

**SUB-LEVEL OPEN STOPING: DESIGN OF THE O640, L651 AND N659
SUB-LEVEL OPEN STOPES IN THE 3000 OREBODY OF THE MOUNT ISA
COPPER MINES, QUEENSLAND, AUSTRALIA**

L. SLOANE

Presented in partial fulfilment of the requirements for the degree:

M.ENG (MINING ENGINEERING)

IN THE FACULTY OF ENGINEERING

DEPARTMENT OF MINING

UNIVERSITY OF PRETORIA



OCTOBER 2010

© University of Pretoria



I hereby declare that this dissertation is my own unaided work. It is being submitted for the degree M. Eng (Mining) at the University of Pretoria. This work has not been submitted before for any other degree or examination at another tertiary education institution.

A handwritten signature in black ink, appearing to read 'Lomar Sloane', with a long horizontal stroke extending to the right.

Lomar Sloane

NAME OF AUTHOR

SYNOPSIS

Supervisor: Professor M.F. Handley

Department: Mining Engineering

University: University of Pretoria

Degree: M.Eng (Mining Engineering)

This dissertation will explore the process followed in the design of a sub-level open stope (SLOS) by using examples of actual stopes scheduled to be in production between August 2006 and February 2007. The main objective is to give the reader an understanding into sub-level open stoping and the design process followed. The objective here is to present a design methodology applicable to sublevel open stoping, but also to then bridge the gap between theory and practice by applying said methodology to an actual design example. The design examples used in this dissertation is based on the O640, L651 and N659 stopes in the 3000 Orebody of Xstrata Copper Operation's Mount Isa Mine, located in North-West Queensland, Australia. The actual design reports as required by the mine are attached in Annexure 1 through 3. Given the similarities of the designs, only O640 will be analysed comprehensively within the main content of this report, with L651 and N659 discussed specifically insofar issues that were unique to these stopes. With the design of O640, all aspects or design considerations as stipulated in the design process were discussed and analysed so as to define the final stope shape. These design considerations include:

- Faulting
- Grade Contours
- Existing Development
- Surrounding Fill masses
- Rock Mechanics

Once the final stope shape has been set, options regarding stope extraction will take place. This is where the initial stope layout takes place and where the engineer looks at the

advantages and disadvantages of all the different options available in mining the stope. In this phase, the most effective extraction option is decided upon. Once the engineer have decided a final stope shape and extraction option, the stope will be analysed in further detail referring to drilling, the amount of drawpoints, ventilation and other stoping requirements. These are all defined as stope design features and are considered a general summary of the stope design.

The design features phase is closely followed with all the safety considerations that have been taken into account since the stope design started. Main concerns and stope specific safety issues are discussed and possible solutions given. It is part of the work of the mine planning engineer to anticipate all possible safety issues and make the production department aware of what can be expected during the development, mining and filling activities of every stope. At this stage the design of the stope nears completion. The remainder of the design now goes into more detail and addresses the critical tasks that from part of sub-level open stoping. These include:

- Reserves and Scheduling
- Development and Drilling
- Production and Firing (Blasting)
- Ventilation
- Services
- Filling
- Economic Analysis

Although all of the abovementioned have already been mentioned during the design features phase, it is still required to give additional details so the different departments involved have an accurate idea of what to expect, when to expect it and therefore be able to sufficiently plan for it. It must be noted that it does happen that something may be “discovered” during any stage of the final design, which may render the current design undesirable. When this happens the stope must be re-designed until all issues have been resolved or at the least have been managed appropriately. Even though this report does not



go into detail with the L651 and N659 designs, these designs are included as they bring to light issues that may arise that are unique to individual stopes. L651 looks at how a design drastically changes when ore not planned for is discovered. N659 looks at what happens when a stope is the first to be mined in an area with inadequate infrastructure.

The main content of the dissertation discusses and explains the design procedure as it would take place at Mount Isa Mines, but it is still quite difficult to follow logically. For this reason a flowchart was included to give the reader a more comprehensive summary of the design process.



Sublevel Open Stoppe Design Methodology

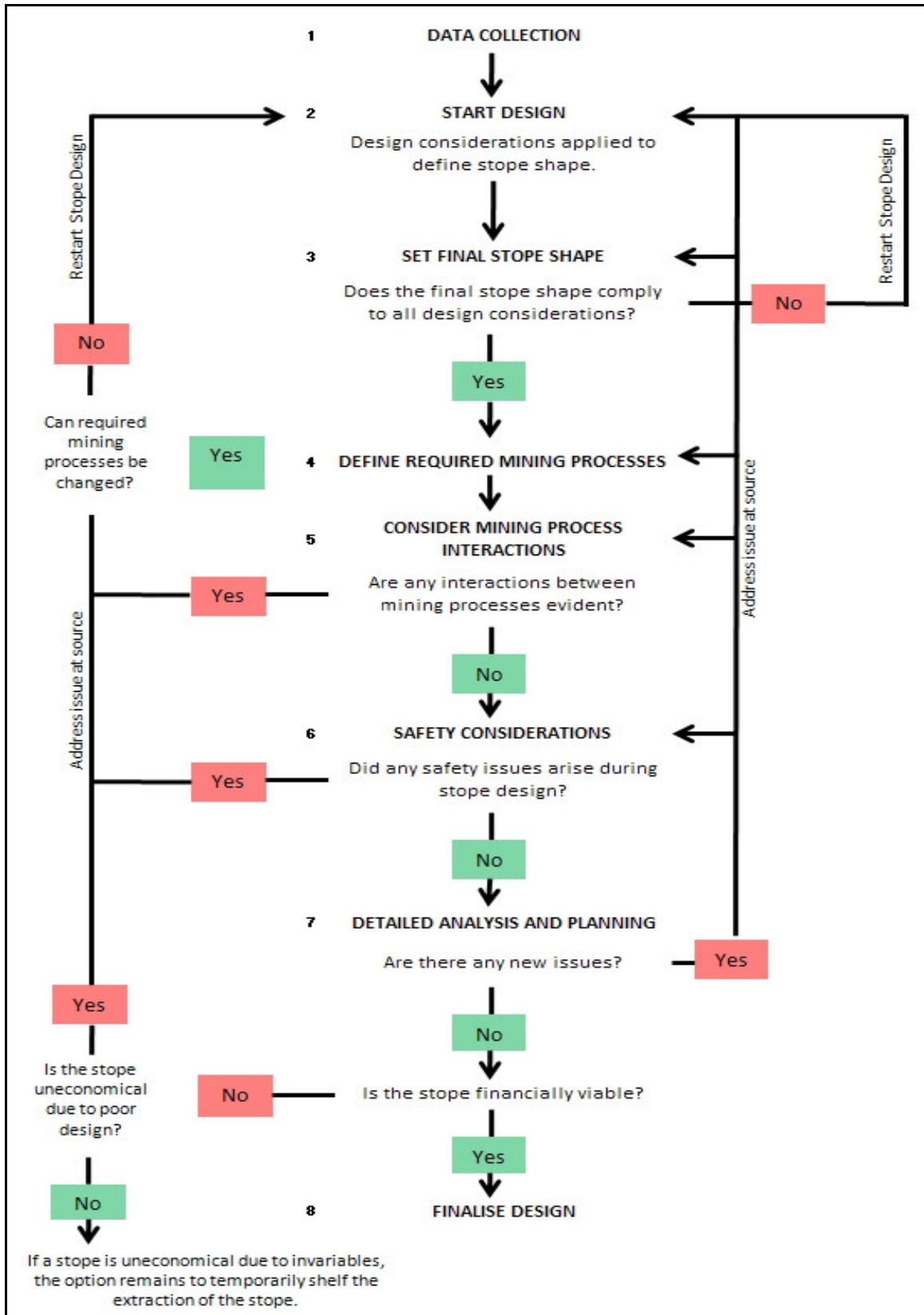




TABLE OF CONTENTS

1. Introduction	
1.1 Mine Background and General Information	1
1.2 Project Background and Literature Review	2
1.3 Design Requirements	7
2. Methodology	8
3. Sub-Level Open Stope Design	
3.1 The Planning Process	9
3.2 O640 Final Design	12
3.2.1 Design Considerations	
3.2.1.1 Faulting	13
3.2.1.2 Grade Contours	16
3.2.1.3 Existing Development	18
3.2.1.4 Surrounding Fillmasses	21
3.2.1.5 Rock Mechanics	23
3.2.2 Development and Drilling	
3.2.2.1 Development Requirements	25
3.2.2.2 Rehabilitation Requirements	26



3.2.2.3	Drilling Requirements	27
3.2.3	Production and Firing	
3.2.3.1	Mucking	34
3.2.3.2	Firing Sequence	35
3.2.4	Ventilation	37
3.2.5	Services	40
3.2.6	Filling	40
3.2.7	Extraction Options	41
3.2.8	Design Features	43
3.2.9	Safety Considerations	
3.2.9.1	Remote Mucking	44
3.2.9.2	Optechs	45
3.2.9.3	Bulkheads	45
3.2.10	Reserves and Scheduling	
3.2.10.1	Reserves	46
3.2.10.2	Scheduling	48
3.2.11	Economic Analysis	49



3.2.12 Stope Physical Data Summary	50
3.3 Considering Other Design Issues	
3.3.1 The L651 Stope	52
3.3.2 The N659 Stope	56
4. Conclusions	61
5. References	62
ANNEXURE 1	
ANNEXURE 2	
ANNEXURE 3	



NOMENCLATURE

1. ANFO	Ammonium Nitrate Fuel-Oil (explosives)
2. BC	Basement Contact
3. BCF	Basement Contact Fault
4. BCZ	Basement Contact Zone
5. CHF	Cemented Hydraulic Fill
6. CO	Cut-off
7. COLHW	Cut-off Long Hole Winze
8. Cu	Copper
9. DDR	Drill drive
10. DH	Downhole
11. DPT	Drawpoint
12. DSS	Mine electronic database
13. FAR	Fresh air raise
14. FD	Final Design
15. FPAC	Fill pass access
16. FWDR	Footwall drive
17. LOM	Life of Mine
18. MR	Main ring
19. Mucking	Broadly refers to load haul dump operations
20. NDR	North drive
21. NEDR	North-east drive
22. NEXC	North-east crosscut
23. NWDR	North-west drive
24. NWXC	North-west crosscut
25. OP	Ore pass
26. PD	Preliminary Design



27.RAR	Return air raise
28.SEXC	South-east crosscut
29.SLOS	Sub-Level Open Stope
30.SWXC	South-west crosscut
31.TUC	Trough undercut
32.UBC	Upper Basement Contact
33.UH	Uphole
34.XC	Crosscut



LIST OF FIGURES

Figure 1	Location of Mount Isa Mines	1
Figure 2	O640 Stope location	12
Figure 3	O640 Faulting (section looking north)	14
Figure 4	O640 Faulting (section looking south)	15
Figure 5	O640 Grade contours (section looking north-west)	17
Figure 6	O640 Existing development (section looking south-west)	19
Figure 7	25A Sublevel required development	19
Figure 8	26B Sublevel required development	20
Figure 9	27C Sublevel required development	20
Figure 10	27L Sublevel required development	21
Figure 11	O640 Surrounding fill masses	22
Figure 12	O640 Reduced crown stress (after Esterhuizen, 2005)	24
Figure 13	O640 Cut-off and COLHW layout	31
Figure 14	MR02 Boundary holes	32
Figure 15	MR06 Holes	32
Figure 16	Long section 45° north-east	33
Figure 17	O640 Mucking and tipping in P64 OP	34
Figure 18	O640 Firing sequence	36
Figure 19	25A Ventilation circuit	38
Figure 20	26B Ventilation circuit	38
Figure 21	27C Ventilation circuit	39
Figure 22	27L Ventilation circuit	39
Figure 23	L651 Preliminary design	52
Figure 24	L651 Preliminary design with 2005 block model	53
Figure 25	L651 Final design with additional required development	54
Figure 26	N659 Final design with no drawpoint level access	56



Figure 27	N659 showing surrounding infrastructure	58
Figure 28	Final design for 28B sublevel	59



LIST OF TABLES

Table 1	Horizontal development	26
Table 2	Rehabilitation requirements	27
Table 3	Production drilling	29
Table 4	Ring design parameters	30
Table 5	Development, drilling and ring firing requirements	37
Table 6	Mucking ventilation requirements	37
Table 7	O640 Stope design tonnes	47
Table 8	Financial results for O640	49

INTRODUCTION

1.1 MINE BACKGROUND AND GENERAL INFORMATION

Mount Isa Mines is a world class copper, silver, lead and zinc orebody located in the north-west of Queensland. The location of the mine is shown in Figure 1. Lead mineralization at this location was discovered in 1923 by John Campbell Miles with diamond drillholes only intersecting and indicating copper deposits in the early 1930's. Not much exploration or exploitation of the copper orebody was done until the early years of the Second World War when the demand for copper was high. The first copper was mined during this time. From here on the mining and further exploration of the orebody took off and the Mount Isa Mines were formed. Different orebodies were discovered and subsequently mined, but it wasn't until 1962 that the 3000 Orebody was discovered and five years later, 1967, the 3500 Orebody was discovered. Even though these orebodies were discovered during the 1960's, production from the first stope in the 3000 Orebody was only started in March 1993. The first stope in the 3500 Orebody only started in December 1996. In 1998 the initial name for the two Orebodies, known as Deep Copper, was changed to the Enterprise Mine.

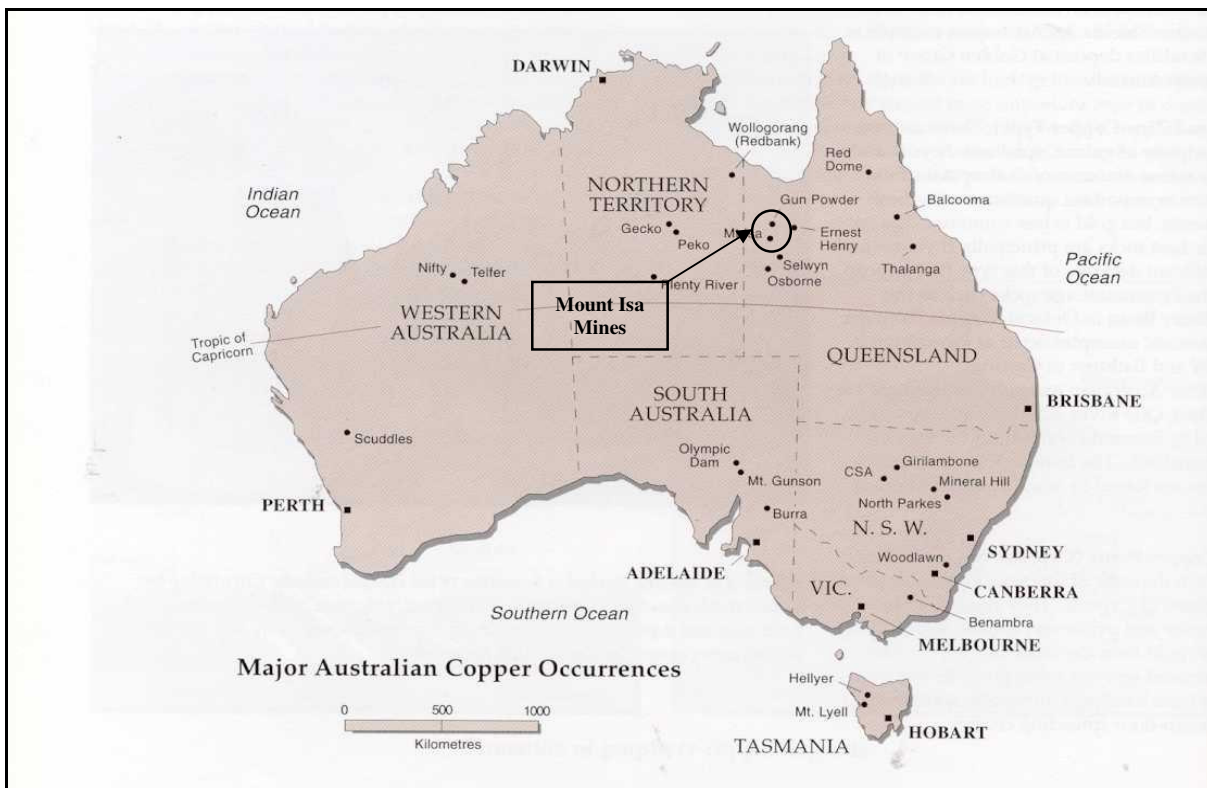


Figure 1: Location of the Mount Isa Mines

1.2 PROJECT BACKGROUND AND LITERATURE REVIEW

All stopes go through various design stages before actual work starts underground. These include the conceptual design phase, the preliminary design phase and lastly the final design phase. Conceptual and preliminary design phases are done years in advance, based on certain indicators such as copper price and relative copper cut-off grades at that time. The final design is done approximately 6 months to a year before planned development for a stope begins and is therefore much more representative of the current situation than previous designs.

The O640 stope was the next stope within the 3000 orebody that reached final design phase. This stope was scheduled to start production in August 2006. The opportunity was taken by the author to shed light on the process of sub-level open stope (SLOS) design as it is practically done in the industry. The main focus of this document is based on the design of the O640 stope, including all relevant design parameters and processes as required by the Mount Isa Mines. Two other stope designs, the L651 and N659 stope designs are also given due consideration in this document as it highlights other design considerations not found during the design of the O640 stope. These will focus on stope specific issues, which will explain the different challenges that are encountered when designing sub-level open stopes.

The author proposes a design procedure/methodology, which forms the basis of the stope designs. The design methodology proposed is mine and application specific, in this case sub-level open stoping. A major aspect of this dissertation, however, is also bridging the gap between theory (proposed design methodology) and actual application, where the design methodology is applied by means of an example stope design.

Design methodologies are by no means a new concept nor have they only cropped up over the last few years. Design methodologies have come a long way and have also evolved to encompass the current industry and current work ethics. The design procedure presented in this dissertation reflects the design process as it takes place at the Mount Isa Mines. Correlations are evident when compared to well published design processes such as given by Bieniawski (1992), but here the design process application is mine(s) specific. Bieniawski (1992) proposed a 10 step design process, which although originally intended

for use and application in the rock engineering field, is very much applicable and useful to other engineering design fields. These ten steps are:

1. Statement of the problem (performance objectives)
2. Functional requirements and constraints (design variables and design issues)
3. Collection of information
4. Concept formulation
5. Analysis of solution components
6. Synthesis and specifications for alternative solutions
7. Evaluation
8. Optimization
9. Recommendation
10. Implementation.

The process as used by Mount Isa engineers are basically an adjusted and site specific version, which has been refined over the years, of the methodology proposed by Bieniawski (1992). Ilbury and Sunter (2005) more recently proposed an “updated” way of looking at the planning process. Where Bieniawski (1992) is a linear and logical approach to design, Ilbury and Sunter (2005) is circular. Stacey (2009) does a remarkable and interesting comparison between the different approaches to planning and design as it is applicable to the mining industry. The available literature confirmed the validity of the design methodology as proposed and applied in this dissertation.

Design methodologies are great tools to arm the engineer with the correct approach to design. It basically directs the engineer as to how he/she needs to think to accomplish a task. Herein also lies the issue. It does not show the engineer how to design anything. Be it a stope, a mine or even just a single drive. It directs the thought process, but not how to actually do it.

There is lots of literature available on design principles and design concepts. The website OneMine.org is a veritable vault of mining and mining related papers and documents. This site contains over 54,000 mining related papers. A search of papers containing the phrase 'designs methods' yielded 16,000 documents. This is excessive and given the nature and aim of this dissertation, the author narrowed the search to 'sublevel open stope design' and related articles. This search yielded 234 papers with regards to the design of sublevel open stopes. Many of these papers refer to and are included in the larger colloquiums such as the SME Mining Engineering Handbook (Cummins et al., 1992), Design and Operation of Caving and Sublevel Stoping Mines (Steward, 1981), and others. These books were highly valuable in starting to narrow down how to design a sub level open stope. That is, ultimately, the objective of this dissertation.

The main issue the author experienced with most of the well known and published literatures was that most of it is either focussing on the larger issues regarding sub level open stoping, i.e., how to design a sub level open stope mine and its associated governing factors (This is also the particular focus of Hustralid et al. (1982), Hustralid and Bullock (2001), Gertsch et al. (1998) and Steward (1981)), or much more technical and stope specific issues relating to sublevel open stopes such as rock mechanics and associated geotechnical issues (Pakalnis, 1986).

Hustralid et al. (1982) is fairly comprehensive with regards to all aspect pertaining to sub level stoping. It covers factors that influences and requires due consideration when designing sub level stopes. As mentioned earlier, however, this is also in the form of a colloquium. Hustralid et al. (1982) briefly describes sublevel open stopes in general and the remainder of the contained literature are examples of stopes at mines throughout the world and the uniqueness pertaining to each of the mines. This gives the reader a broad understanding of the concept of sublevel stoping. Hustralid et al. (1982) does not, however, contain any reference to design methodologies or design processes. Hustralid et al. (1982) mainly focus on the technical/engineering considerations of SLOS mine design.

This is almost exactly the same focus as pertained in Cummins et al. (1992), the SME Mining Engineering Handbook. Pakalnis (1986) on the other hand approaches SLOS design differently than Hustralid et al. (1982) and Cummins et al. (1992). Here is an example of SLOS design, but it is rock mechanics orientated and focuses on designing a SLOS based on rock mechanics principles. Although this forms an important part of all

SLOS designs, there are other critical parts of the design process that is not given due consideration here. The contained works of Pakalnis (1986) is interesting as it provides insight into SLOS design at the Ruttan Mine in Canada, but it does tend to suggest that this is what SLOS design would be like if done by rock mechanics.

It is evident that there is no shortage of literature on sublevel open stopes. In fact, it seems every major SLOS mine in the world is represented by a published paper. In some cases there are multiple papers. Steward (1981), another colloquium of papers, contains works on a SLOS mine in Finland. This is another generic paper on SLOS's; however, there is a more technical view on the actual requirements of individual SLOS's. The information here is considered closer to what the author aims with regards to the design of a sublevel open stope.

Literature was found to be available on generic design methodologies, sublevel open stope mine design concepts and mine layouts, highly technical papers dealing with specific sublevel stoping issues and so on. The author, however, was specifically interested in what literature is available that deals with the actual design of an open stope. Only two papers were found that deals with this subject directly.

Villaescusa (2004) attempts to quantify the performance of sublevel open stopes via the design process. He describes design methodology applicable for the design of a SLOS, the finer designs points, the stope extraction sequence and finally the reconciliation of actual vs. planned by means of cavity monitoring. A major focus of this paper is that the design process should include for reconciliation of stopes (feedback) once it has been mined. This is in order to improve future stope designs. Although the focus of Villaescusa (2004) is not specifically how to design sublevel open stopes, the information contained largely covers the methodology of how to design an individual sublevel open stope. This is very close to the aim of this dissertation, where theory is presented and practically applied by means of a design example.

Hustralid and Bullock (2001) contains a paper by Soma Uggalla, which discusses the design and planning practice as it takes place at the Olympic Dam Mine in South Australia. The aspects covered in this paper basically cover the aspects considered in the design example of this dissertation. In other words, there is a very strong similarity between how sub level open stopes are designed at Mount Isa Mines and the Olympic Dam Mine. Again,

however, this paper is limited to theoretical considerations and there is no example of how a design is done in practice.

It became evident that there is very little published with regards to actual sublevel open stope design examples. Generic design methodologies such as given by Bieniawski (1992) and even application and mining method specific design methodologies such as Villaescusa (2004) are available, but the author could not find any literature where theory is bridged and practically applied by means of a design example. Perhaps this is because it may be considered an extremely mine or application specific thing to do.

This dissertation, therefore, is considered something of a novelty in that it proposes a design methodology for the design of sublevel open stopes and then also explains the application of said design methodology by means of a design example. Neither the design methodology nor the design of a sublevel open stope is a new concept. In fact, most likely hundreds if not thousands of mining engineers have in their careers designed a sublevel open stope. None, however, seems to have attempted to share this knowledge. That is done in subsequent chapters of this dissertation.

1.3 DESIGN REQUIREMENTS

Design the O640, L651 and N659 sub-level open stopes within the 3000 orebody so that it complies with all relevant mine codes of practice and government regulations. The final designs for these stopes must prove the stopes able to be mined effectively, profitably and above all else safely.

Once the designs are completed it will be scrutinized and approved by all parties involved in the design; development, drilling, firing (blasting) and filling of the stopes.

The O640 design was completed in mid November 2005 and the sign-off sheet (copy) is attached in Annexure 1. L651 and N659 are only scheduled to produce much later and therefore no sign-off sheets are presented.

In order to make a valid and financially viable SLOS design, certain key aspects need to be identified and established throughout the contents of this report. The principle of these includes:

- Designing a final stope shape
- Designing the required development for stope access
- Designing a drill layout for stope firing (blasting)
- Determining an effective firing (blasting) sequence for the stope
- Designing and determining other stope requirements including mucking (loading), ventilation, stope filling, and other considerations.
- This design examples will address and explain all the above mentioned aspects in an effort to design a sub-level open stope that will be profitable, but most importantly, will be safe to mine.

2. METHODOLOGY

The final design was performed in a manner which closely represents the process as it would take place underground once mining activities relating to that stope starts. Initially the design looks at all factors governing the final stope shape. After a stope shape has been set, the design will continue with the development design pertaining to accessing the stope, followed by drilling, firing, mucking, ventilation, filling and the stope economic evaluation, once all data have been gathered. Should serious issues be encountered during any stage of the design, certain alterations to the stope design may be required to compensate for this and changes may be required as far back as the initial stope shape defining stage. The whole design procedure is in essence iterative, with changes continuously taking place during all stages of the design. The followed methodology closely resembles that of Villaescusa (2004) and even broader ones as postulated by Bieniawski (1992).

Once the final design is complete, mining activities will commence underground. The setting up of the stope may take several months and other stopes in the area may be at some other stage in the mining process be it firing (blasting), filling, etc., but any one of these can over the time periods involved cause the final design to become unsuitable. This does not constitute a re-design, but the planning engineer must continuously inspect the progress of designed stopes underground and monitor possible influences to the final design and rectify these changes on the go. As a contingency, the design process for sub-level open stopes have been split, with the final design being the first and major design stage and a ring design stage following the final design once all development for the stope is complete and drilling is about to commence.

The ring design is not discussed here, but in short is when the final drilling plans are done (based on the final design drill layouts), but compensating for any deviations from the original final design. It must be noted that at this stage geology and grade estimates would have been updated, based on development done around and though the stope boundaries, so the planning engineer will now have a better understanding of how the stope will perform. In almost all cases only minor changes to the final design will take place to optimise stope extraction.

3. SUB-LEVEL OPEN STOPE DESIGN

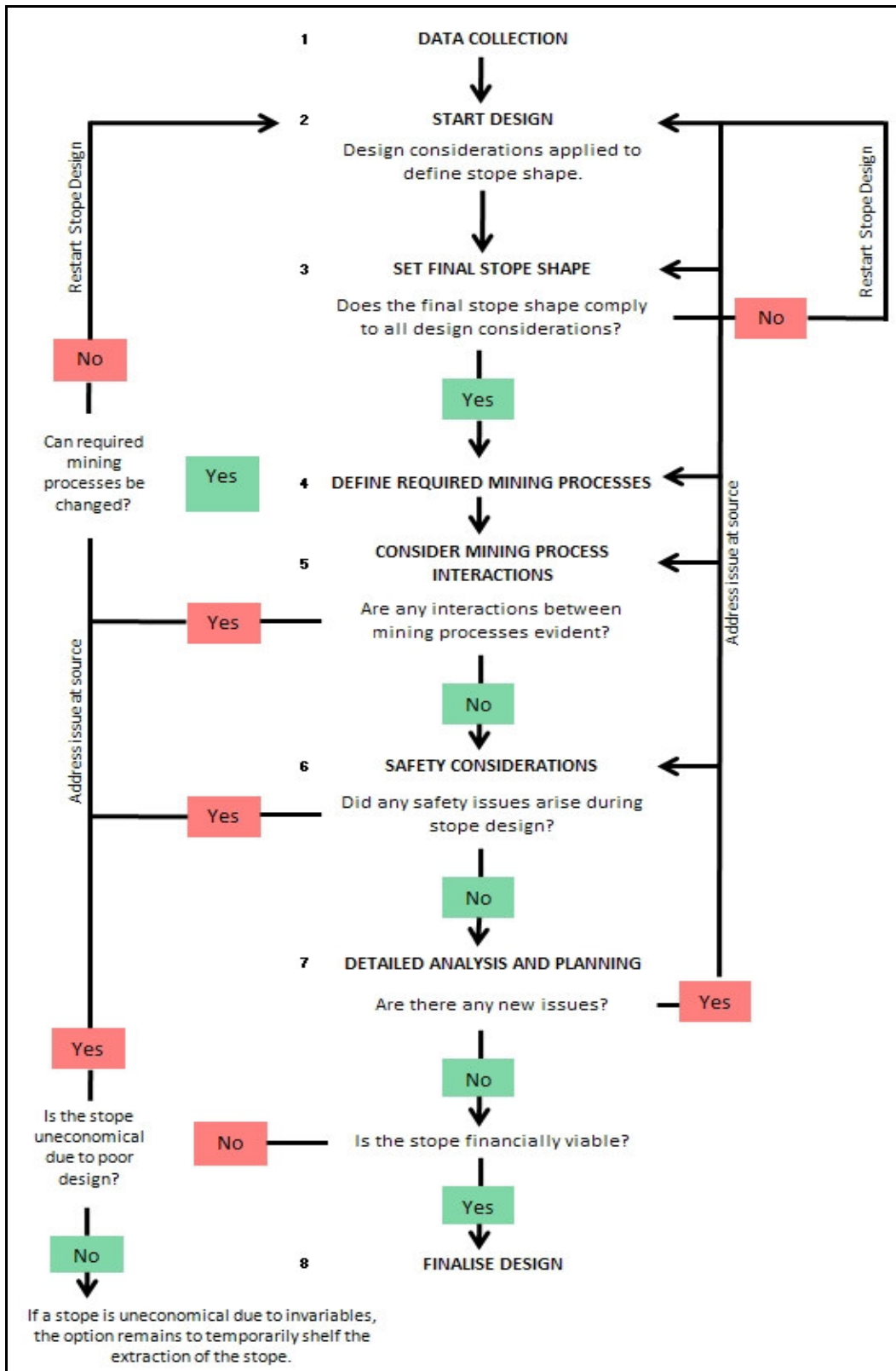
3.1 THE PLANNING PROCESS

The mine planning engineer lies at the heart of all design work done. Given the nature and most likely the sheer size and complexity of even some smaller mining operations, the planning engineer needs to do his/her work in an orderly and pre-determined fashion. Because of this it is necessary to follow, as closely as possible, a design methodology as given on the next page. This ensures that all aspects of the design process and area responsibilities that fall under the care of the planning engineer are thoroughly investigated. In no way does this mean that the duties of the planning engineer are either monotonous or straightforward. Every section of the mine and every stope for that matter will encompass its own unique set of challenges and features, which makes every single stope design unique and different to the next. The methodology used by the planning engineer to design stopes and see them through to reconciliation is called the planning process.

The planning process encompasses the whole design philosophy of a sub-level open stope and is not confined to the design of a stope only. The planning process describes the initial stope design to final stope design continuing though to stope production, stope filling and finally stope reconciliation. Planning plays a major role in each of these areas.

The planning of any given stope will always follow a set design process. First of these are the conceptual design, followed by the preliminary design and then the final design. These are all stages of design where no actual underground work has been done. Each of these stages plays an important part in the overall mine plan. For instance, the conceptual design gives valuable information that helps with long term mine planning (LOM planning). The conceptual design is largely based on assumptions and estimates with relatively limited measurables.

The preliminary design is done in much more detail than the conceptual design and information and figures generated here are used in the next year's annual mine budget. At this stage nearby stopes and development drives in the area of the planned stope have already been mined, which gives a much better idea of the surrounding area. The preliminary design therefore entails less assumptions and estimates than the conceptual design.



Sublevel Open Stope Design Methodology

The final design is the last phase of design work done before physical mining activities will start on the stope. This does not mean that no development for the stope has been done. In many cases development for one stope also serves as development for another stope in order to reduce the amount of overall development. At this stage the confidence in area geology and geotechnics are very high given the amount of mining already done. At the final design phase confidence in measurements and facts run close to the 90% mark.

In no way is any design the work of one person. The planning engineer will do the actual design, but will liaise with several other professionals during this time. Three fields of expertise work closely together to produce the stope final design. These include the geologist, the rock mechanics engineer and the mine surveyor. They are the primary information sources and no design is possible before information regarding the area has been gathered from them. This report will therefore include extractions from geology and rock mechanics notes prepared specifically for the final design of O640 in order to explain reasons why certain decisions were made.

To do a sub-level open stope design, the following information is required:

- The preliminary stope design
- Geological data
 - Diamond drill hole data and stratigraphy
 - Block models (grade indicator)
 - Faulting
- Survey data
- Relevant mining standards and regulations
- Key indicators – Metal prices, development unit costs, equipment scheduling and availability, and others.

Once all these are known to the highest degree of certainty, the final design of the stope can begin

3.2 O640 FINAL DESIGN

Sub-level open stoping is a complicated procedure with many deviations from the generic examples taught in universities around the world. For this reason a design example is used to explain the design procedure as it applies to Mount Isa Mines and the sub-level open stoping unique to this mine. All that follows is extracted from the actual O640 stope final design done by the author as well as explanations as to how and why it is done.

“O640 stope is a 1-SLOS stope located centrally within the 3000 orebody. This stope is currently scheduled for production in August 2006.” (Quoted from Sloane, 2006)

The “O” in the stope name is derived from dividing of longitudinal lines (eastings) into alphabetical sections and the “640” gives the mean location of the stope in relation to latitudinal lines (northings). This is illustrated in Figure 2. Figure 2 also shows current active stopes, filled stopes and stopes yet to be mined.

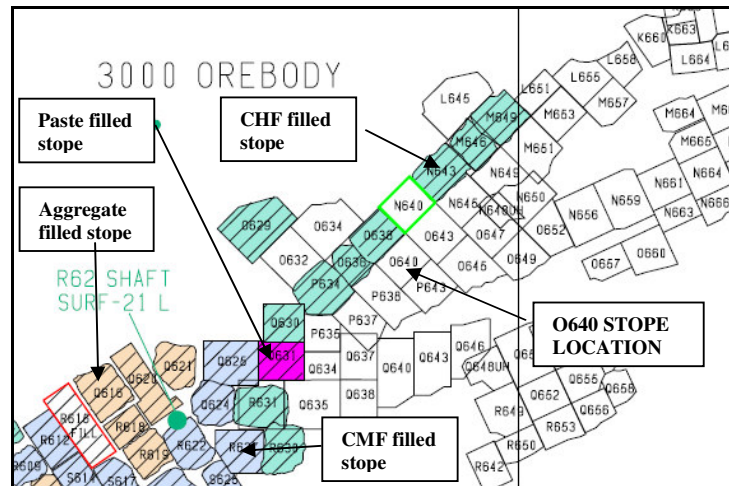


Figure 2: O640 stope location

Active stopes, which are indicated by the red border around the stope shape, shows that these stopes are in some stage of mining. Filled stopes are completely coloured. The colour of the block indicates the type of backfill used to fill the stope. Different types of backfill used at Mount Isa Mines includes cemented hydraulic fill (CHF), cemented mullock fill (CMF), aggregate and paste fill. Paste was the latest addition to 3000 orebody and it is planned to fill all future stopes with paste only. CHF will be used as a back-up fill system.

The scheduling engineers at the mine determine the time when a stope is up for production and the planning engineer does all designs accordingly.

3.2.1 DESIGN CONSIDERATIONS

“Several factors were considered in this design and will be discussed under separate headings as follows: Faulting, Grade contours, Existing Development, Surrounding Fillmasses and Rock Mechanics.” (Quoted from Sloane, 2006)

3.2.1.1 FAULTING

“The 30N N62 Dark Green Fault intersects the crown of the stope at 6400mN. This is an area in which crown overbreak is a possibility and is discussed in more detail in Section 3.2.1.5. O640 is also intersected by the 30N Q61 Dark Blue Fault roughly through the middle of the stope at 2120mRL towards the bottom and will intersect the drawpoints on 27L.

The upper basement contact (UBC) forms the western boundary of O640. Some issues with dilution are possible where the basement contact dips steeply, particularly where intersected by the 30N N62 and 30N Q61 Faults. The basement contact has in the past caused stability problems drawpoints and stope cut-offs, hence adequate measures must be taken once development enters this zone.” (Quoted from Sloane, 2006)

The geologist supplies the planning engineer with the relevant geological information needed to start the stope design with. Two critical components are required from the geologist. These are the faults that intersect the stope and the grade contours (Section 3.2.1.2) that lies within the stope. Faulting in the stope gives the engineer a very good indication as to how the stope will perform in terms of overbreaking and possible failure areas once mining starts. It will be noted that in this case there are three major fault systems that run through the stope. The location of these faults in relation to the stope is shown in Figures 3 and 4.

Note the bottom portion of the stope in Figure 3. This area is where the initial stope shape (shape from preliminary design) intersects the basement contact fault zone (BC in short). The BC basically determines the stope’s lower boundary as mineralization abruptly ends on

this contact. This contact (BC) is in essence a large shear zone, which denotes the one major boundary of the total mine reserve and no copper is found beyond this zone.

Ground conditions in the BC zone are usually poor and require significant support to keep the area operational and safe for the duration of the stope life. Generally stopes are planned to stop all development once the BC is intersected, but in some cases it is necessary to go through or into the BC in order to reach all mineralization above this zone. One characteristic of the BC is that mineralization tends to be at its highest just above this zone, hence the occasional need to intersect the contact.

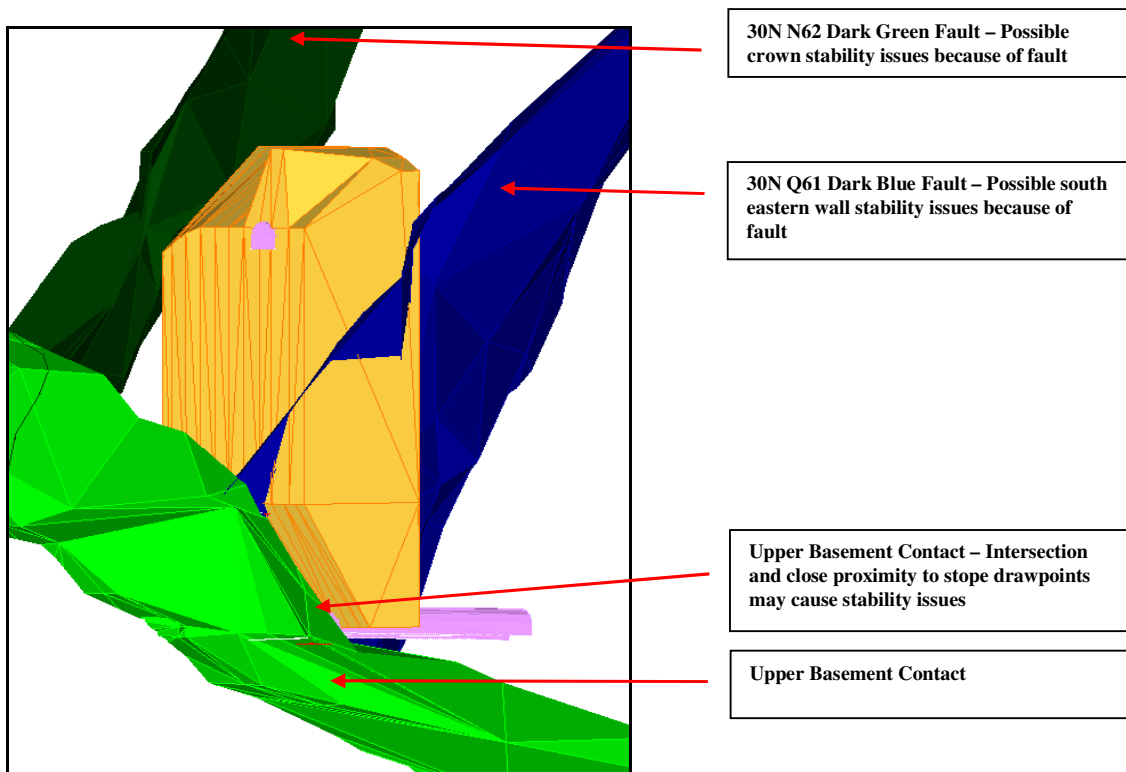


Figure 3: O640 Faulting (Section looking north)

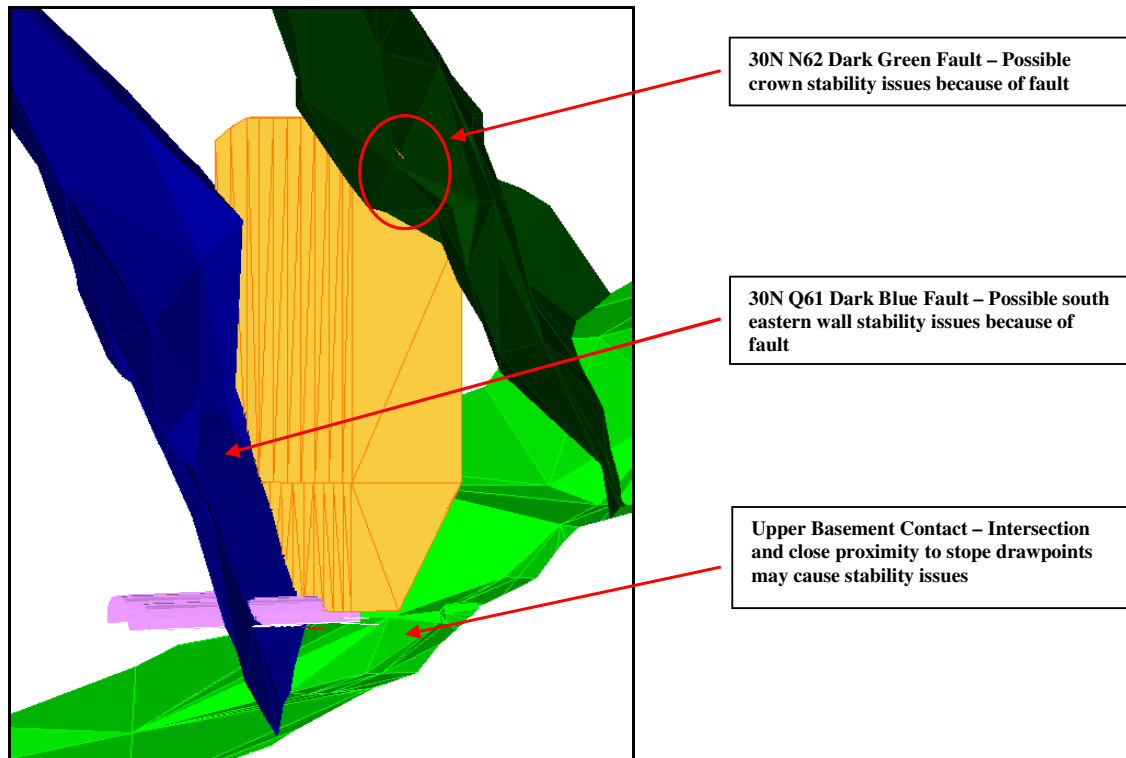


Figure 4: O640 Faulting (Section looking south)

Both of the other two faults indicated terminate on the BC, which creates problems if this intersection falls within the stope boundaries. This is also the case in O640 where the Dark Blue Fault intersects the BC at drawpoint level. This is probably the most undesirable situation as the drawpoints must maintain integrity throughout the whole stope life and is the only area from where ore can be extracted. Should the drawpoints fail, then all remaining ore is most likely lost. In the case of O640 options were limited. Changes to preliminary stope shapes are usually restricted to small variations, as any major changes will impact all future stopes in the area. So changing the stope shape to be more suitable in this case would be extremely difficult and expensive. The only realistic approach would be to install the maximum amount of support available and then to load the stope empty before stope deterioration reaches levels rendering the stope unsafe for continued loading. Should it not be possible to mine the stope safely by installing additional support, then ultimately a complete re-design would be required.

Figure 4 highlights another area of concern. This area is indicated in the figure where the Dark Green Fault intersects the crown of the stope. Stope crowns and floors (also called footprints) are designed within the cut-off grade contour (2% Cu within 3000 orebody). Overbreak usually causes areas outside these contours to fall in, hence causing grade dilution. Even though overbreak usually contains some copper, it still impacts negatively on overall stope grade and increases overall stope unit costs. Failure towards the sides of the stope is usually not so much of a problem as this most likely still fall within high grade areas, but this is likely then failure into a future stope's boundaries. This will affect the design and profitability of said stope.

When designing a stope it is wise to review the performance of other similar stopes in the surrounding area. The 3000 orebody is known to have good competent ground despite the presence of faults. Overbreak at fault intersections do occur, but is usually much less than in other parts of the mine. Given the average stope size, it will also mean that O640 can be mined in relatively little time, so stope deterioration should not be a problem. The decision was made to try and leave the stope shape to minimize the impact it would have on future stopes should there be significant shape changes. Where faults intersect drives and the crown of the stope, it would be more prudent to install ground control systems to try and maintain stope integrity for the durations of the stope life.

3.2.1.2 GRADE CONTOURS

"The stope lies almost entirely within the 2.0% kriged Cu contour. Approximately 30% of the stope lies within the 5.0% kriged Cu contour with a small 8.0% pod close to the top of the stope. The Ore Reserve/ Mineral Resource Estimate (2003-2004) for O640 were 230,863t @ 4.62%Cu. The 2005 Block Model based on the O640 preliminary design shape calculated 225,634t @ 4.79%Cu. The latest calculation, based on the new final design shape in which the north-western boundary was moved 1m in, yields a design tonnage for O640 at 211,611t @ 4.77%Cu. The Geology Note can be seen in Annexure 1, Appendix 1."
(Quoted from Sloane, 2006)

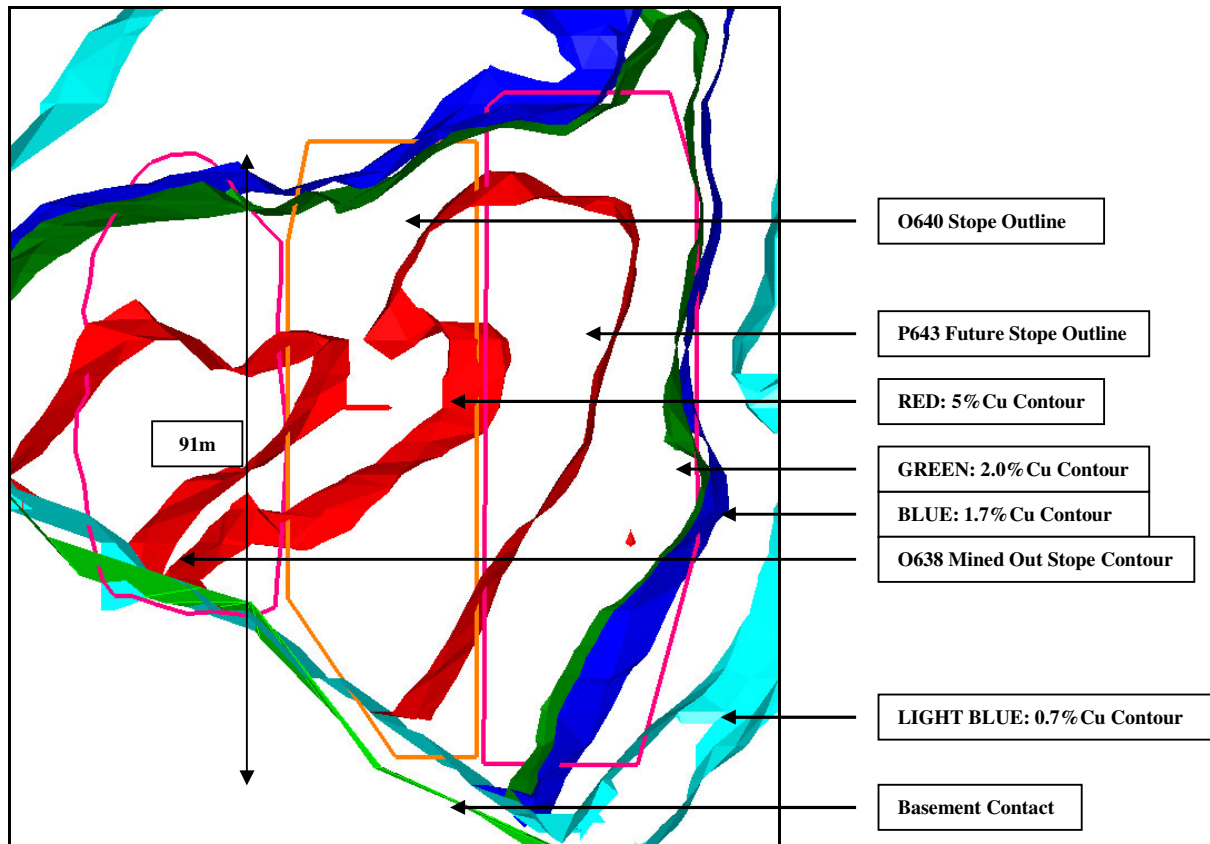


Figure 5: O640 Grade Contours (Section looking North-west)

Stope shapes and sizes are controlled by numerous factors. It would be easier to have big stopes. This would mean less development for more tonnes. Geology and rock mechanics factors, however, largely determine the size and shape of stopes in order to minimize failures, ground movement and increase overall safe working conditions. One aspect remains universal in all SLOS designs, all of them are designed to minimise the amount of waste taken with ore. In many cases small areas of waste may be included for some reason, but usually stopes are designed to fall within the cut-off grade for that area. In the case of the 3000 orebody, the cut-off grade is 2% Cu content. This is illustrated in Figure 5. The red contour shows the 5%Cu contour, the green contour the 2%Cu contour, the blue one the 1.7%Cu contour and the light blue contour the 0.7%Cu contour. Notice that all contours terminate upon intersection with the basement contact. No grade occurs below this contact.



3.2.1.3 EXISTING DEVELOPMENT

“O640 requires development and/or rehabilitation on sublevels 25A, 26B, 27C and 27L. Primary development locations and rehab required to mine this stope are largely influenced by existing headings on the mentioned four sublevels. The O640 FPAC and top exhaust on 25A was governed by the existing headings R63 NDR and Q64 SWXC. The stope boundary on 26B is defined by the existing M65 SEDR, which also influenced the placement of the CO from this drive (O640 CO). The P63 NDR on 27C defines the north-eastern boundary of O640 and here the existing O638 DPT1 and O638 DPT2 determines the amount of fill mining required as well as the placement of the CO drive on 26B so as to ensure we get a favourable CO position. The required mining on 27L, which is the DPT level for O640, is governed by the existing P64 NDR and primary development is required here in order to reach the stope position.” (Quoted from Sloane, 2006)

Mount Isa Mines encompass a vast amount of horizontal development to access all orebodies. Levels are denoted by the numerical value and sub-levels are denoted by the alphabetical denotation. It is basically used to describe a depth below surface to within 10m of the actual depth of the development. Stope shapes are mainly determined by ore reserve shapes and rock mechanic aspects as mentioned earlier. A development layout is then decided upon to access all areas of the orebodies. Because the development for one stope is likely to serve another stope or even several stopes, the chances are that the existing development for one stope will likely influence the effective mining of another, hence profitability. Care needs to be taken for this reason when any development designs are done. It is of no use to profitably mine one stope, but to lose another in the process. Figure 6 shows the existing development in relation to O640. These sub-levels will serve as the platform for all access development to reach O640.

Note that on 26B and 27C sub-levels development are already present within the stope boundaries. 27L does not pass through the stope boundary but behind the stope as shown in Figure 6. This will be crucial in designing where other development is required and how and where the stope will be drilled from. Figure 7 through 10 shows plan views of the sub-level used in the O640 design. It shows the existing development as well as new development (design) that will be needed in accessing and mining O640 stope.

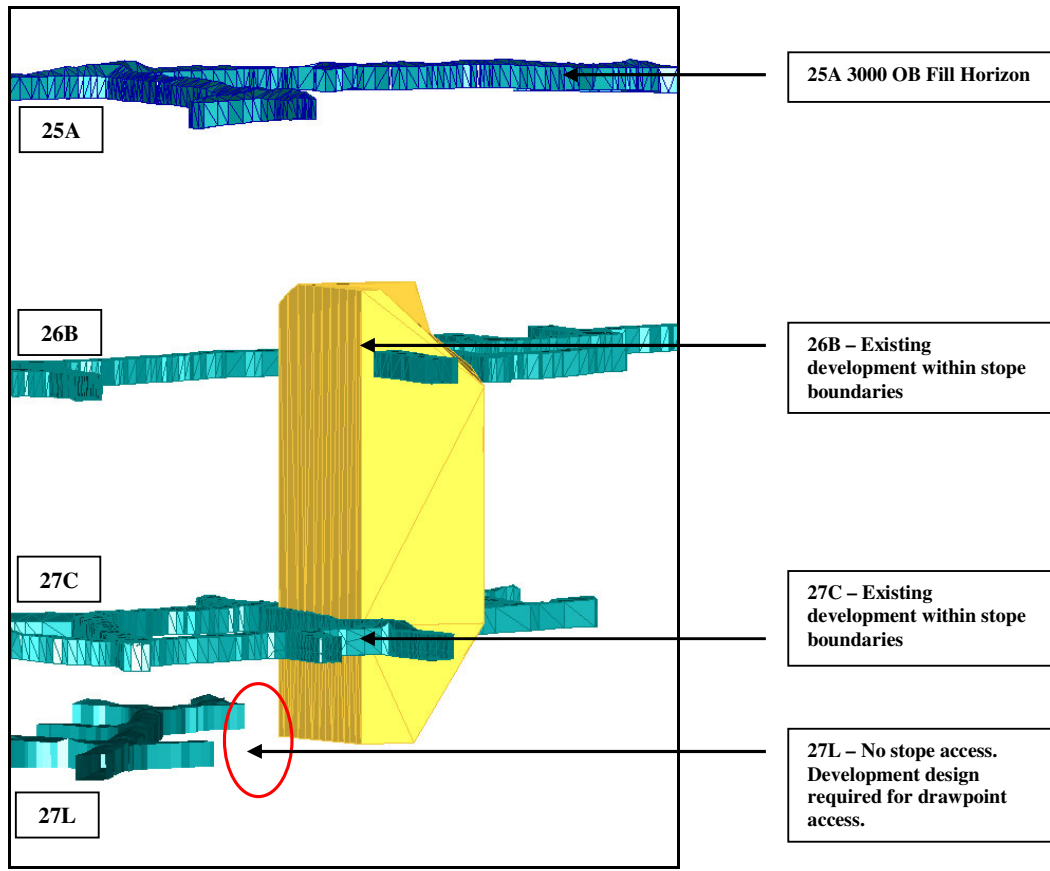


Figure 6: O640 Stope Existing Development (Section looking South-west)

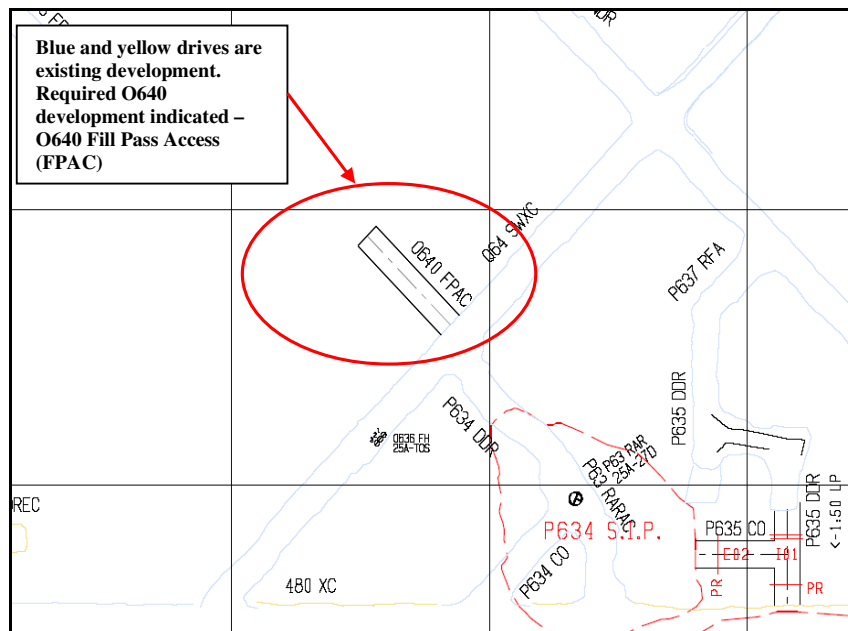


Figure 7: 25A Sublevel required development

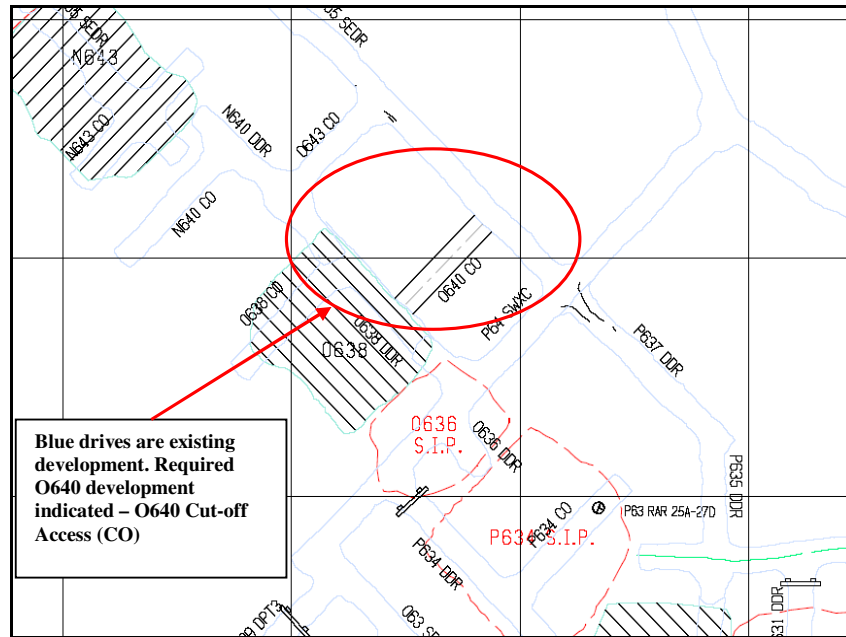


Figure 8: 26B Sublevel required development

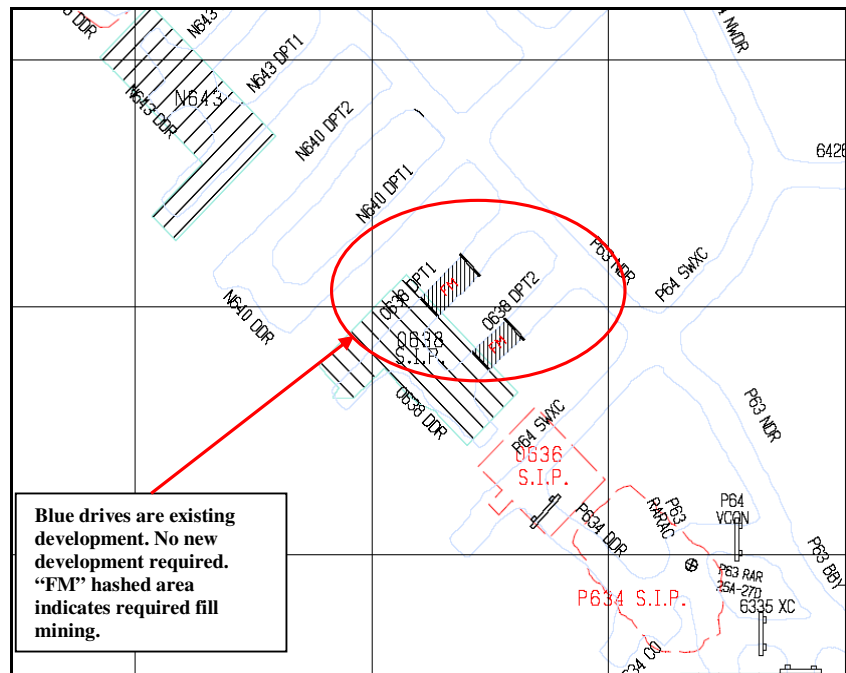


Figure 9: 27C Sublevel required development

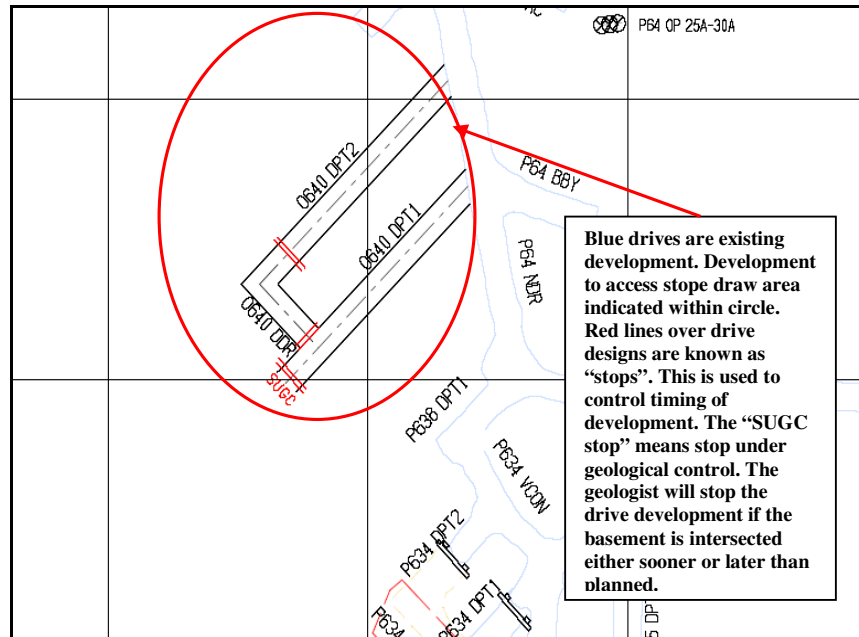


Figure 10: 27L Sublevel required development

3.2.1.4 SURROUNDING FILLMASSES

"O640 is a 1-SLOS and will therefore only expose one fillmass. This referring to the O638 fillmass, which is a 100% cemented hydraulic fill (CHF) fillmass. Both O636 and M646, which are similar stopes to O640, have exposed CHF fillmasses and very little fill dilution was encountered in these instances. Confidence is therefore high that the O638 fillmass should remain intact with the taking of O640. Possible corner exposures exist with O636 and N640 stopes, but given the way that CHF fillmasses behave in general in this area, no problems in this regard are expected. The exposure area of O638 lies between 26B and 27C sublevels." (Quoted from Sloane, 2006)

It is very important to know where the surrounding fillmasses are. One would imagine that this is a given, however, it does quite often happen that stopes are not fully filled, filled volumes compared to calculated volumes differ and stope under-or-overbreaking can cause that fill masses are in positions other than initially thought. A detailed investigation into fill levels of surrounding stopes as well as fill type of the surrounding stope is required before a

stope can be designed. The height and type of the fill mass to be exposed determines how close and what type of explosive is needed for firing close to filled stopes. When it is believed that the integrity of a fill mass is compromised, a pillar between stopes may be required, which means a possible alteration of stope shape and size and therefore a loss of mineable ore. Figure 11 shows the position of O638 fill mass in relation to the planned O640 as well as other fillmasses in the surrounding area. O640 will only expose O638 and exposures relating to other stopes resulted in no to very little fillmass failure, so confidence in the safe exposure of O638 is high.

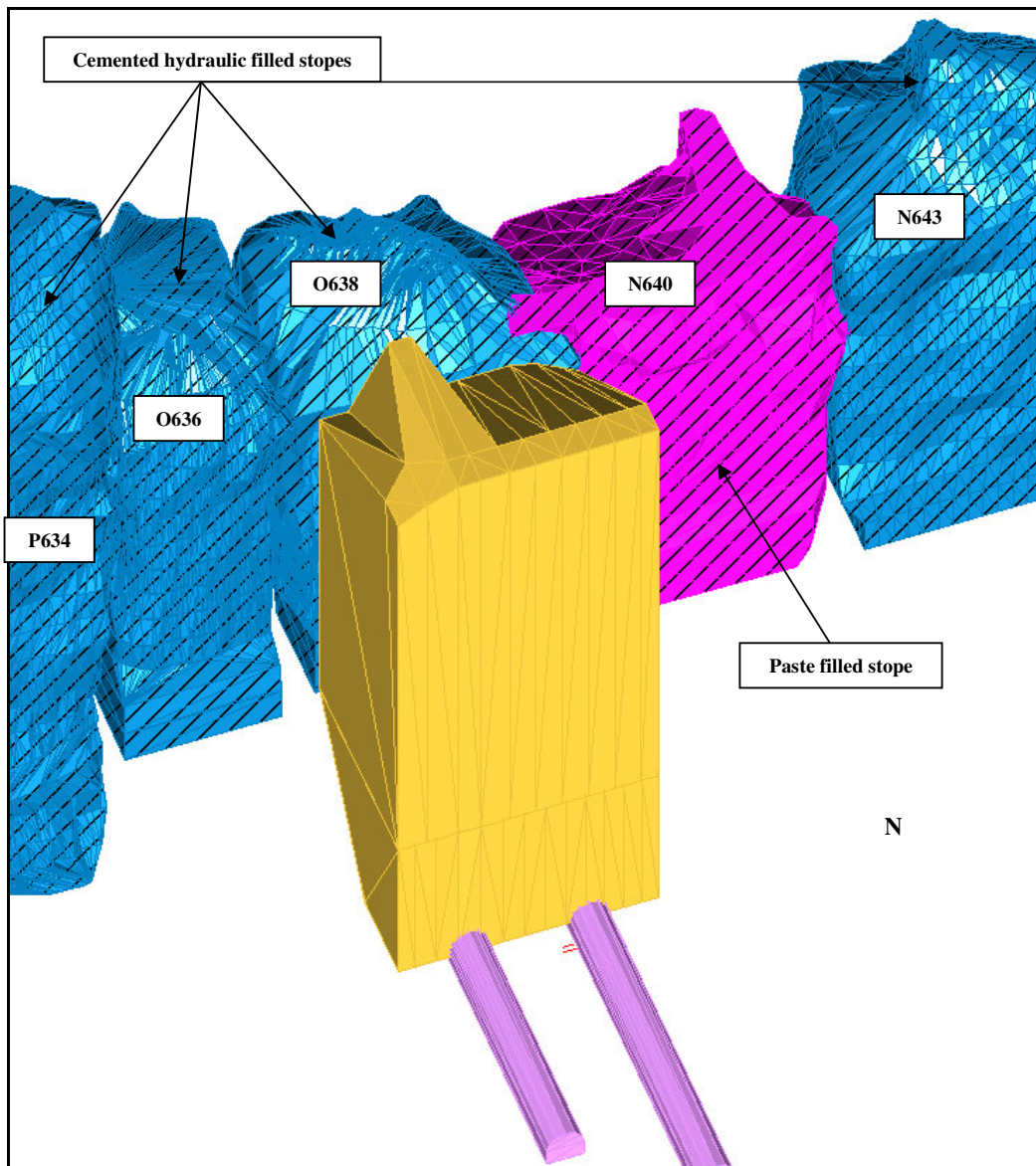


Figure 11: O640 Surrounding fill masses

3.2.1.5 ROCK MECHANICS

“O640 crown is approximately 13m above 26B sublevel and the extraction level on 27L. Access to O640 is on 3 levels, namely 26B, 27C and 27L. An overall reduction in crown stress is expected due to the stope geometry forming an “inverted wedge.” This could lead to crown overbreak due to the presence of the 30N N62 fault. This overbreak is expected to be minor. The drawpoints will be highly stressed and will require deep reinforcement and possibly shotcrete to limit stress induced ground control issues. In general, no major issues are expected for O640 stope.” (After Esterhuizen, 2005)

The Rock Mechanics Note can be seen in Annexure 1, Appendix 2.

This is one of the more important aspects relating to stope final design. Whole stopes have been lost because of failure to recognise potential ground movements, induced stresses and other rock mechanics issues. The rock mechanics engineer is responsible for three major components of the stope’s design.

1. Overbreak prediction – This allows the planning engineer to either redesign or proceed with the design as is. Operations also need to know the amount of overbreak so as to schedule and budget for additional lower grade tons. These predictions also may anticipate major failures, which could goaf or self mine between levels, destroying mine infrastructure and in some cases prevent major and possibly fatal air blasts.
2. Stress analysis – This helps the planning engineer to decide how and where to access the stope from as well as what support is recommended by the rock mechanics engineer.
3. Firing Sequence – The planning engineer with consultation by the rock mechanics engineer will sequence stope firings in such a manner to “place” mining induced stresses or to control and minimise damage from stresses to the stope itself and surrounding stopes and area development.

In the case of O640 two major issues regarding rock mechanics were highlighted. These are the possibility of “inverted wedge” crown failure and excessive stresses around the stope drawpoints.

O640 Crown – The crown of the stope was analysed looking at three aspects. The first included a Map3D analysis of stresses around the O640 and O638 crowns. Mining of O640 will induce reduced crown stresses as an inverted wedge is formed between the two stopes. Failure may occur as a result of this.

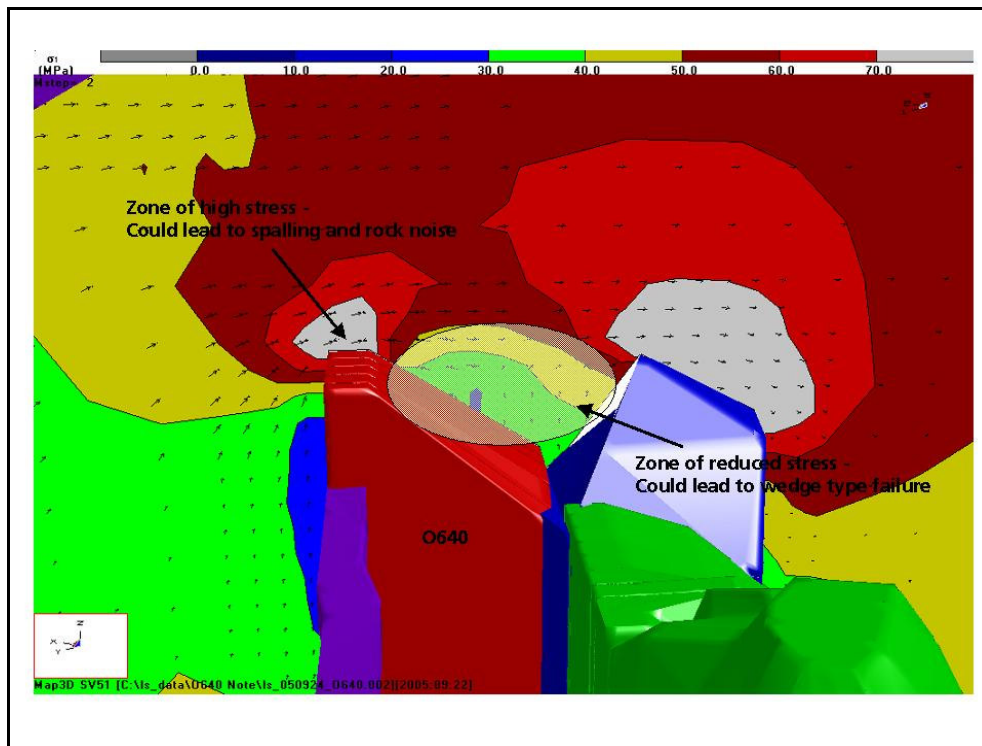


Figure 12: O640 Reduced crown stress (After Esterhuizen, 2005)

The second analysis consists of an empirical method known as the Matthews Stability Graph. This assesses the stability of stope spans. According to the analysis the stope crown falls within the transition zone (leaning towards the stable zone). This indicates failure may take place given current design geometries.

The third analysis looked at the overbreak potential, where the “inverted wedge” supposedly does fail. It is then estimated to where this failure may take place. This failure is then looked at to see whether it holds any safety concerns, will impact other openings or mine infrastructure and what tonnes and grade this failure contains. A decision is then made as to how this potential failure will be regarded. In the case of O640 it was decided to continue with the design as it is, because the potential failure is more than likely to be less

than modelled (historic underbreak of other stope crowns in this area) and in the event that failure does take place, it holds no safety concern and still carries enough grade as to have no or little economic impact on the stope.

O640 Drawpoints – An analysis is required on all stope drawpoints (DPT's) because this is the only way that stopes can be mucked (loaded). Should the drawpoints fail, then the stope is most likely lost. In the case of O640, it was determined that there will be a large increase in stress around the drawpoints which will manifest itself as spalling and rock noise. Based on this analysis the rock mechanics suggested a support pattern which will be suited for the stope for the duration of its life. This support suggestion is then approved by the relevant managers and given to the operations department to implement.

3.2.2 DEVELOPMENT AND DRILLING

Every final design is approved by the different operations departments and other individuals involved. The logical lay-out of the final design is such that it represents the order of mining activities. In the final design these sections include more details relevant to specific areas. In other words, here the design goes into detail as to why certain decisions were made or not. The following sections describe in more detail the development and drilling required before the stope is ready for firing and mucking.

3.2.2.1 DEVELOPMENT REQUIREMENTS

Development costs in the region of \$5000/m. This is extremely expensive compared to some mining operations in different countries. For this reason development must be kept to a bare minimum, but is not allowed to negatively impact safety or the effective mining of the stope. It is for this reason that existing development is used as far as possible and new/primary development is only done as a necessity for mining a stope. Not all development, however, is a total loss. Most of the development of a stope actually takes place within the stope, meaning that payable ore is mined and can be sent to the concentrator as ore. It is for this reason that it is extremely important to know not only where the high grade ore is, but also where the cut-off limits are. This clearly indicates what is ore and what is waste. Limit all development in waste then to a bare minimum.

The horizontal development requirement for O640 is 164 metres. Development requirements are summarised by sublevel in Table 1. Floor plans for each sublevel are shown in Figure 7 to 10. Two issues need to be taken notice of here. First is the O640 FPAC on 25A as shown in Figure 7. It will be noted that the FPAC development as well as the COLHW stops directly in line with the 30N N62 Dark Green Fault. It is believed that the 30N N62 Dark Green Fault is not in the position as indicated on the plan, but more to the north as was found to be the case with N640. Mapping of the fault as development advances will give a better indication of the actual fault position and any design changes will then be done. Secondly, DPT1 development for O640 is to be stopped under geology control. Because the location of the BCZ is not known for certain, once DPT1 intersects the BCZ, this will be used to map the BCZ. A stop will be in place on O640 DPT2 and O640 DDR, as these locations may change once the exact location of the BCZ is known. This was also the case with N640, where the BCZ rolled upon itself causing a significant gain in high grade ore.

LEVEL	MINING		COMMENTS
	Primary	Fill	
25A	22.5	0	O640 FPAC
26B	24.2	0	O640 CO
27C	-	21.4	O638 DPT 1 – 11.8m & O638 DPT2 – 9.6m
27L	117.3	-	O640 DPT1 – 49m, O640 DPT2 – 52m & O640 DDR – 16m
TOTAL	164m	21.4m	

Table 1: Horizontal Development

3.2.2.2 REHABILITATION REQUIREMENTS

Rehabilitation refers to the re-supporting and fixing-up of existing development in order to comply with regulations and safe working practices. It often happens that drives have been closed off for long periods of time before it is re-opened to serve a specific stope. O640 was designed in a predominantly active area, which meant the existing development only required very little rehabilitation, which was also limited to only one sub-level. See table 2.



LEVEL	REHAB	COMMENTS
25A	-	
26B	-	
27C	40m	O638 DPT1 – 22m & O638 DPT2 – 18m
27L	-	
TOTAL	40m	

Table 2: Rehabilitation Requirements

3.2.2.3 DRILLING REQUIREMENTS

The drilling of a stope is one of the most important aspects of sub-level open stope design. At Mount Isa mines a stope can easily require up to 20,000 m worth of drilling. This is time consuming and also makes up a significant part of the mining cost component. When a stope shape is decided upon, it takes into account various governing factors as mentioned earlier, but it will always include whether it is possible to drill the stope shape. In other words, can the final stope shape realistically be drilled given the available development. The typical SLOS always consists of a cut-off slot, which is designed in such a way that holes are vertical between all the sublevels over which the stope stretches. The CO slot also consists of a cut-off long hole winze or raise (COLHW/R). This closely resembles a typical burn-cut, which is fired first to create a free breaking area into which the rest of the CO can be fired into. The CO is always taken first to create a void into which the rest of the stope is fired into. A CO usually is three meters in width and stretches over the length of the entire stope. Obviously different mines have different distances relating to their CO's, but 3m is standard for Mount Isa mines. Holes are drilled in what is known as a "dice-five" pattern, but also can be described as a diamond pattern. The CO also have much more holes than any other rings, given the fact that this is the void creating firing and additional holes are required to ensure that the CO is effectively taken. Once the CO is out and the necessary void for the stope has been established, then the other rings may be taken. The objective with stope drilling is to ensure all ore within the stope boundary is covered. Different drill rigs are available for different drilling requirements. Downholes (DH's) are mainly drilled with 140mm diameter bits, but smaller 102mm bits can also be used. Upholes (UH's) are exclusively drilled using 89mm bits as anything bigger makes ANFO (ammonium nitrate fuel oil explosive) loading extremely difficult. The main objective with drilling any stope is of course to cover all ore with as least holes possible, but still maintaining the

required fragmentation to allow ease of mucking of the stope. Larger diameter holes allow for less drilling, but larger fragments can be expected with firing. Smaller diameter holes are ideal for reasons of fragmentation, but too much drilling makes it expensive and time consuming. A balance has to be found for every single stope so as to optimise drilling meters against fragmentation. It is important to realise that fragmentation is closely linked with the shaping of the stope. Larger diameter holes also makes it extremely difficult to reach stope design shape, whereas smaller diameter holes do not, but a balance is required for exactly the same reasons as already mentioned.

Stopes are typically drilled using a combination of UH's and DH's. The typical stope for the given orebody (3000 orebody) would use 89mm UH's to reach all grade above the top sub-level with 140mm DH's on the same sub-level to the next sub-level below. On the bottom sub-level or drawpoint (DPT) level, trough undercuts (TUC's) are usually drilled to shape the stope bottom so as to ensure the efficient and safe extraction of ore in the stope. This means that DH's from the level just above the DPT level extends only until TUC's and DH's intersects. Unfortunately, even though this is standard practice, the charging of TUC does remain unsafe and extremely difficult. Planning Engineers usually tries and keep the amount of UH drilling in any stope to a bare minimum. In the case of O640 stope a new approach will be tried. This was discussed at length with various parties and a new design will be tried for this stope. The aim is to do away with TUC's. The reasoning behind this is explained in the actual final design extraction below.

"The primary metres for the drilling of O640 Stope are summarised by sublevel in Table 3. Drilling only takes place on 26B and 27C sublevels. On 26B there will be 89mm UH's to reach all ore within the 2.0% Cu contour and to shape the stope crown. 140mm DH's will also be drilled from 26B down to 27C. An option exists to drill all holes from 27C to 27L using rig 2232 102mm DH's. This design is based on the assumption that there are no availability constraints on this rig at the time O640 is to be drilled. The reason to use the 102mm rig (2232) to drill 27C-27L is to completely do away with TUC's so that most hole charging is DH only, which is in itself a huge safety improvement as it is. By closing down the toe-spacing to 3m (instead of 4m) and a 2m sub-drill to completely fracture the stope floor, which will allow the mucking units to shape the floor as they muck. Of course this means more drilling, which is evident in the fact that 3 more MR's are required. In the event that 2232 is not available, rings will be spaced similar to that for 26B-27C and 140mm DH's

will be used. Again, toe spacings will be closed up with extended sub-drills to try and create the same effect. The 102mm rig is preferred as it is believed better results can be achieved than with a 140mm rig.” (Quoted from Sloane, 2006)

LEVEL	CO			MAIN RINGS			COMMENTS
	89mm	140mm	102mm	89mm	140mm	102mm	
25A	-	681	-	-	-	-	COLHW
26B	440	1970	-	1030	5055	-	
27C	-	-	886	-	-	3880	
27L	-	-	-	-	-	-	
TOTAL	440m	2651m	886m	1030m	5055m	3880m	13942m

Table 3: Production Drilling

Burden and spacing is a function of the blast hole size and the fragmentation required. Standard burden is 3m between rings with a 6m toe spacing on 140mm blast holes. This becomes less for smaller sized blast holes. The distances used are pretty standard and deviation to these is kept to a minimum. Deviations from standard will be mainly to line up rings on different sublevels or to fit the drill pattern into the stope boundaries. Table 4 summarises the ring design parameters used for the final design of O640 Stope. Figure 13, which illustrates the position of the stope CO, also shows a typical blast hole layout. The blast holes are the dashed lines. Figure 14 shows a boundary ring (same on the other side of the stope) and figure 15 a section view through Main Ring 6 (MR06), where O638 DPT1 necessitates a change in drilling pattern from the rest of the stope. Here breakthrough holes are drilled from 27C to the drive below on 27L. Figure 16 is a stope long section where all stope rings can be seen. Notice here the different amount of rings for 26B-27C and 27C-27L. This is because of different blast hole diameters.



LEVEL	RING	HOLE DIAMETER	BURDEN/ SPACING	EXPLOSIVE	COMMENTS
26B	MR01	140	4.2 / 6.0	ANFO	
	MR02	140	3.8 / 6.0	ANFO	ANFO used even though edge ring due to burden
	MR03	140	3.8 / 6.0	ANFO	
	CO	140	3.0 / 3.0	ANFO	Dice 5 pattern with centre hole 2m from front holes
	MR04- MR08	140	3.5 / 6.0	ANFO	
	MR09	140	2.5 / 5.0	ISANOL 50	
	All	89	As above / 3.5	As above	
27C	MR01	102	3.0 / 4.0	ANFO	
	MR02	102	2.8 / 4.0	ANFO	
27C	MR03	102	2.5 / 3.0	ISANOL 50	
	CO	102	3.0 / 3.0	ANFO	Grid layout Standard
	MR04	102	3.0 / 4.0	ANFO	
	MR05- MR11	102	2.5 / 4.0	ANFO	
	MR12	102	2.3 / 3.0	ISANOL 50	

Table 4: Ring Design Parameters

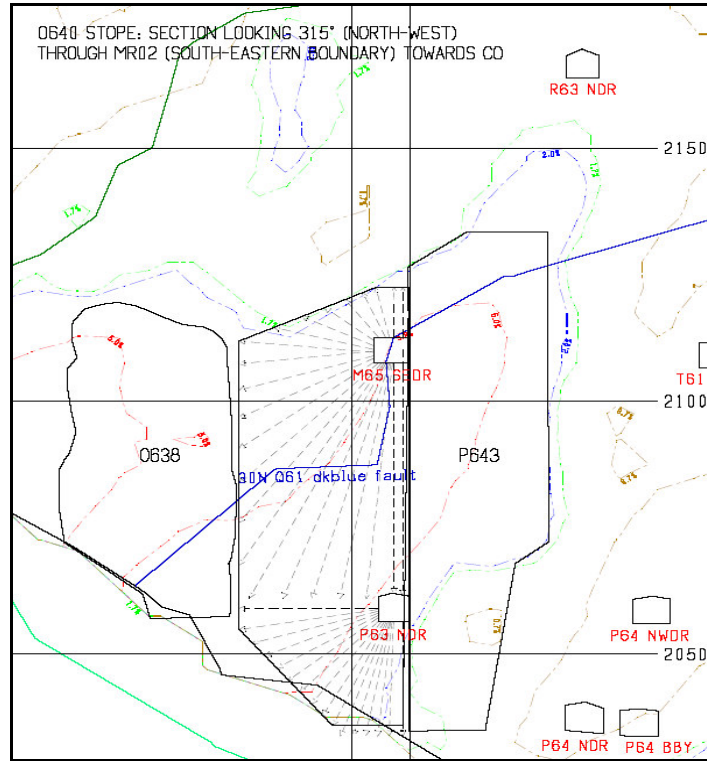


Figure 14: MR02 boundary holes

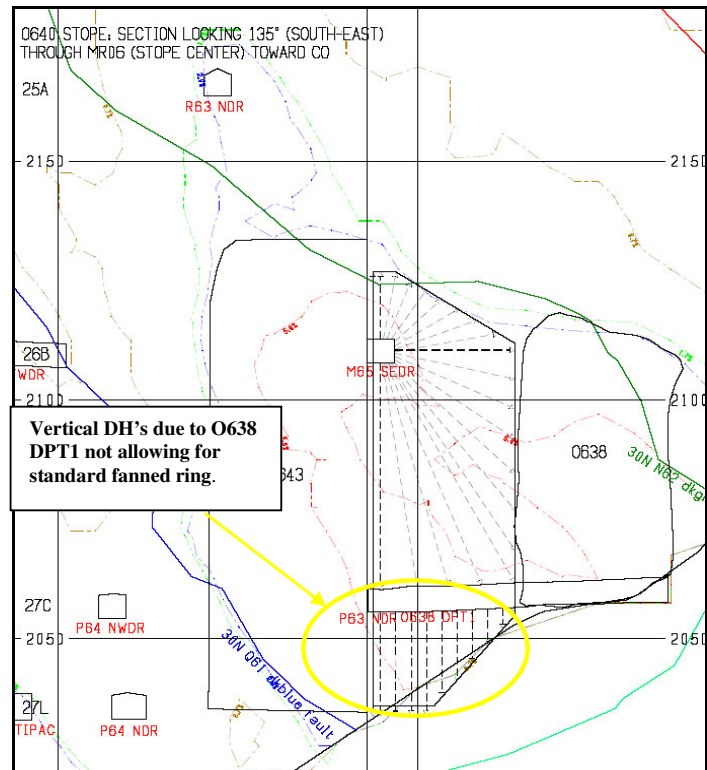


Figure 15: MR06 holes

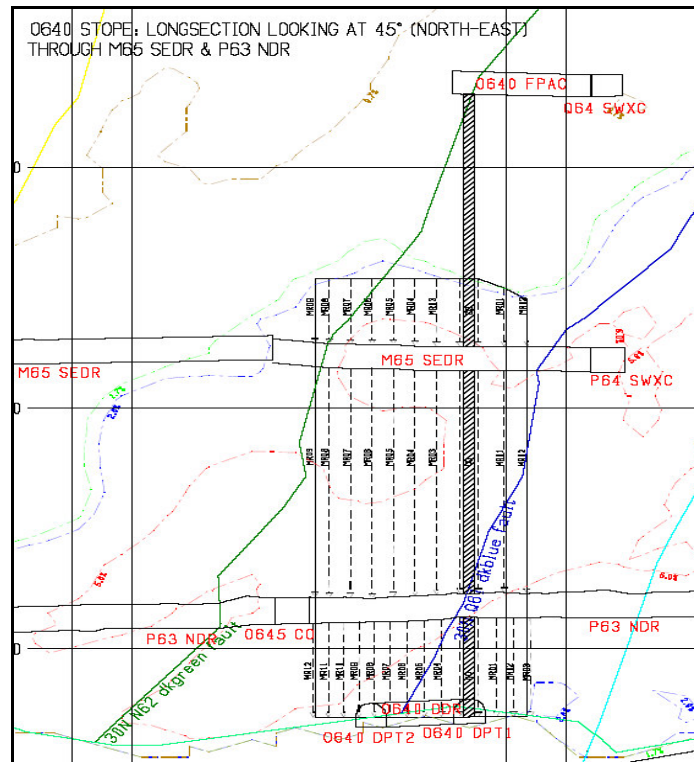


Figure 16: Long section 45° north-east

3.2.3 PRODUCTION AND FIRING

3.2.3.1 MUCKING

Stope mucking for the 3000 Orebody is limited to the ore passes that are present on the drawpoint level. This sometimes is a limiting factor when passes are long distances away or when double handling is required on lower levels of the mine. In the case of O640 stope, the P64 orepass is situated directly across from the DPT entrances and the angle of the orepass breakaway favours quick loading of DPT's. O640 will be able to be loaded relatively quick in comparison with other similar stopes. This is advantageous in terms of tonnes scheduling because quick and profitable tonnes can be loaded from this stope without negatively influencing other stopes or production in other areas. See Figure 17.

“O640 can be mucked on 27L via two drawpoints to P64 OP which is a tram of 95m one way (based on the average between DPT1 & DPT2) and then mucked again for 270m (one way) from P64 OP to the ROM hopper on 30A. The P64 BBY is right across from O640 DPT1, so secondary breaking should not be an issue.”

(Quoted from Sloane, 2006)

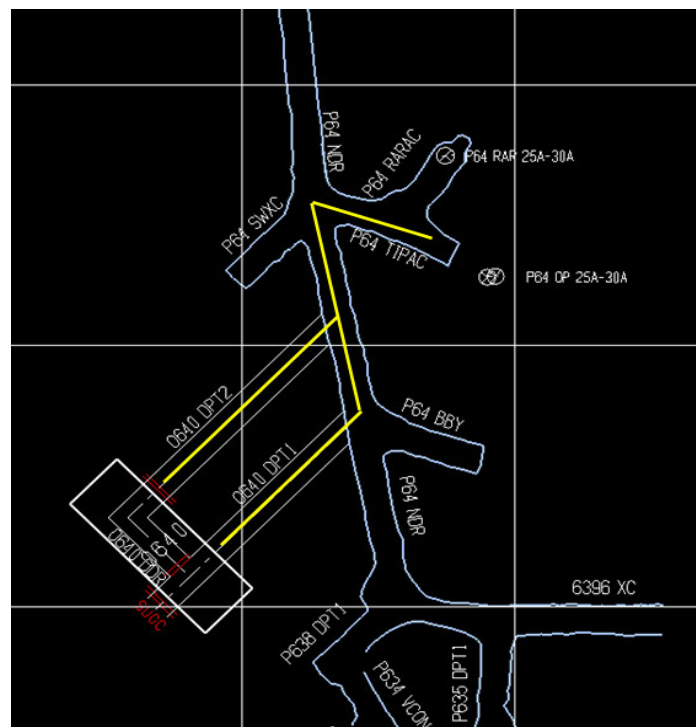


Figure 17: O640 mucking and tipping in P64 OP

3.2.3.2 FIRING SEQUENCE

The firing sequence in sub-level open stoping refers to the manner in which the stope will be fired, mucked and then fired again. This sequence of events may take place only two or three times, or it may involve as many as ten or more firings in a stope, depending on the size and complexity of the stope. O640 spans over 3 sublevels and is considered average in size, but because of the simple design and ring layout, the firings required to take the stope can be reduced to a minimum. At Mount Isa Mines stopes will have either a COLHW or a raisebore hole which serves as the initial free breaking area. In the case of the COLHW, this needs to be fired from the bottom up in approximately 6m advances until it is close to breaking through to the level. With a raisebore hole these initial firings aren't needed, but the pros and cons of both these methods makes them fairly similar in effective use. Of course it would be wonderful to fire the stope in one firing, but this is impossible given basic mining practice. Rock must break into void and given the swell factor of broken rock for Mount Isa Mines and the RD, the volume of rock fired requires 30% of the in-situ volume of the firing as void already available. If not, chances are more than likely that the last holes fired will "freeze" and some of the stope will be lost.

Another reason for breaking a stope up into several small firings is due to ground vibration. The city of Mount Isa is within 1km of the mine and for this reason regulations require the mine to monitor and keep ground vibrations to within acceptable limits. Smaller firings make it unlikely that ground vibration limits will be exceeded.

It often happens that deteriorating ground conditions during the stope life necessitates that the stope be fired and loaded quicker than originally planned. This calls for all remaining firings to be combined into one to put all remaining muck on the floor before level failures or other issues render part or all of the remaining ore inaccessible. These combined firings are called mass firings, which can also only take place once 30% of the overall stope design is void. Mass firings can vary in size and firings of up to 400,000t of ore have taken place in the past, however, all mass firings still need to comply with regulations regarding ground vibrations. The way this is controlled is by limiting the amount of explosives per delay in order to minimise vibrations. Mass firings can be fired over several seconds to minimise ground vibrations. In consultation with the scheduling engineer and the rock mechanic, the following firing sequence was decided upon for O640.

“The firing sequence for O640 is listed below and shown in Figure 18.

1. Progressively fire the COLHW and CO from 27L through to 15m above 26B. The COLHW is to be fired through to 25A to act as top exhaust for the stope.
2. Fire MR01-MR02 (26B-27C) and MR01-MR03 (27C-27L).
3. Fire MR03-MR05 (26B-27C) and MR03-MR07 (27C-27L).
4. Fire MR06-MR09 (26B-27C) and MR08-MR12 (27C-27L).

This firing sequence may change depending on conditions at the time of production. It will be possible to make a decision based on the production requirements from O640 at the time and the actual void available after firing 1 & 2, to determine whether this stope will be mass fired or not.” (Quoted from Sloane, 2006)

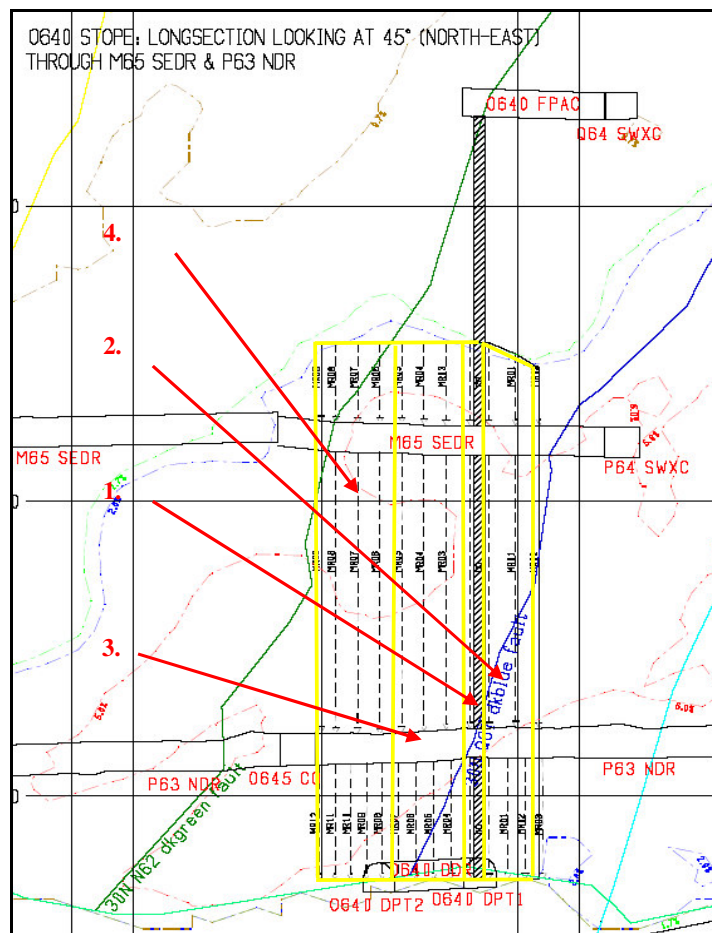


Figure 18: O640 Firing sequence

3.2.4 VENTILATION

Stopes are ventilated in different manners during its lifecycle. The planning engineer, with advice from the ventilation department, must allow for the adequate ventilation of all drives and of the stope itself once firing starts so that during no time in the stope's life work needs to be suspended because of ventilation issues. Each orebody is served by main fresh air raises and return air raises intersecting each of the sub-levels that comprise that level. Ventilation of the 3000 Orebody is fairly simple, where fresh air is ducted to any area where either development or charging up takes place. Natural flow from workings to return air raises is how sublevels are ventilated. Because of the complex network of drives and open stopes, it is sometimes difficult to control the ventilation in certain areas. Several ventilation controls assist with these issues.

The O640 ventilation circuits are given below (Tables 5 and 6) and are illustrated in Figures 19 to 22.

	FRESH AIR		RETURN AIR	
LEVEL	SOURCE	FAN/WORKS	SOURCE	FAN/WORKS
27L	R64 FAR	Install duct	P64 RAR	No work required
27C	Q65 FAR	Install duct	P64 RAR	No work required
26B	R64 FAR	Install duct	P64 RAR	No work required
25A	R64 FAR	Install duct	H75 RAR	No work required

Table 5: Development, Drilling and Ringfiring ventilation requirements

	FRESH AIR		RETURN AIR	
LEVEL	SOURCE	FAN/WORKS	SOURCE	FAN/WORKS
27L	T63 DEC	Natural flow off decline	P64 RAR	No work required

Table 6: Mucking ventilation requirements

3.2.5 SERVICES

There is no service work required for this stope.

This is a section within the final design, which specifically deals with what services are needed so that work on the designed stope can start. This is not so much a design component, but it is the responsibility of the planning engineer to determine what is needed and where it is needed as services that are installed will probably be used for future stopes as well. In some cases cable holes and drain holes must service the stope/s and the planning engineer is responsible that these holes are drilled from the appropriate place to desired breakthrough point without passing through any other mine opening or planned future opening if it is to serve future stopes.

3.2.6 FILLING

Stopes are filled after they have been mined. This is for the alleviation and redistribution of stresses in and around stopes. Stopes cannot be left void as they will eventually start to deteriorate and cave. Once caving started it will not easily stop and much of the mine infrastructure and reserves can be lost in such failures. In the 3000 orebody, different types of backfill have been used for stope filling. Most of these aren't in use any more and backfill for the 3000 orebody consists mainly of cemented hydraulic fill (CHF) and paste fill. The preferred fill type is paste as it is a slurry type backfill with very little water drainage compared to the large quantities of water associated with CHF filling. Continuous problems are encountered with flooded workings due to the excessive water drainage out of stopes that was CHF filled.

Once a stope is empty, it is bulk-headed (sealed) off. A bulkhead is a wall built to keep fill inside the stope. It is equipped with drains that reach into the stope which assists with stope drainage. With the quantities of fill that is placed in stopes in short periods of time, pressure builds up behind these bulkheads, which can (and have in the past) failed causing mud rushes and fatal injuries on mines. With paste these failures may still occur, but the mud rush will choke itself off over a much smaller distance due to the lack of water, hence it contains lower risk in usage. Mount Isa mines are trying to fill all stopes in the 3000 and 3500 orebodies with paste fill only. At this stage, the capacity to do so is not there and CHF fill is used in conjunction with paste.

The filling of a stope is the responsibility of the mine planning engineer. Even though the subject of filling a stope is considered in the final design phase, a Fill Note is only drawn up once the stope is empty and exact volumes have been determined.

“O640 is currently scheduled to be filled with CHF. This should pose no major problems given the stope geometry and the fact that there are two DPT’s for stope drainage and another two bulkheads that will assist in drainage once fill levels reach 27C, which is only about 20m above 27L. CHF is currently piped to the 3000 orebody via the fill line in 360XC on 24A and to 390XC on 25A and then along R63 NDR. O636 lines then divert into Q64 SWXC. Lines are currently set up for the filling of O636, but need only be swung around into O640 FPAC to reach the COLHW, which will be used to fill the stope.

Should it be required that the stope be filled using paste at the time, then paste can be run to O640 FPAC from lines that are currently being set up along R63 NDR 25A for the filling of K672.” (Quoted from Sloane, 2006)

3.2.7 EXTRACTION OPTIONS

It must be noted that by this time the design is in fact more than half complete as overall stope shape has been set and existing development will largely pre-determine where access to the stope can be placed. This section, as described in the extraction below, looks at the options that remains and key decisions made regarding the mining of this stope as well as the reasons behind these decisions.

“Several aspects were considered in regard to extraction options for O640 stope. Key aspects include existing development, grade contours and the interaction of O640 with stopes already extracted and future stopes. Options were mainly restricted to stope boundary position, placement of the CO slot and drawpoint design on 27L.

- *The reserve shape for O640 remained largely unchanged with the exception of the north-eastern boundary. The P63 NDR on 27C and M65 SEDR on 26B north-eastern sidewalls run on the initial reserve shape floorplan for O640. This means that in order to drill and shape the north-eastern wall of O640, that hole positions would have had to be moved away from the boundary to fit the rig and then dumped to reach desired end*

positions. The result would have meant an uneven stope wall, which would influence the design of P643 and could also lead to unwanted failures during the actual production phase of O640. Because of this the boundary was moved 1m towards the south-west and boundary holes can now be drilled vertically on all drilling sublevels.

- *The placement of the CO slot was determined by development requirements on 25A and existing development on 27C. O640 will be top exhausted via 25A-26B COLHW, which also doubles as a fill pass once the stope finished production. The CO slot could have been placed in either O638 DPT1 or O638 DPT2. Development design for 26B would then only be required to align with whichever DPT was chosen. O638 DPT2 was chosen because this would then yield the least development required on 25A for the O640 FPAC. This also has the advantage that we now have a single COLHW straight from 25A to 27L. (See figure 13)*
- *The O640 FPAC could have extended from either R63 NDR or Q64 SWXC in order to reach the desired position of the fill pass. The decision was made to develop the FPAC from Q64 SWXC so as to minimise the development for this stope. The downside was that should we have used R63 NDR, the position could have been selected so that some of the required development of P643 is then already completed. This was, however, not done as it would ultimately fix the position of the future CO for P643 and restricts design options for P643 considerably. In this way P643 is not at all influenced (on 25A sublevel) by the design for O640. See Figure 7. Also, R63 NDR is the host drive for all major services for the 3000 OB (CHF and Paste lines, etc.) and to develop out of this drive would interrupt these services considerably, which would lead to delays in several other areas.*
- *Two drawpoints are required for O640 when taking into account the location of the CO slot and the stope dimensions require more than one drawpoint for the optimum extraction of ore. This also favours the geometry of P643, which is similar to that of O640 and will also be extracted from the same level as O640. The current DPT design also serves as the future drawpoints for P643.”*
(Quoted from Sloane, 2006)

3.2.8 DESIGN FEATURES

The design features section of the final design is basically a summary of the stope to date. Here special emphasis is placed on the smaller or more detailed design features and include final stope dimensions, drilling layouts, stope extraction, etc. This is still a summary and most of the aspects mentioned here is to give the reader an idea behind the stope design and how things will be done.

“O640 lies centrally within the 3000 orebody and is designed to yield approximately 211,611 tons @ 4.77%. The stope will be drilled from two sublevels; 26B and 27C, but development requirements for the production of the stope include levels 25A, 26B, 27C and 27L. O640 is approximately 92m in height, 35m wide and 28m in length. The CO is located towards the south-east of the stope and aligns with O640 CO (to be developed) on 26B, O638 DPT2 on 27C and O640 DPT1 (to be developed) on 27L.

O640 is to be drilled from 26B and 27C sublevels and includes a CO and MR's. 27C will be drilled using 102mm holes for the CO and all MR's. The decision to do this is based on the availability of the 102mm rig (2232) and by drilling from 27C down to 27L with 2232 it is possible to effectively shape the stope floor without needing to drill and fire any TUC's. Obviously, the use of the 102mm rig is subject to availability at that time as 2232 is scheduled to mainly serve X41. This means that the eventual design could actually be for the use of 140mm down holes from 27C-27L. By drilling down holes from 27C-27L, whether 140mm or 102mm, up holes will be restricted to 26B only. 140mm holes will be used for drilling from 26B down to 27C. In using different sized down holes, the amount of MR's will differ from 26B-27C and 27C-27L. 26B - 27C will have 2x MR's to the south-east of the CO and 7x MR's towards the north-west. 27C- 27L will have 3x MR's to the south-east of the CO and 9x MR's towards the north-west. Should 140mm down holes be used from 27C-27L, because 2232 is not available for use in O640, then the ring layout from 27C-27L will be the same as for 26B-27C. Boundary rings will be fired using Isanol 50 (low density explosive).

Two drawpoints will be developed on 27L for the extraction of O640. These will also serve as the drawpoints for P643. O640 DPT1 will be developed and will be stopped under geology's control, as the actual location of the Basement Contact (BC) may differ from that in the DSS, as was the case with the development of N640 stope. DPT1 will be developed

until it intersects the BC. Once the location of the BC is known, then DPT2 can be completed and the DDR be developed. This may change the eventual stope shape, but should only result in an altering of drill designs to cover any gain or loss in ore.

A COLHW will be drilled from 25A to 26B, from 26B-27C and from 27C-27L. This can be seen in Figure 7. The COLHW will be fired through to 25A and will initially be used as a top exhaust for O640, and after production, it will also be used as a pass for the filling of the stope. The stope will be mucked from two drawpoints on 27L to P64 orepass which is a tram of 95m one way (average between the two DPT's) and then 270m one way on 30A (ore is loaded again on this sub-level and tipped into the crusher).

(Quoted from Sloane, 2006)

3.2.9 SAFETY CONSIDERATIONS

Sub-level Open Stopping has three major safety issues, which must be addressed in the stope final design. Should there be any other critical or stope specific issue then it will also be addressed in the final design. Any other run of the mill safety issue will be identified, assessed and addressed in the day to day working of the mine or as they arise. The aspects that are mentioned here are a given no matter where, how, when or whatever the stope design encompass. These include remote mucking, optechs (stope volume survey) and bulkheads.

3.2.9.1 REMOTE MUCKING

Every stope is designed to be mucked remotely. This means that once the stope draws close to empty (drawpoints clear of muck) then the operator of the mucker is not allowed to drive into an open stope and muck. He is to remotely muck the stope from a safe distance. It is for this reason that it is included in the stope final design. It does sometimes happen that a stope is stopped before remote mucking for reasons of poor grade, but this seldom happens.

“Remote mucking of the stope will be through the two drawpoints, O640 DPT 1 and O640 DPT2 on 27L once the brow of the stope is exposed by more than 1m. The operator should then cease conventional mucking procedures and remote muck the stope as is required by the remote mucking procedure PRO-34-05-03. Because of the Basement Contact Zone

(BCZ) and the stope design, the footprint of the stope is small, which limits the required amount of remote mucking to a minimum.” (Quoted from Sloane, 2006)

3.2.9.2 OPTECHS

An Optech is the firing of laser beams into a stope to eventually obtain a digital image of the stope void in order to calculate stope void volumes. This gives a highly accurate and detailed image of how the stope has performed. This unfortunately requires the surveyors to hang their equipment out over the edge of a stope. In any event, this is extremely dangerous no matter what safety precautions taken, but is necessary for stope analysis as well as the calculation of fill required for the eventual filling of the stope. Optechs are also known as CMS (Cavity Monitoring Systems) and this is a major tool for reconciling stope design to actual performance. Villaescusa (2004) emphasises the importance of this phase of the SLOS mining process, but as can be seen, this is also considered a hazardous task.

“Optechs for O640 should be conducted from 26B in M65 SEDR on the north-western side of the stope and also from 27C in P63 NDR on the south-eastern side of the stope. The sites for the optechs will be inspected by the Area Responsible Planning Engineer before any optech commences and monitored through the duration of the optech. Lanyard anchor points should be used as per the site procedure at both locations to facilitate the survey of the stope.” (Quoted from Sloane, 2006)

3.2.9.3 BULKHEADS

Bulkheads are built once the stope ceases production and is ready to be filled. In general, bulkhead building is not hazardous, unless it is being built in the stope drawpoints. People working in or around stope drawpoints run the risk of being seriously injured or even killed by rocks falling in the stope and then being ejected out of the stope drawpoints. For this reason it is required as a safety concern in the final design note and is required for all stopes.

“Filling bulkheads in the drawpoints must have mullock bundwalls pushed up into the drawpoints, which will be at least 4m high and 2m back from the brow, prior to the bulkheads being built. O640 stope will require 6 shotcrete arched wetfill bulkheads for the filling of the stope. The location and final placement of bulkheads will be determined once

an optech for the stope is done and the area inspected by the Area Responsible Planning Engineer and Drilling and Wetfill Supervisor.” (Quoted from Sloane, 2006)

3.2.10 RESERVES AND SCHEDULING

3.2.10.1 RESERVES

The stope that is being designed is most likely intersected by diamond drill holes used in the past to get an estimation of copper deposits and grade for the area and to form a 3D image of the resource. This image, along with its grade distribution is known as the block model. When a stope is designed, it is necessary to know; with as high a degree of confidence as possible, what the tonnes and grade for that stope is going to be. This is so that the run of mine ore can be scheduled to be produced at as constant a grade as possible. The metallurgists will then know what to expect and compensate accordingly in order to maximise copper recovery. Because stopes tend to be mined over a period of months (given stope sizes) and blasted in segments, the final design also requires the stope to be divided into ring tonnes and grade. A typical stope includes a cut-off (cut-off consists of initial series of firings to create a void or free face) and then a series of rings. These rings can be main rings (parallel to cut-off), diaphragm rings (perpendicular to cut-off) or expansion rings (rings either parallel or perpendicular to cut-off, but drilled for reaching specific areas). These are the main ring types although other specialized ring types do exist. Once the tonnes and grades for the individual rings are known, the grade during production of the stope can be predicted with a fairly high degree of certainty and run of mine ore tonnes and grades can also be better controlled. The individual rings can now be scheduled in terms of tonnes and grade over the life of the stope.

“The design tonnes and grade for O640 are shown in Table 7. There are no tonnes rated as high risk for this stope. The extraction tonnes and grade for the stope, based on values calculated in the reserve calculation spreadsheet, is given as 208,206t @ 4,61% Cu. It should be noted that the extraction values are lower than the original design values. This is attributed to the subtracted planned and existing development within the stope, which is more than the added expected overbreak for the stope as well as ore losses attributed to flat bottom stopes. Design tonnes, calculated in MineSight, do not include overbreak or development within the stope.” (Quoted from Sloane, 2006)

Also note that reference is made to high risk tonnes, design tonnes and extraction tonnes. High risk tonnes refer to ore within the stope boundary that is economically viable to mine, but that the normal mining or designed stope extraction may result in some of the stope reserve being lost. These tonnes are not scheduled and are viewed as a bonus should they be successfully extracted. Obviously it is desired that no stope be designed to include high risk tonnes, but in some cases this is unavoidable. Design tonnes are the tonnes and grades calculated using the design software and are based on the current block model and reserve shapes. The design tonnes are never the same as the extraction tonnes for the stope, although both tonnages are estimated before the stope starts production. Extraction tonnes includes possible overbreak and excludes development inside the stope boundaries. The idea is to design a stope in such a way as to get the design and extraction tonnes as close to each other as possible and to eventually have these closely resemble the tonnes extracted.

O640	RING	TONNES	GRADE
26B-27C	Cut-off	14,384	4.84%
	MR01	20,108	4.75%
	MR02	18,253	4.74%
	MR03	18,381	4.86%
	MR04	17,075	4.83%
	MR05	17,064	4.83%
	MR06	16,916	4.74%
	MR07	16,846	4.54%
	MR08	16,839	4.29%
	MR09	10,944	4.18%
		166,810	4.68%
27C-27L	Cut-off	3,670	4.60%
	MR01	3,815	4.48%
	MR02	3,656	4.43%
	MR03	3,675	4.31%
	MR04	3,727	4.91%
	MR05	3,608	5.23%
	MR06	3,663	5.39%
	MR07	3,555	5.38%
	MR08	3,003	5.37%
	MR09	2,943	5.50%
	MR10	3,040	5.68%
	MR11	3,143	5.76%
	MR12	3,303	5.70%
		44,801	5.10%
TOTAL		211,611	4.77%

Table 7: O640 Stope Design Tonnes



3.2.10.2 SCHEDULING

The scheduling of any stope basically entails the scheduling of all activities associated with the stope to ensure no mining activity interacts or negatively impact another mining activity which may influence overall mine production. Scheduling includes the “when” component for all activities ranging from development of drives specific to the stope through drilling, firing and eventually the filling of the stope.

“O640 is currently scheduled to produce between August 2006 and January 2007. There are limited interactions between the production of O640 and any other stope in the area. The first direct interaction with production of O640 is the timely filling and curing of N640, which must be completed before O640 can be produced. N640 is behind schedule by approximately 2 weeks at the time of writing this FD. The second interaction is with P635 production. O640 DPT development must be completed before P635 production can start as P635 extraction takes place on 27L. There is no delay scheduled between end of production of P635 and the start of production for O640, which would have offered a window to complete O640 development. Should P635 start production before O640 development is complete, then O640 will be pushed back in the current schedule. At the time of drafting of this FD, one 3000 and one 3500 OB stope is being drilled. After this another eight stopes for enterprise is scheduled to be completely drilled by August 2006. This leaves very little time for any deviation from schedule so cognisance of this must be taken as the possibility exist that O640 may slip in position with reference to the current schedule. Cognisance must also be taken in the fact that currently scheduled filling of P635 coincides with O640 production. Drainage water from P635 could interfere and delay mucking operations in O640, but a more detailed investigation will be done closer to the scheduled filling time of P635.”

(Quoted from Sloane, 2006)



3.2.11 ECONOMIC ANALYSIS

“Economic analysis was carried out using Cash Margin Model CashCu37d, updated with copper price, exchange rate (USD/AUD), copper treatment and refining cost assumptions and to include budget and actual cost information to November 2004.

CashCu37d has not yet been updated with the 2006 budget assumptions. The 2006 budget assumptions are more closely reflected by the assumptions made for 2005 in CashCu37d rather than those made for 2006. As such O640 has been analysed using the 2005 assumptions in the model rather than 2006.

The budget direct unit cost in Cash Margin Model CashCu37d is assumed to be the same for both X41 and Enterprise. At present all copper production is being sold as cathode. Results from the cash margin model analysis (2005 Assumptions) are shown in Table 8.”

(Quoted from Sloane, 2006)

The final design as it pertains to the planning engineer requires that the engineer perform an economic evaluation of the stope designed to ensure that it is economically viable. The analysis is based primarily on supplied model and spreadsheets, and more detailed financial planning and budgeting is done by the senior planning engineers and the scheduling engineers. For the scope of the final design, the planning engineer wants to see if the stope is profitable or not. In the case of marginal stopes, the input of other engineers will be required to re-design the stope to make it more profitable, or re-schedule the stope to be mined in conjunction with higher grade stopes. In the case of the 3000 and the 3500 orebodies, the grade of these areas are such that the stopes will be profitable, the aim here is more on optimising and getting most out of the stope. There are other areas at Mount Isa mines where the grade is lower and financial analysis of stopes takes higher priority.

Stope	Concentrate		Cathode	
	Total Cashflow	Cash Margin (\$/ t)	Total Cashflow	Cash Margin (\$/ t)
O640	\$9,808,682	\$47.11	\$17,341,790	\$83.29

Table 8: Financial Results for O640 Stope

3.2.12 STOPE PHYSICAL DATA SUMMARY

GENERAL STOPE DATA: O640

O640	1-SLOS		
Top Sub-Level	25A	Design Tonnes (t)	211,611
Sub-level	26B	Design Grade (%)	4.77%
Sub-level	27C	Scheduling Tonnes (t)	208,206
Mucking Level	27L	Scheduling Grade (%)	4.61%
		High Risk Tonnes (t)	-
		High Risk Grade (%)	-

Note: Scheduling Tonnes and Grade includes expected overbreak tonnage as well as development ore already removed at the time of production and factored for recovery.

DEVELOPMENT AND REHABILITATION DATA:

Sub-level	Drive Name	Type of Mining / Rehab	Metres Required	Comments
27L	O640 DTP1	MINING	49	
27L	O640 DPT2	MINING	52	
27L	O640 DDR	MINING	16	
27C	O638 DPT1	FILL MINING	12	
		REHAB	22	
27C	O638 DPT2	FILL MINING	10	
		REHAB	18	
26B	O640 CO	MINING	25	
25A	O640 FPAC	MINING	23	



PRODUCTION DRILLING DATA:

Sub-level	Diameter	Type	Drill Metres	Comments
25A	140	COLHW	681	
26B	140	CO & MR's	7025	
	89	CO & MR's	1470	
27C	102	CO & MR	4766	

FILLING DATA:

Sub-level	Bulkhead Type	Number Required		
27L	FILL BH	2	Fill Type	CHF
27C	FILL BH	2	Fill Volume (m ³)	73,732
26B	FILL BH	2	Filling Horizon	25A
			Fill Hole Collar Level	-
			Fill Hole No. Required	-
			Fill Hole Diameter (mm)	-
			Fill Hole Length (m)	-
			Fill Line Length to install (m)	25
			Fill Curing Time (days)	90
			MP / Tip Level	-
			LHW or Raisebore	COLHW used for top exhaust and filling

3.3 CONSIDERING OTHER DESIGN ISSUES

The O640 stope design considers most of the design parameters pertaining to a SLOS design. There are, however, some instances where unique issues arise that are specific to a given stope. In this section two such stopes, each with their own unique issues, will be discussed. Note that only the issues will be discussed and not the whole design philosophy, as this is the same as for O640. The complete Stope Final Designs for the L651 and the N659 stopes are included in Annexure 2 and 3.

3.3.1 THE L651 STOPE

The L651 stope is a relatively small scavenger stope located within the central 3000 orebody. The PD for the stope was for a 58,480t @ 3.29% Cu stope lying between the 26B and 27C sublevels. This is shown in Figure 23.

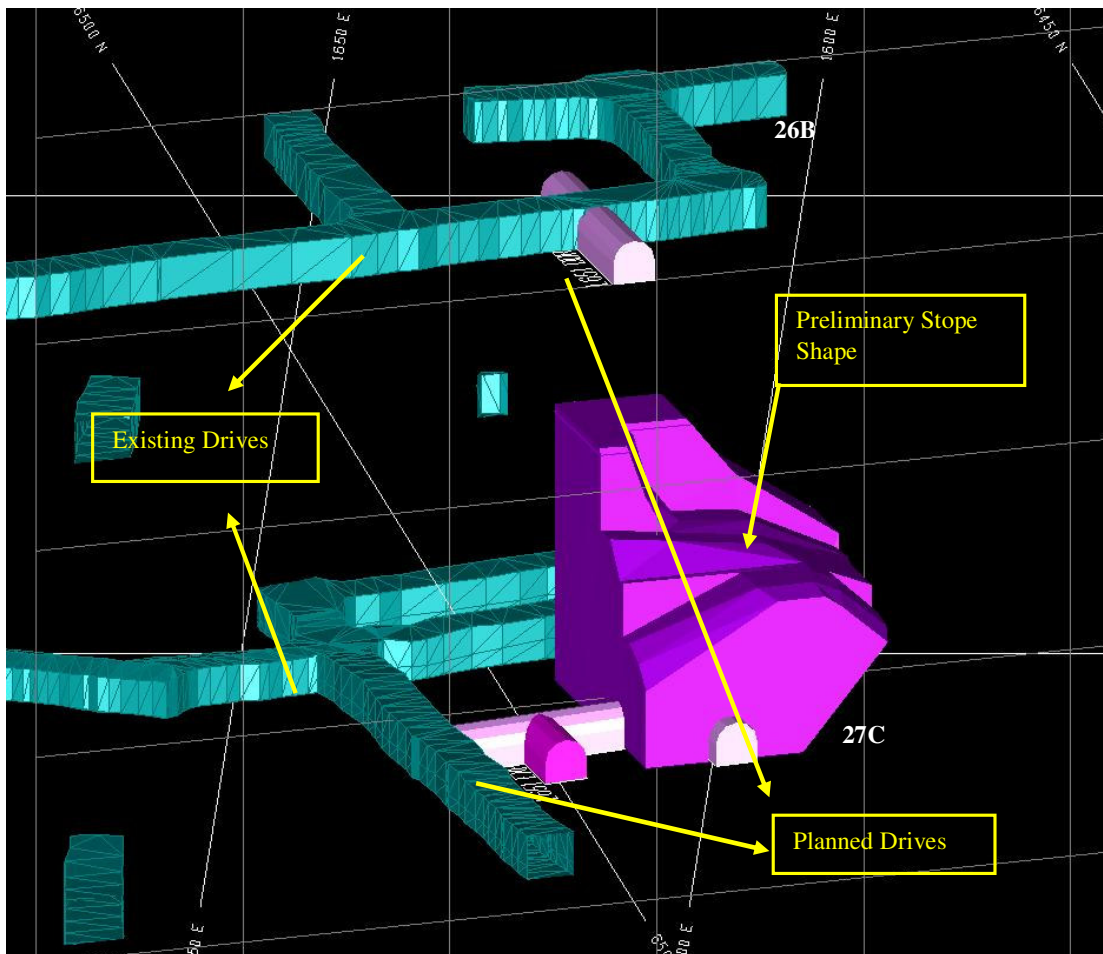


Figure 23: L651 Preliminary Design

Initially the design was fairly straightforward with minimum development required to quickly take the stope. Issues, however, arose with reviewing grade contours in determining a final design stope shape. The PD was done some time ago and was based on the 2004 resource block model.



Figure 24: L651 Preliminary Design with 2005 Block Model

The block model is updated yearly and includes new diamond drill and mapping data. In this way the block model is kept as up-to-date as possible. The final design of L651 was done using the 2005 (latest) block model. The model showed a high grade pod of copper ore just below the proposed preliminary design shape for the stope stretching across the whole length of the stope. This is shown in Figure 24.

The pod of 5% Cu ore translates into approximately 18,500t of ore with a contained metal value of in the region of A\$ 6,607,000.00, which makes this worth while to reclaim. This pod means a total re-design of the stope to include this ore, which is likely to include an additional sublevel (27L) to act as the drawpoint level. It is important at this stage to realise

that no long term planning was done for the required amount of additional mining to include another sublevel; hence no budget was set aside for this.

The problem was viewed from every possible angle, but it was found that the 5% pod could only be taken by development on 27L to create access to the stope floor. Figure 25 shows the development required on 27L to access L651.

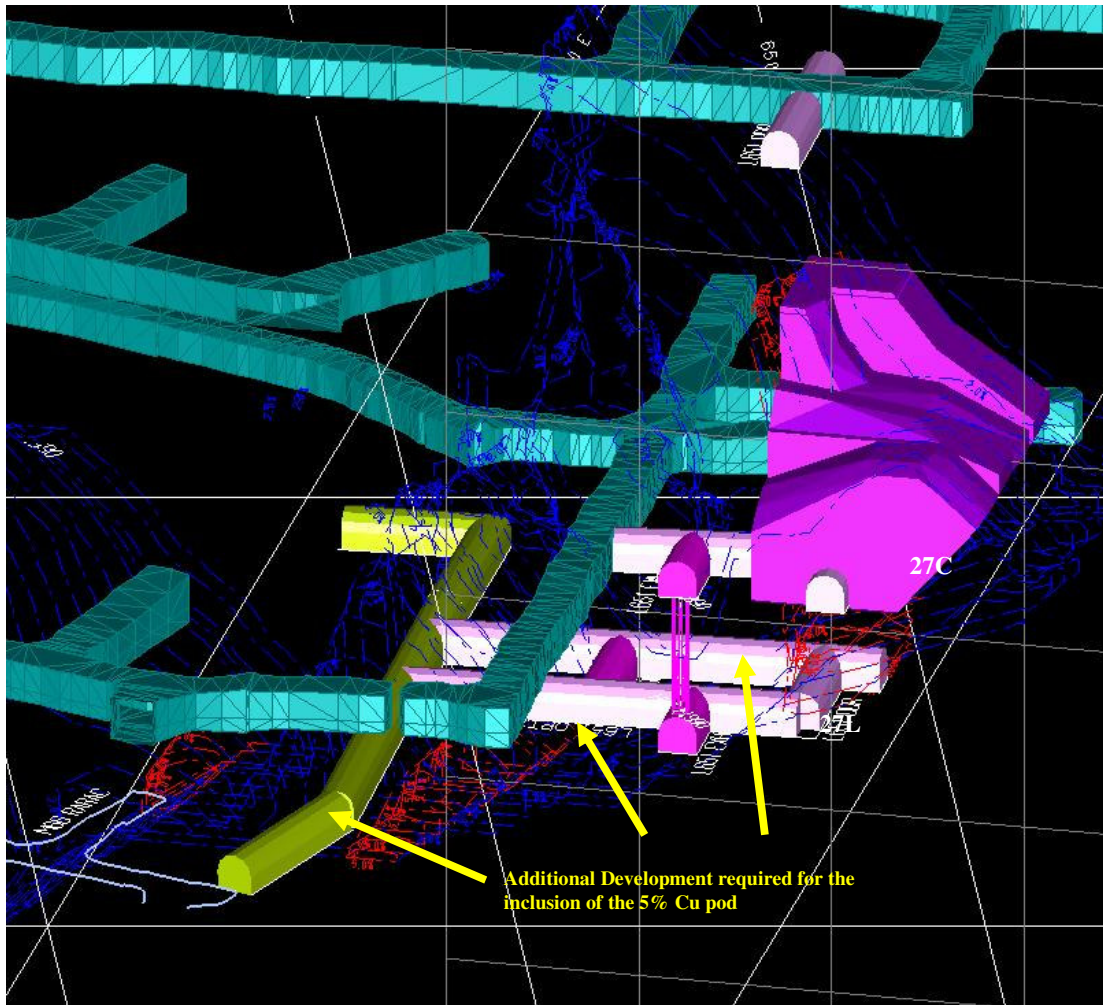


Figure 25: L651 Final Design with Additional Required Development

As can be seen from Figure 25, significant additional development is required to mine the additional copper ore. The decision was made to extract the stope from 27L, which increased the stope size from 58,480t @ 3.29% Cu to 104,443t @ 3.55%. This is both an increase in tonnes and grade. Unfortunately the decision to include another sublevel was not the end of design issues. The following is a summary of the issues and the solutions that arose as a result of the “discovery” of additional ore.

- Issue: Reaching the 5% Cu pod just below PD stope shape.

Solution: Include 27L into design to act as drawpoint level for L651 stope.

- Issue: The inclusion of 27L requires additional development possibly influencing future stopes along this line.

Solution: Review and re-design 27L long term development requirements considering all stopes surrounding L651 or any other stope possibly influenced.

- Issue: New sublevel development design optimum for all stopes in the area, but drawpoints of 50m+ required, which means forced ventilation required.

Solution: Design a return air raise to the sublevel above to extract air from L651 drawpoints to the level above. This can be seen in Figure 25 as the vertical opening just to the left of the stope.

These are the major issues that arose with the re-design of L651. One change in the design causes a ripple effect, which forces changes throughout the design of the stope. In this case, a design change in the beginning of the stope final design caused a ripple effect that not only changed the whole stope, but also affected the mine production schedule as well as surrounding future stope designs.

The complete Final Design for L651 can be viewed in Annexure 2.

3.3.2 THE N659 STOPE

The N659 stope lies centrally within the 3000 orebody, but is located in such a position that it lies in mainly virgin ground. This is the first stope to be mined in this area. The issues that arise from this are quite straightforward in the sense that there is neither access nor services to the stope. See Figure 26. In the case of N659 this was only partially true. Long term planning took into account the establishment of future stopes. Most of the required capital development for N659 was done with the establishment of the 27C and 27L sublevels, which was originally mined with the purpose of mining the more western stope within the 3000 orebody. At this stage for N659, there is no sublevel servicing either N659 or any of the future stopes along this horizon. The issue, therefore, in the design of this single stope, is the establishing of a whole sublevel, which will service N659 as well as all future stopes in this area.

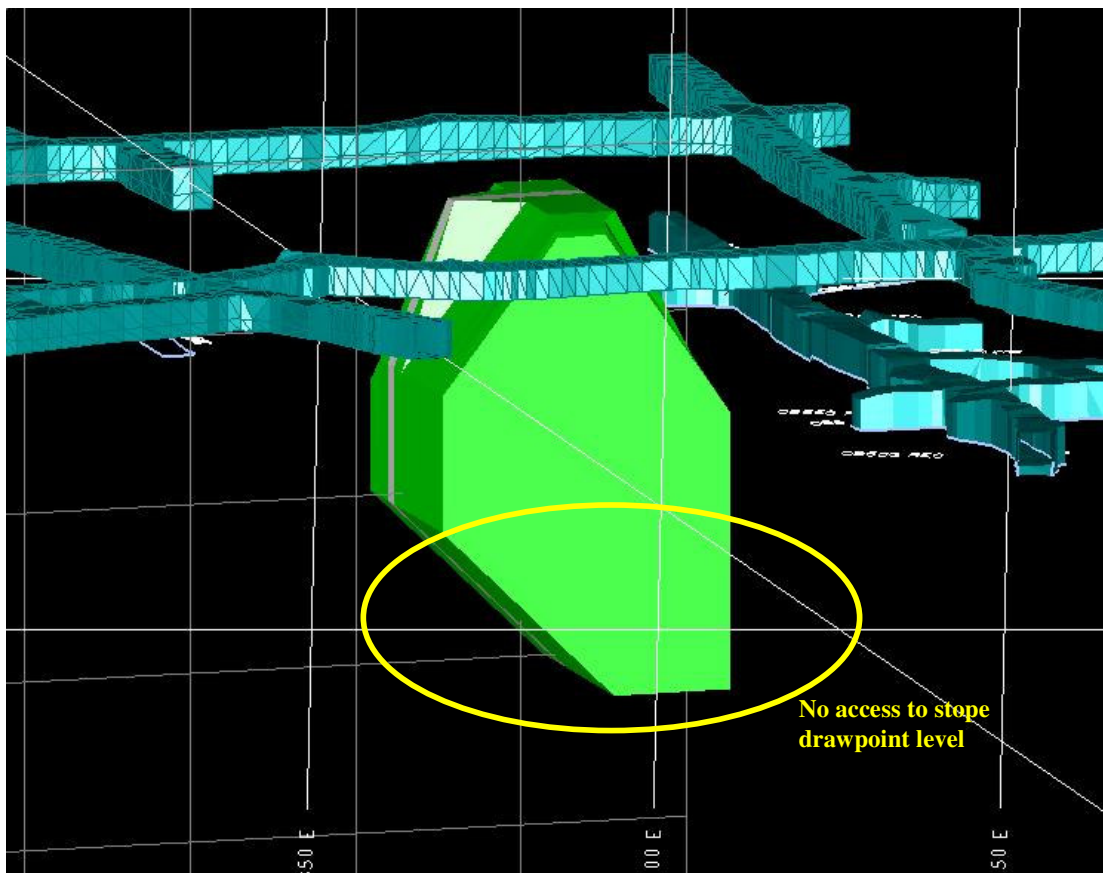


Figure 26: N659 Final Design Shape with no drawpoint level access

The establishment of a new sublevel does not only pertain to the design of some development ends to reach the stope. Several other aspects needs considering and must be included in the overall sublevel design. The main aspects to consider are:

- Access from existing development to the proposed sublevel location.
- Service provision including:
 - Electricity
 - Compressed Air
 - Water
 - Drainage
- Establishing ore handling systems for this sublevel.
- Providing fresh air and return air points for this sublevel for adequate ventilation.

The mine as a whole includes various air raises for the provision of fresh and return air. In the case of the establishment of the 28B sublevel, most of the mine fresh air, return air and ore handling passes pass within close proximity to the proposed sublevel location. The main design consideration is to tap into these raises and passes in such a way to effectively service the new sublevel, but without influencing any other part of the mine.

The obvious starting point with the establishment of a new sublevel is at what depth and how do we get to this area. Figure 27 shows N659 stope with infrastructure in the immediate area. Development existing for the upper levels of this stope was discarded and not shown in Figure 27, as these levels were never designed to accommodate mining lower down. 28B sublevel needed to be completely new and feeds off main mine infrastructure with as little influence from other sublevels as possible.

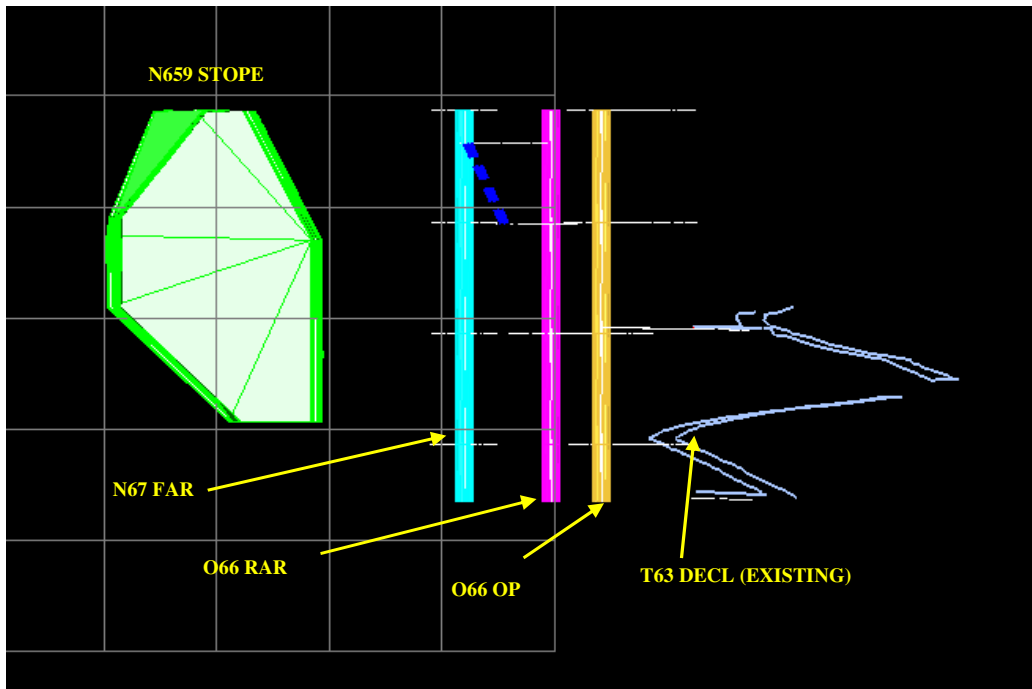


Figure 27: N659 showing surrounding infrastructure

With the establishment of the 28B sublevel, use had to be made of the entire shown infrastructure. It is easy enough to design a sublevel to incorporate all the required infrastructure so as to have an usable sublevel, but the last critical aspect to consider is that even though the sublevel may be suitable for the extraction of N659, it must also be suitable for the mining of all the stopes that will be drawn from this level. Figure 28 shows the final sublevel design (as shown in Annexure 3) with all the future stopes in the area.

Figure 28 also shows the final layout for the 28B sublevel. The major FWDR runs along the bases of all the stopes (in purple) so as to ensure that drawpoints are at the correct elevation. From here drives connect in with the already existing infrastructure to provide fresh air, a return air, and a tipping point for operations in this area. All other services to the level will be fed of the main decline.

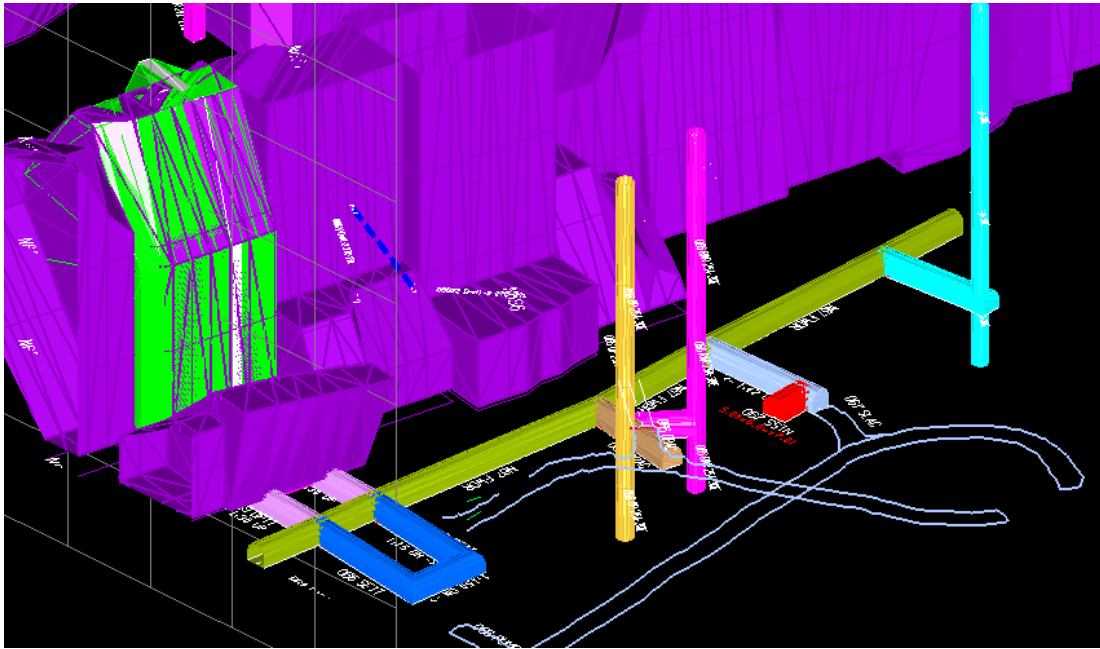


Figure 28: *Final Design for 28B sublevel*

When designing a new sublevel, a few questions need to be asked and answered. These include:

- Where will the rest of the stopes be in this area – This will determine where the major sublevel drive (FWDR) will run.
- How do we get to the stopes – Typically the closest major decline or other major development end will be used to reach the desired FWDR location.
- How will we ventilate the area – The location of the closest FAR and RAR must be known and it must be viable to tap into these for ventilation purposes.
- Where will we tip – No stope can be mined if the ore cannot be tipped somewhere. The closest (the closer the better) OP will have to be accessed before any mining can commence, otherwise difficult and expensive ore and waste removal from the sublevel may ruin a profitable stope.
- What else – Other aspects to consider would include:
 - Drainage of mine water
 - Electricity feed



- Compressed air and water
- Bomb bays

Numerous other aspects have to be considered, but seldom would stop the establishment of a new sublevel. These issues are considered at this stage, but closer attention to the finer details is usually given closer to the time of actual mining. The four questions asked resemble some of the ideas and design methodologies as discussed in detail by Stacey (2009). Stacey is not primarily concerned with practical application of design methodologies, as his dissertation is mainly about comparing design philosophies. But here we can see its practical import.

The complete Final Design for N659 can be viewed in Annexure 3.

4. Conclusion

Although there are definite similarities between sub-level open stopes, each and every stope also has a component to it that make it completely different from the next. This dissertation was drafted with the intention to explain the role of the Mine Planning Engineer, but more importantly the work performed by the engineer. It looks at the design methodology that is needed to successfully design a sublevel open stope, but also, and very important, it looks at applying theory into practise by means of example designs.

The design of sub-level open stopes is complicated process with numerous design considerations, all of which must be accounted for during the design of the stope. For this reason it is necessary to approach every design systematically. The O640, L651 and N659 stope final designs are examples and results of this systematic approach, but they also clearly illustrate that even though there are similarities, there are also large differences between designs.

The O640 stope was used as the design example in this dissertation as it will be the first stope to be mined. The design was analysed and explained to give the reader an understanding as to how and why certain decisions are made.

To some the role of the Mine Planning Engineer may seem straightforward and even not that difficult. The three stopes used in this report have a combined design tonnage of 547,818t of Cu ore at an average grade of 3.91% Cu content. This equals a contained metal content of 21,420t of copper. In monetary terms this is approximately AU\$152,997,741.00 worth of copper at the time the designs took place.

There is very little room for error in mining given the nature of the work underground, the large quantities of rock moved and the large sums of money involved. The Mine Planning Engineer must ensure that with good, well thought through designs, great results are achieved.



5. References

- Bieniawski, Z.T., 1992,** *Invited Paper: Principles of engineering design for rock mechanics, Rock Mechanics, Proc. 33rd U S Symp. on Rock Mech.* Tillerson and Wawersik (eds.), Balkema, 1992. pp. 1031–1040.
- Cummins, A.B., Given, I.A., Hartman, H.L., 1992,** *Mining Engineering Handbook 2nd Edition, Society for Mining, Metallurgy and Exploration, Inc., pp 1717-1731.*
- Esterhuizen, H., 2005,** *Rock Mechanics Stope Note – O640, Internal Mine Report, Mount Isa Mines, Queensland, Australia*
- Esterhuizen, H., 2006,** *L651 Rock Mechanics Stope Note, Internal Mine Report, Mount Isa Mines, Queensland, Australia*
- Esterhuizen, H., 2006,** *N659 Rock Mechanics Stope Note, Internal Mine Report, Mount Isa Mines, Queensland, Australia*
- FRM 45-03-02,** *Copper Mines Final Design Note, Mine Standard Forms (Code of Practice), Mount Isa Mines, Queensland, Australia*
- Gertch, R.E., Bullock, R.L., 1998,** *Techniques in Underground Mining: Selections from Underground Mining Methods, Society for Mining, Metallurgy and Exploration, Inc., pp 45-86, pp 223-247.*
- Harper, S., 2005,** *Geological Stope Note for: O640 PD, Internal Mine Report, Mount Isa Mines, Queensland, Australia*
- Harper, S., 2006,** *L651 Geology Stope Note, Internal Mine Report, Mount Isa Mines, Queensland, Australia*
- Harper, S., 2006,** *N659 Geology Stope Note, Internal Mine Report, Mount Isa Mines, Queensland, Australia*
- Hustralid, W.A., Bullock, R.L., 2001,** *Underground Mining Methods: Engineering Fundamentals and International Case Studies, Society for Mining, Metallurgy and Exploration, Inc., pp 1-80, pp 205-286*

Hustralid, W.A., 1982, *Underground Mining Methods Handbook*, Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, pp 364-374

Ilbury, C., and Sunter, C., 2005, *The Games Foxes Play – Planning for Extraordinary Times*. Human & Rousseau / Tafelberg

OneMine: <http://www.OneMine.org/>

Pakalnis, R.T., 1986, *Empirical Stope Design at the Ruttan Mine*, Sherrit Gordon Mines Ltd., University of British Columbia.

Sandvik Tamrock, 1999, *Rock Excavation Handbook for civil engineering*, Publisher not specified.

Sloane L., 2006, *O640 Final Design, Internal Mine Report, Mount Isa Mines, Queensland, Australia*

Stacey, T.R., 2009, *Design – A Strategic Issue*, *The Journal of the South African Institute of Mining and Metallurgy* Volume 109, pp 157-162.

STD 45-03-03, *Copper Mines Final Design, Mine Standard Guidelines (Code of Practice)*, Mount Isa Mines, Queensland, Australia

Steward, D.R., 1981, *Design and Operation of Caving and Sublevel Stopping Mines*, Society of Mining Engineers of AIME, pp 627-633.

Uggalla. S., 2001, *Sublevel open stoping: Design and planning at the Olympic Dam Mine*. In: *Hustralid W.A., and Bullock R.L., (2001): Underground Mining Methods*, Society for Mining Metallurgy and Exploration, Inc., pp 239-244

Villaescusa, E., 2004, *Quantifying Open Stope Performance*, MassMin2004.

Xstrata Reference, 2004, *New Personnel – Copper Mines Reference File: Planning – Surveying – Ring Design – Drafting*, Mount Isa Mines, Queensland, Australia

Xtrata Mines DSS, *Mine Database & Mine Records* , Mount Isa Mines, Queensland, Australia