	100	0.00	30.0	120	100	0.00	30.0	125

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