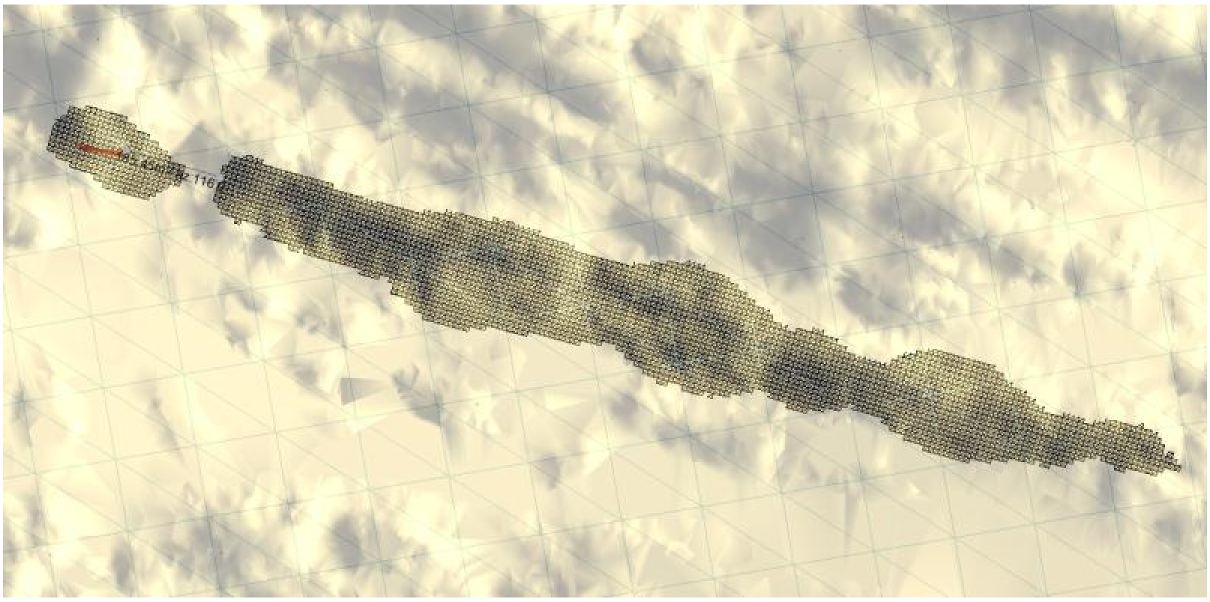
Calidus Resources

Assessment of Blasting on the Klondyke Queen. A roost site for Pilbara-Leaf-nosed Bat and Ghost Bat.



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Executive Summary

Calidus Resources are developing the Warrawoona Gold Project, located 25 kilometres (km) south east of Marble Bar in the Western Australia Pilbara region. Threatened species, the Pilbara Leaf-nosed Bat (PLNB) and Ghost Bat (GB) roost within the Klondyke Queen, an abandoned underground working, that is located approximately 185 metres (m) from the proposed Stage 1 Pit of the Warrawoona Gold Project.

Blast It Global was engaged to assess the effects of blasting on the structure in which the PLNB and GB roost. A set of blast parameters have been modelled for potential blast vibration, airblast overpressure and flyrock to be able to determine a safe set of blast parameters to commence drill and blast activities at the Klondyke Mine.

The modelling determined that 102 mm and 115 mm blast holes, on a 5m bench height can be successfully used within 350m of the PLNB/GB roosting habitat and can control blast vibration, airblast overpressure and flyrock. This would also require favourable wind direction to control post blast dust and fume from drifting within close proximity of the roosting habitat entry point(s).

At distances greater than 500m from the PLNB/GB roosting habitat 127 mm and 165 mm blast holes may be able to be used on a 7.5m or 10m bench respectively. All blasting within 1000m of the roosting habitat will require blast monitoring at a permanent blast monitor location established within close proximity of the roosting habitat.

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Introduction

Calidus Resources is currently in the process of infill resource drilling to increase and/or improve the orebody knowledge of the Klondyke gold deposit within the Warrawoona Project. The stage 1 pit is currently proposed to be located adjacent to the Klondyke Queen, historical gold workings that have a colony of Pilbara Leaf-nosed Bat (PLNB) (*Rhinonicteris aurantius*) and Ghost Bat (GB) (*Macroderma gigas*), which are both considered by state and federal governments as a threatened species.

The PLNB and GB are roosting in an old abandoned underground mine workings. Calidus Resources current pit shells are not planned to intercept the location of the PLNB and Ghost Bat colonies.

This document is a desktop study of the proposed blasting parameters to be used on the Warrawoona Gold Project, assessment of potential blast vibration, airblast and flyrock caused by blasting operations and the likely affects that the blasting operations may have on the Klondyke Queen workings in which the PLNB and GB roost.

Literature Review

The literature review focussed on a blasting study conducted by Rio Tinto at their proposed Koodaideri Iron ore mine, located in the Pilbara region of Western Australia (Martin 2012 – author of this report). In addition, a review of new studies on the effects of blasting on bats was also conducted.

The paper "Potential Effects of Surface Mine Blasts Upon Bat Hibernaculum" (WVDoEP 2006) was a key piece of work that focused on the effects of blasting at a location in Western Virginia, United States of America. Key points were that blast vibration measured using geophones was recorded between 0.08 inches per second (1.524 mms^{-1}) to 0.2 inches per second (5.08 mms^{-1}) and caused no disturbance to the bat colony being monitored. The study was for a total of 44 blasts.

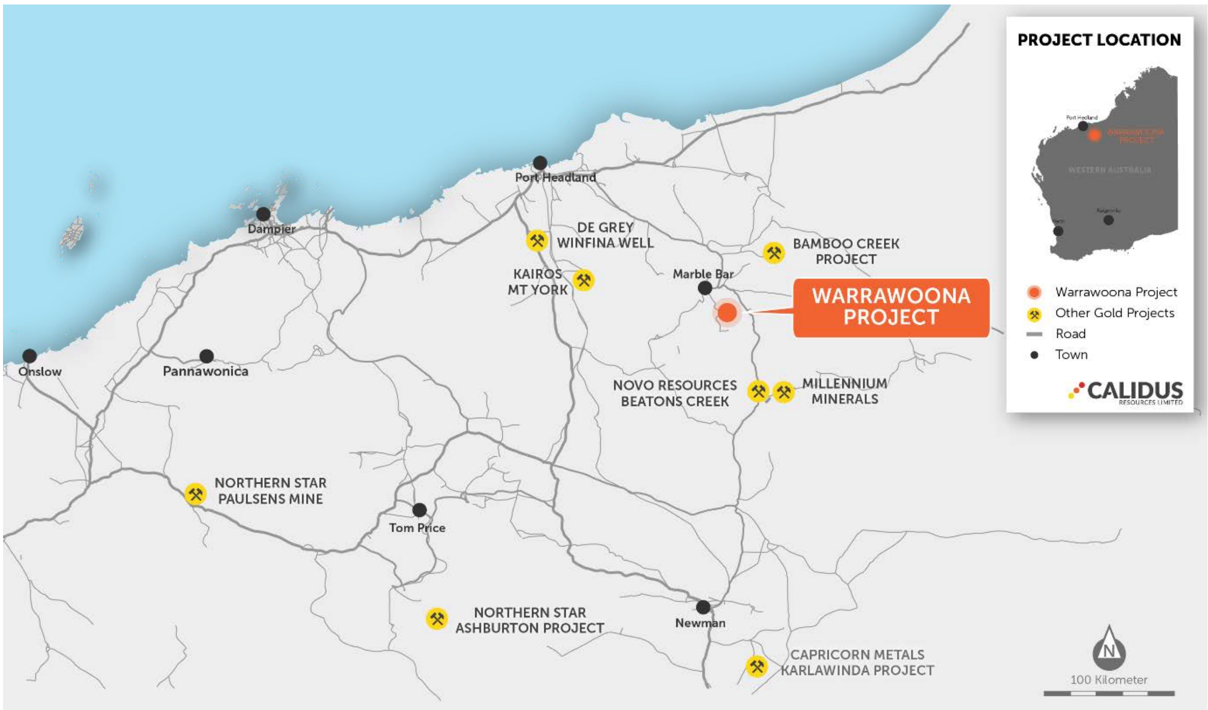
A more recent study that was documented "Whitecleave Quarry Development – Bat Hibernation Caves Monitoring" (URS), which was conducted in 2011 and 2012 and focussed on the effects of blasting on the bat colony. A maximum blast vibration of 1.8 mms^{-1} was recorded, with the results being inconclusive. This paper references a case study in Australia that recorded blast vibration of 6.1 mms^{-1} at a bat colony causing no disturbance. The source could not be verified.

The paper "Scientific Evaluation of Fauna Sensitivity to Blasting" (Martin 2012) documents a seismic blasting trial that monitored the blast vibration generated at the PLNB colony for a total of 6 explosives charges and correlated the data to bat monitoring data. In summary the blast events recorded between 0.58 mms^{-1} and 12.2 mms^{-1} at the monitoring located closest to the PLNB colony. No disturbance to the PLNB colony was concluded on assessment of the bat monitoring data. The proposed mine site conducted the study to validate that using a blast vibration limit of 10 mms-1 at the PLNB colony would cause no disturbance to the bats.

The vibration limits evaluated in the paper written by Martin (2012) will be used to assess the potential effects of blasting on the Klondyke Queen workings located adjacent to the proposed stage 1 pit location.

Klondyke Queen Location

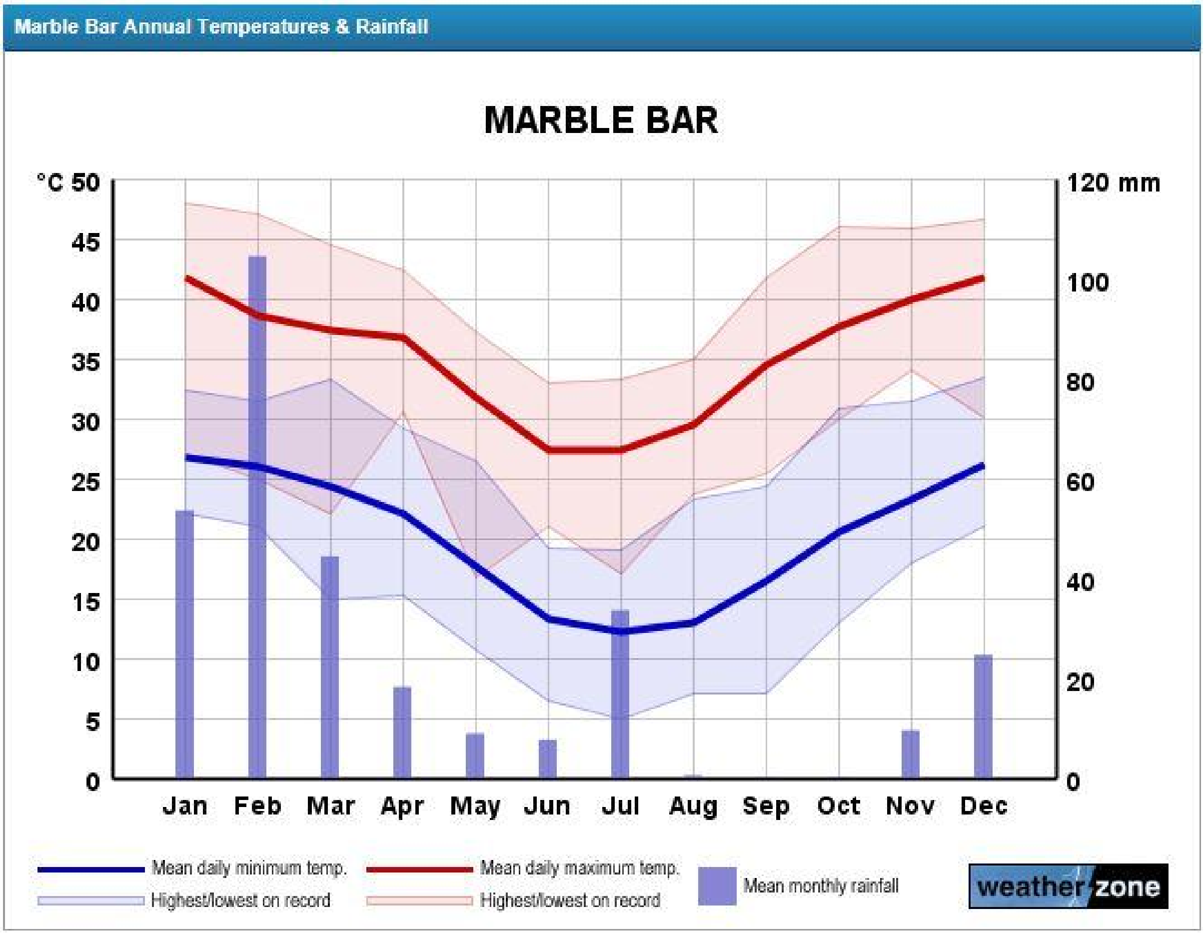
The Klondyke Queen is located 25 km south east of Marble Bar, in the Pilbara region of Western Australia. The workings are part of the Calidus Resources Warrawoona Gold Project, with other potential resource targets also being explored in the locality (Figure 1). .



(source: Calidus Website)

Figure 1 Project Location Map

The region experiences climatic condition can be summarised as hot and dry. Most of the rainfall occurs during the cyclone season, December to March. Figure 2 displays a summary of Marble Bars monthly temperature averages.



(source: http://www.farmonlineweather.com.au/climate/)

Figure 2 Marble Bar Annual Climate Summary

Understanding climatic conditions in the Pilbara region of Western Australia is important for selecting the correct bulk explosives and controlling post blast fume.

Environmental Blasting Concerns

The PLNB and GB are both listed as Vulnerable under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999. The PLNB is listed as a Schedule 1 species under the Western Australian Wildlife Conservation Act 1950, the GB Schedule 3. With both species being classed as significant species blasting parameters must be assessed prior to using them in the field.

The Pilbara Leaf-nosed Bat (*Rhinonicteris aurantius*) is a small (10 g) insectivorous mammal endemic to northern Australia. It is an acrobatic, high-energy flyer that forages for its prey along the gorges and ridgelines close to its roost. It is most often observed in flight over water holes or flying along road easements less than two metres from the ground (Churchill 2008).

The population in the Pilbara is isolated from tropical populations by an uninhabitable arid zone to the north and east. The Pilbara form has been found to be distinct from tropical populations in having a higher echolocation call frequency, reflecting differences in nasal chamber morphology. (Armstrong and Coles 2007). In addition, preliminary data indicate minor genetic divergence within the region using population-level DNA markers (Armstrong 2006a).

The species is heavily reliant on warm (28-32°C), humid (85 to 100%) sites for roosting (Armstrong, 2001a), which enable individuals to reduce water loss and energy expenditure (Baudinette et al., 2000). The distribution of the species is therefore limited by the scarcity of caves that possess the required microclimates (Armstrong, 2001a; Churchill, 1991).

A diurnal roost for the PLNB occurs within the Klondyke Queen. The Klondyke Queen colony potentially represents a PLNB permanent breeding roost although further confirmation is required (Biologic 2017).

The Ghost Bat (*Macroderma gigas*) formerly occurred over a wide area of central, northern and southern Australia but has declined significantly in the southern parts of its' range in the last 200 years (Armstrong & Anstee, 2000). The species now occurs in only a few highly disjunct sites across northern Australia, confined to the Kimberley and Pilbara regions in Western Australia (van Dyck & Strahan, 2008). In the Pilbara region, the species roosts in deep, complex caves beneath bluffs of low rounded hills, often composed of Marra Mamba or banded iron formation, granite rock piles and abandoned mines (Armstrong & Anstee, 2000). They roost either individually or in colonies (Churchill, 2008) and move between a number of caves, both seasonally and as dictated by weather changes (van Dyck & Strahan, 2008).

A permanent maternity roost was confirmed at the disused Klondyke Queen in 2017 (Biologic, 2017).

The Koodaideri project had not commenced at the time of this blasting assessment and therefore the information presented in the paper is the only information available, relevant to blasting within 500 m of PLNB colonies.

Key blasting environmental concerns are focused around airblast overpressure, blast vibration, flyrock, dust from blasting and post detonation fumes (CO) and NOx) gases. Using the proposed distances and mining bench heights, blast parameters will be assessed against conservative limits for all blasting environmental effects. The limits that will be used, with no other limits available with reference to native fauna and specifically PLNB and GB are as follows:

- Airblast Overpressure < 125 dBL within 20m of any PLNB/GB roosting habitat entry point(s);
- Blast Vibration < 10 mms^{-1} within 20m of any PLNB/GB roosting habitat entry point(s);
- Flyrock – No flyrock to be project within 50m of the PLNB/GB roosting habitat entry point(s); and
- Dust and Fume – No fume (NOx) orange gas or dust to drift within 200 m of the PLNB/GB roosting habitat entry point(s);

The limits imposed are the same as human comfort limits. The limits are set low as any disturbance that could make the PLNB and GB take flight during roosting hours, has the potential to consume excess energy disabling the nocturnal mammal from foraging for food away from the roost during the hours of darkness.
For the purposes of this review the PLNB and GB roosting habitat is defined as the abandoned Klondyke Queen workings. Further definition of the PLNB and GB habitat and entry points within the Klondyke Queen and surrounds will be determined by the specialist consultants working on this aspect of the Warrawoona Gold Project.

Regulations and Standards

To evaluate the proposed blasting activities on the sensitive sites, the relevant Australian Standards and legislation will be used:

- Australian Standards 2187.2 – 2006 Explosives – Storage and use Part 2: Use of explosives (Appendix J, Table J (4.5)A); and
- Environmental Protection (Noise) Regulations 1997 (Part 2 - Section 11);

It should be noted that the current version of the Environmental Protection (Noise) Regulations 1997 has amendments that are currently being drafted. The proposed lower levels of airblast overpressure are used in this report. These are 115 dBL for 9 out of 10 consecutive blasts and all blasts must be less than 120 dBL. This is for the hours of 07:00 hrs to 18:00 hrs, all days of the week.

No Standards or Regulations have environmental blasting limits for native fauna.

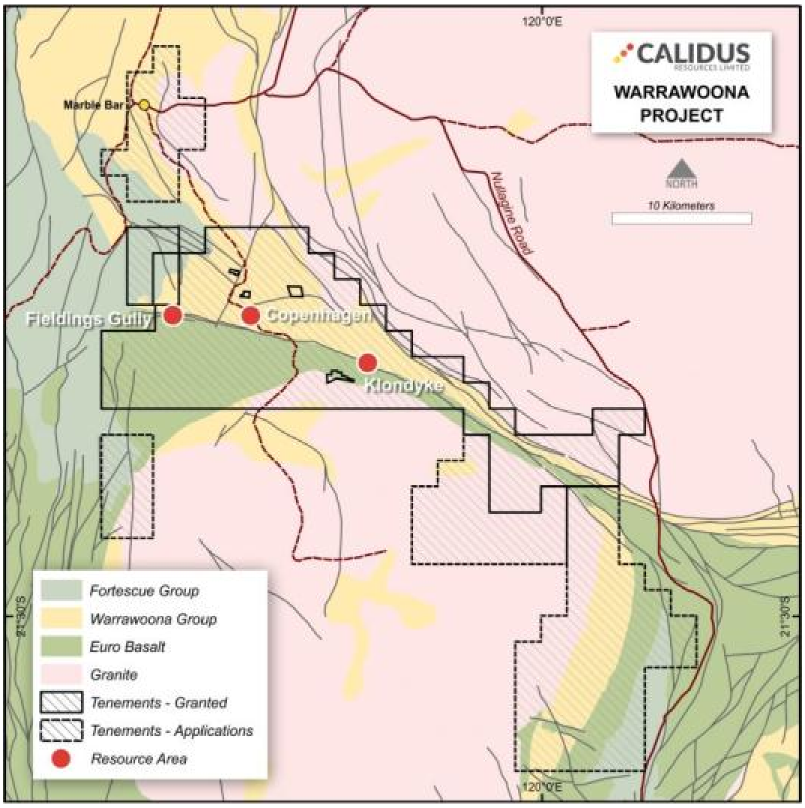
Technical Evaluation

Blast vibration, air overpressure and flyrock are assessed using industry recognised equations, which are based on assuming site attenuation constants and inputs of the proposed blast parameters, including separation distances. Fume and dust evaluations are experienced based, using industry knowledge of explosive application techniques.

Using the sites geology domains and proposed mining techniques, blast parameters will be selected and used to evaluate the potential of alternate blast parameters to comply with suggested environmental blasting limits, as outlined in section "Environmental Blasting Concerns".

Geological Setting

The local geological setting comprises of Basalt and the Warrawoona Group ultramafic rock types. The geology consists of outcropping shear zones, where the mineralised ore is present. Oxidised sedimentary geology can occur to depth of 20m, but is considered minimal in mining volume.



(source: Calidus Website)

Figure 3 Project Regional Geology Map

The whole deposit will require drill and blast mining techniques to fracture the rock for removal.

Proposed Blast Parameters

Blast parameters are linked to the rock properties, bench heights, mining methods and crushing and processing requirements. The proposed blast parameters will assume a maximum particle size of 1.0m for both ore and waste material and will use an assumed powder factor (based off experience) to determine blast parameters. The mining will be assumed to use a 100T to 200T backhoe excavator for mining.

The proposed mining method may utilise the following blast parameters or similar alternatives:

	Standard Blast Parameters	Alternate # 1	Alternate #2 Ore Mine to Mill	Alternate # 3	Alternate # 4
Bench Height (m):	5	5	5	7.5	10
Blast Hole Diameter (mm):	102	115	115	127	165
Burden (m)	2.8	3.0	2.5	3.5	4.4
Spacing (m)	3.2	3.4	2.9	4.0	5.0
Stemming Length (m):	2.0	2.3	2.0	2.3	3.3
Subdrill (m):	0.7	0.7	0.5	0.8	1.0
Explosives Type:	Emulsion	Emulsion	Emulsion	Emulsion \ HANFO	Emulsion \ HANFO
Explosives Density (gcm^{-3}):	1.1	1.1	1.1	1.1	1.1
Explosives Charge per Blast Hole (kg):	33.3	38.8	40.0	83.6	181.1
Powder Factor (kgm^{-3})	0.70	0.76	1.10	0.80	0.82
No explosive decks	1	1	1	1	1
Inert deck length	NA	NA	NA	NA	NA
Initiation System:	Non-electric	Non-electric	Non-electric	Non-electric	Non-electric
Maximum Instantaneous Charge (kg):	126.0	155.2	160.0	323.2	724.4
No of blast holes per delay	4	4	4	4	4

Table 1 Modelled Blast Parameter

The blast parameters documented in Table 1.0 can be considered an average set of blast parameters, if implemented the required fragmentation could be achieved with experienced hard rock drill and blast designers. No fragmentation modelling has been conducted, as uncalibrated models (KUZRAM and\or SWEBREX) only provide ± 20% accuracy. Blasting experience and knowledge in similar Pilbara Basalt rock masses will provide similar or better predictions of fragmentation results.

Fragmentation in rock masses is driven by six major contributing factors and using powder factor only addresses a single component. The six major contributing factors to fragmentation include:

- Pre-existing fragmentation (sand, clay, columnar basalt)
- Energy distribution;
- Explosives chemistry and physical detonation conditions (confinement);
- Powder factor kg/m3;
- Burden relief ms/m; and
- Wave reflection.

The most influenceable factor is the geological pre-existing fragmentation, joint sets. A columnar basalt will fragment to below the required maximum particle size using much less explosives than a massive basalt rock mass.

Energy distribution is largely driven by hole diameter selection. Smaller diameter blast holes on tight burden and spacings will typically result in smaller fragmentation than pattern with larger diameters on bigger burdens and spacing that have the same powder factor (kilograms of explosives per cubic meter of rock).

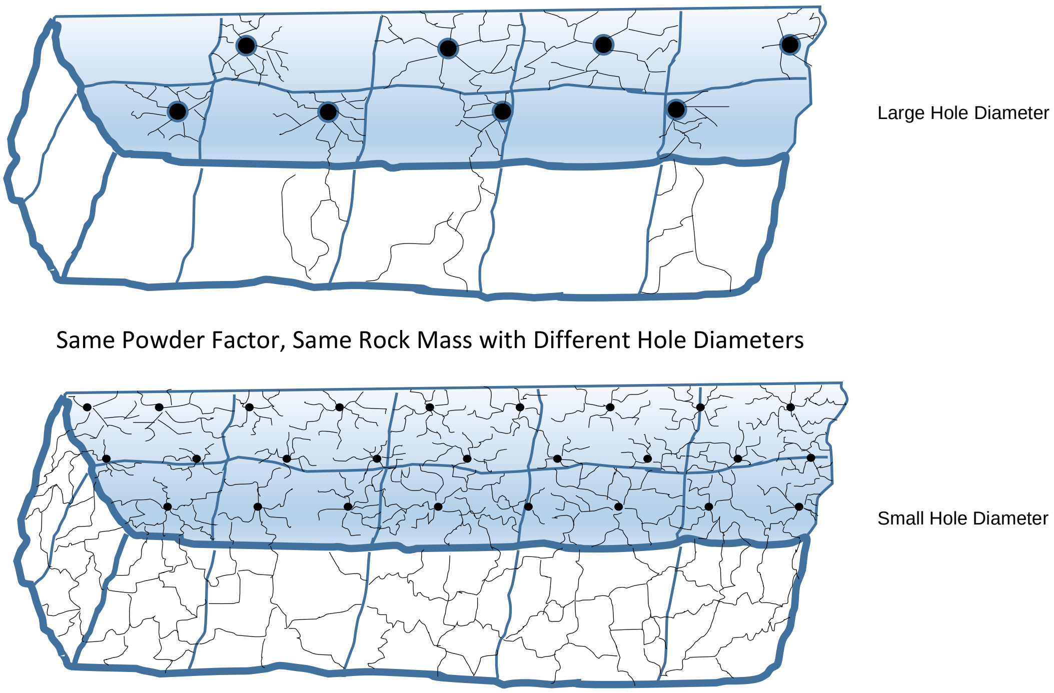


Figure 4 Explosive Distribution - Hole Diameters Effect on Fragmentation

Energy distribution can also be influenced by the distribution of the explosives throughout the explosives column. In rock that creates significant oversize in the stemming zone, the stemming can be reduced to improve explosives distribution, or a deck charge can be placed into the stemming zone. Figure 5 displays examples of altering energy distribution with a blast hole.

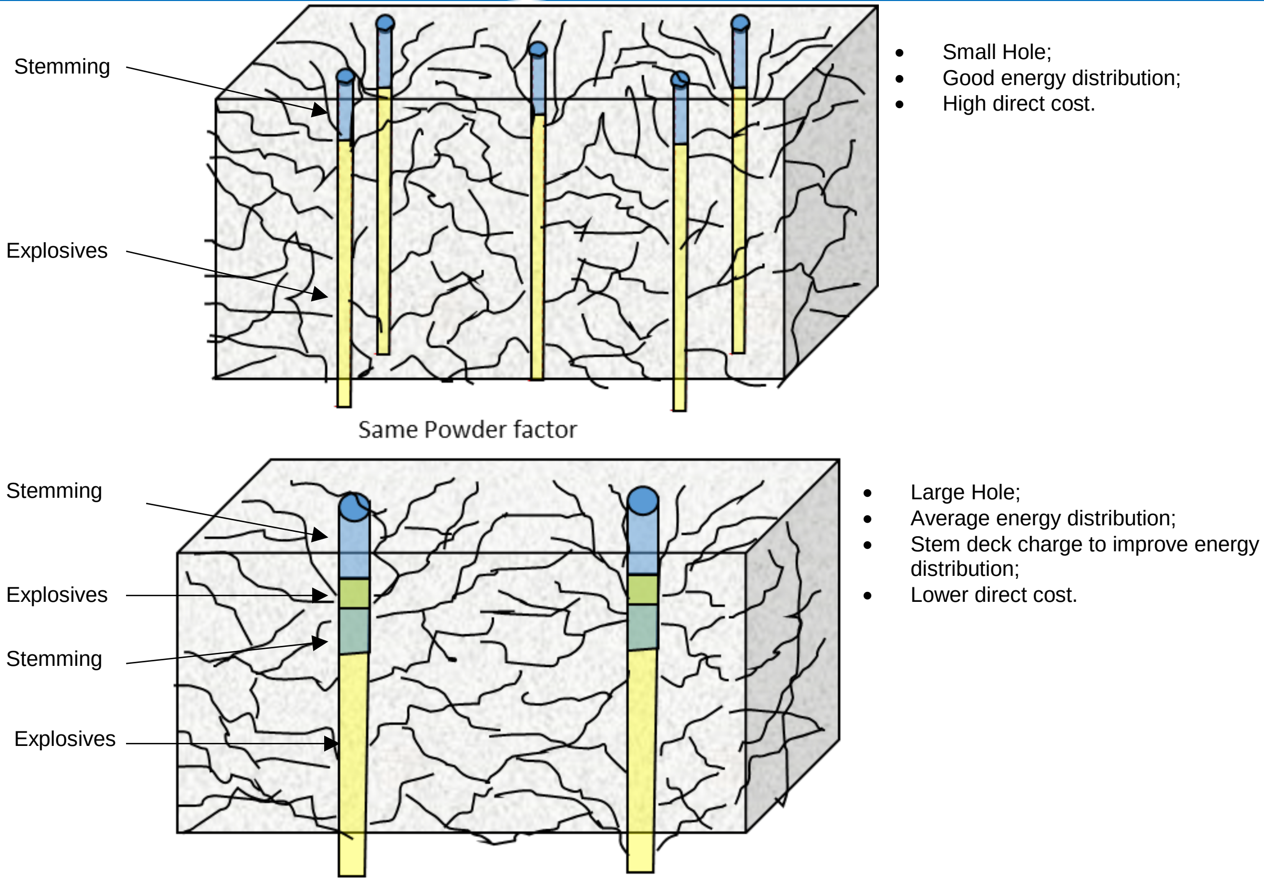


Figure 5 Influence of Energy Distribution on Fragmentation

Explosive chemistry is an important factor to consider when selecting an explosive supplier and determining most economical solution. In the past, explosive suppliers offered only a brand name product for Ammonium Nitrate Emulsion (ANE) based explosives. This allows the supplier to increase or decrease the energy of the supplied explosives with no accountability. Water content in ANE based explosives can vary between 16% by weight to < 25% by weight. This component of water is not considered when comparing suppliers and determining pattern parameters using a powder factor calculation. Increasing water content of ANE decreases explosives energy in combination with reducing the sensitivity of the ANE based explosives.

The geology conditions at the proposed Warrawoona Gold Project will provide high confinement and therefore dependant on hole diameter explosive will detonate effectively at densities up to 1.2 gcm^{-3}. In overburden sedimentary material bulk explosives with densities over 1.1 gcm^{-3} will commonly produce noxious post blast fume, indicating pour detonation conditions (low ground confinement) or the product has been desensitised by water (ANFO loaded into wet holes). Where the ground geology is causing post blast fume, not due to water, the density of the explosives must be reduced to increase the sensitivity of the explosives. This technique is called impedance matching. Increasing explosives density to increase the blast powder factor can cause the mentioned occurrence, as increasing explosives density decreases explosives sensitivity and can cause poor detonation conditions.

Burden relief is a factor which is related to initiation sequencing of the blast. Burden relief is measured by initiation delay in milliseconds per meter of firing burden within a blast. The smaller the delay between blast holes, the quicker the burden relief, which will improve fragmentation. Burden relief less than 15 ms/m will improve fragmentation. Caution must be taken as maximum fragmentation driven by burden relief is achieved at 0 ms/m, although, if the blast can be excavated, the excavation rates will be very slow, as the blast will lock up. This factor is not considered with a powder factor calculation either.

Wave reflection is another fragmentation mechanism which is promoted by initiation sequencing. The technique utilises quicker initiation sequencing to reflect blast hole pressure waves back toward the source to improve crack propagation intensity. Technique is commonly used when sequencing electronic detonators to improve fragmentation. This technique is not considered in a powder factor calculation.

Prior to selecting the set of blast parameters to begin blasting at a site all the required inputs must be considered, which includes all the mechanisms of fragmentation. Then the required outputs can be assessed e.g. required environmental results, fragmentation and costs using comprehensive and effective methodology.

Blast Vibration Evaluation

Ground vibration is caused by the detonation of explosives in the ground. For the evaluation of the blast induced ground vibration at the proposed Klondyke mine sensitive sites, industry recognised equations will be used. AS2187.2-2006 recommends the use of the following equation to predict blast vibration levels:

$$PPV = K\left(\frac{\mathrm{R}}{\sqrt{Q}}\right)^{B}$$

Where:

PPV	= Peak Particle Velocity (mms^{-1})
R	*= Distance from blast to sensitive receiver (m)*
Q	*= Charge weight detonating within given time window (8ms for this assessment)*
K	*= K intercept of line*
B	*= Slope of the line (slope is negative)*

Equation 1 Blast vibration prediction equation

The initial pit development, which will include blasting operations, may be located, at the closest distance, 185 metres from the Klondyke Queen workings. Separation distance between the Klondyke Queen and the proposed stage 1 pit is displayed in Figure 6. The shaft has been identified as having PLNB and GB roosting within it confines. The K factor for the prediction of vibration will use a value of 1140 for the 50-percentile probability and a value of 2000 for the 95-percentile probability. Without actual vibration measurement data for the specific site, industry standard methods would require the use of the 95 percentile calculations to be used. The authors experience would suggest that a K value of 1140, 50 percentiles would be more probable to be aligned to an actual measured site value, although this would require verification to be used.

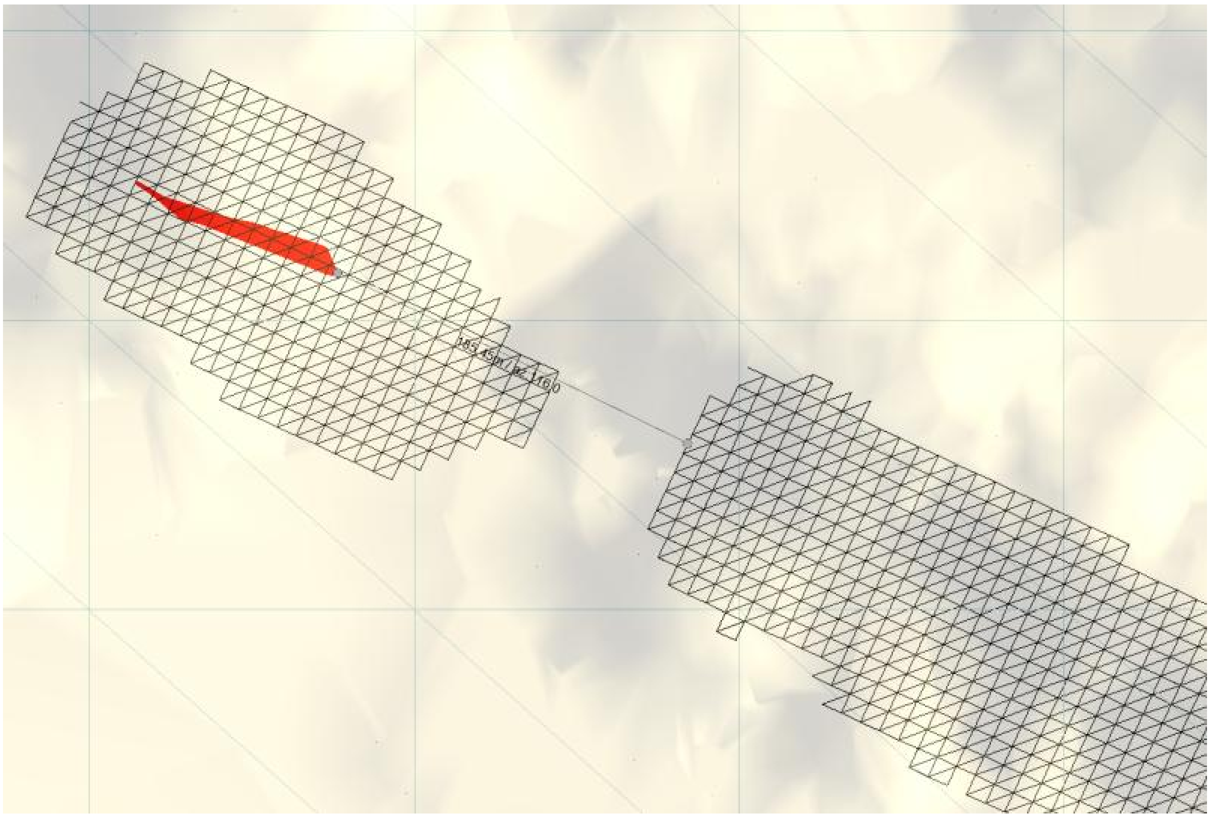


Figure 6 Separation Distance Between Stage 1 Pit and Klondyke Queen workings that contain the PLnB and GB roosts,

Charge Weight (Kg)	Distance (m)						
	50	**100**	**200**	**500**	**800**	**1000**	**2000**
126.0	104.4	34.45	11.36	2.62	1.24	0.87	0.29
155.2	123.39	40.07	13.22	3.05	1.44	1.01	0.33
160.0	126.43	41.72	13.76	3.18	1.50	1.05	0.35
323.2	221.89	73.2	24.15	5.57	2.63	1.84	0.61
724.4	423.19	139.6	46.05	10.6	5.01	3.51	1.16

Table 2 Predicted blast vibration results (mms^{-1}) 50 Percentile

Charge Weight (Kg)	Distance (m)						
	50	**100**	**200**	**500**	**800**	**100**	**2000**
126.0	183.22	60.44	26.90	2.56	0.63	2.67	0.01
155.2	216.47	71.41	23.56	5.44	2.56	71.41	0.59
160.0	221.81	73.17	24.14	5.57	2.63	73.17	0.61
323.2	389.27	128.41	42.36	9.78	4.61	128.41	1.06
724.4	742.44	244.91	80.79	18.6	8.79	244.91	2.03

Table 3 Predicted blast vibration results (mms^{-1}) 95 Percentile

Using standard initiation sequencing, non-electric, based on the results displayed in Table 1.0 and Table 2.0 blasting would not be able to occur within 200 m of the closets bat habitat. With modifications to initiation designs, blasting could occur at the closest separation distance of 185m. This would require the control of the Maximum Instantaneous Charge (MIC). Maximum instantaneous charge is defined as the combined charge weight firing within a given time frame, industry standard is the 8ms firing window. This would mean that no two holes or more could be firing with an initiation timing that is within 8ms of any other blast hole firing time in the blast pattern.

Table 4 documents the five alternate sets of blast parameters utilising an initiation sequence which would ensure single hole firing.

Charge Weight (Kg)	Distance (m)						
	50	**100**	**200**	**500**	**800**	**100**	**2000**
31.5	60.44	19.94	6.58	1.52	0.72	19.94	0.17
38.8	71.41	23.56	7.77	1.79	0.85	23.56	0.20
40	73.17	24.14	7.96	1.84	0.87	24.14	0.20
80.8	128.41	42.36	13.97	3.23	1.52	42.36	0.35
181.1	244.91	80.79	26.65	6.15	2.90	80.79	0.67

Table 4 Predicted blast vibration results (mms^{-1}) 95 Percentile- Single Hole Firing

Based on the results displayed in Table 4 the blast parameters documented in Table 1 for the “Standard Blast Parameters”, “Alternate #1” and “Alternate #2 (Ore) Mine to Mill” blasting scenarios could be implemented at the minimum separation distance of 185m and be compliant with the 10 mms^{-1} vibration limit at the closest extent of the Klondyke Queen workings.

Figure 7 displays the MIC (kg) at a given distance to comply with a 10 mms^{-1} PLNB/GB disturbance limit.

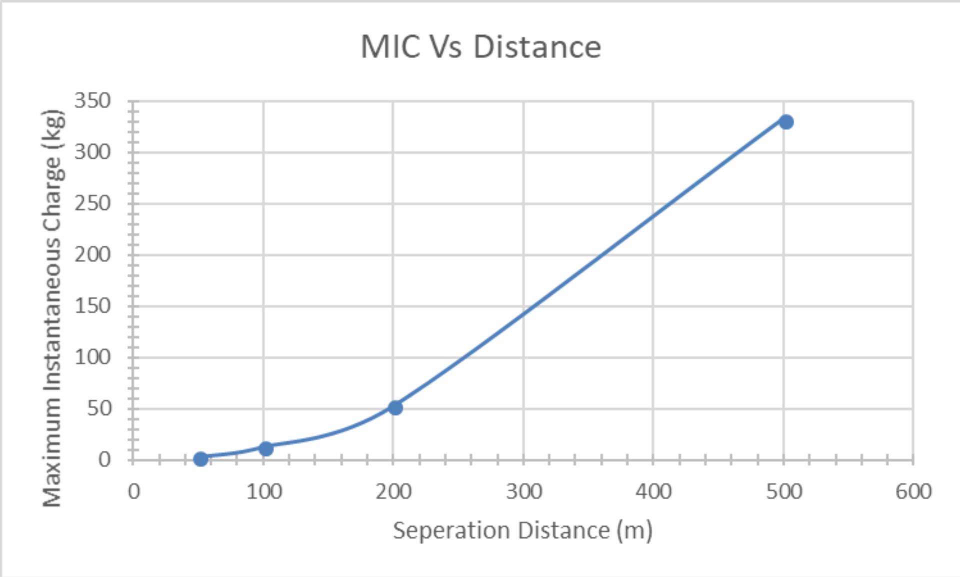


Figure 7 Maximum Instantaneous Charge at Distance to Achieve 10 mms^{-1} Blast Vibration Limit (K = 2000)

Concerns will be raised over the blast vibration limit to ensure that the Klondyke Queen's structural integrity is not damaged. Without a comprehensive geotechnical survey of the workings, informed general vibration limits can only be applied, with regards to structural integrity e.g. restricting rockfall events. New fractures start to form in softer rock (low strength) types at approximately 250 mms^{-1} and in high strength rock types new fractures start to form at +1000 mms^{-1}. Rock that has already fractures and is only sitting in place by confinement of the surrounding rock may start to move and spall at levels as low as 25 mms^{-1}. Many Pilbara based sites use a 30 mms^{-1} as a vibration limit for heritage sites, this would be suggested as a maximum limit to restrict any rock fall events that may cause harm to the PLNB and GB inhabiting the underground voids.

The no disturbance limit of 10 mms^{-1} is lower than the spalling blast vibration limit and therefore all blast designs must be designed to comply with this limit unless further field work is to be conducted to establish site blast vibration constants. In addition to establishing a blast vibration equation with site specific constants, a biologist consultant specialising in bats could also be engaged to monitor bat activity for disturbances, if site required the 10 mms^{-1} limit increased. An increase to 20 mms^{-1} could be possible using an approved scientific program.

Airblast estimation equations are generally very inaccurate as the actual airblast result is heavily dependent on factors such as blast confinement, atmospheric conditions and the topography between the blast and sensitive receiver. Equation 2 is an empirical equation developed by the United States Bureau of Mines when conducting blasting research, as documented in the RI 8507 report (Siskind).

$$Airblast\ (dBL) = 165 - 24\log_{10}(R/W^{1/3})$$

Where R = distance to point of concern (m)
W = charge mass per delay (kg)

Equation 2 Airblast Estimation Equation

In the author's experience, this equation delivers a better estimation of real world blasting results when compared to using the equation documented in AS2187.2-2006 Appendix J section J7.2.

The data in Table 5 is a prediction of air overpressure produced when using the proposed blasting parameters and Equation 2.

Charge Weight (kg)	Distance (m)						
	50	**100**	**200**	**400**	**800**	**1000**	**2000**
126.0	141.0	133.8	126.6	117.0	112.1	109.8	102.6
155.2	141.8	134.5	127.3	117.8	112.9	110.5	103.3
160.0	141.9	134.6	127.4	117.9	113.0	110.6	103.4
323.2	144.3	137.1	129.9	120.3	115.4	113.1	105.9
724.4	147.1	139.9	132.7	123.1	118.2	115.9	108.7

Table 5 Air overpressure prediction for standard blasting conditions (4 Hole MIC)

The calculated values in Table 5 for standard blasting practice, non-electric initiation sequencing targeting optimal dig rates and fragmentation for the given powder factor are displayed as not being compliant at distances of 200m. The limit of 125 dBL is for human comfort levels. This limit is regularly exceeded by nature with the noise (air pressure) generated by thunder storms. With noise bunding in specifically designed locations close to the roosting habitat entry point, airblast if measured at the levels documented in Table 5 at 200m, could be reduced by the noise bunds.

The author has conducted field tests at quarrying operations and found a noise bund reduced the measured airblast overpressure by 7 dBL. If this reduction was applied to the values in Table 5, 4 of the 5 blast scenarios would become compliant with the 125 dBL airblast overpressure limit.

Airblast overpressure is also influenced by the number of charges initiating within a given time frame (MIC), time window. With airblast overpressure the MIC time window is typically 40 ms or greater to deliver a reduction in pressure. Table 6 displays the predicted airblast overpressure using single hole firing with the alternate blast parameter scenarios documented in Table 1.

Charge Weight (kg)	Distance (m)						
	50	100	200	400	800	1000	2000
31.5	136.2	129.0	121.8	112.2	107.3	105.0	97.8
38.8	136.9	129.7	122.5	112.9	108.0	105.7	98.5
40	137.0	129.8	122.6	113.0	108.1	105.8	98.6
80.8	139.5	132.3	125.0	115.5	110.6	108.3	101.0
181.1	142.3	135.1	127.8	118.3	113.4	111.1	103.8

Table 6 Air overpressure prediction for standard blasting conditions (Single Hole MIC)

The calculated values in Table 6 for using a single hole firing initiation sequence would deliver compliance with 4 of the 5 sets of blast parameters, documented in Table 1. With the introduction of noise bunds, the scenario using 165mm blast holes would also become compliant with limit of 125 dBL is for human comfort levels.

Blast Fume and Dust Evaluation

Blasting of rock using conventional bulk explosives can generate toxic fume (gasses) and dust. Bulk explosives selection is a key control for reducing or eliminating post blast fume. Post blast fume consist of two gases, Carbon Monoxide (CO) that is odourless and colourless and can cause suffocation at elevated levels. Over fuelled bulk explosives will generate excess CO gas in combination with dotation conditions. Heavy ANFO's and Ammonium Nitrate Emulsion (ANE) \ Ammonium Nitrate Suspension (ANS) (Watergels) have been recorded to generate excessive CO in low confinement geology. An oxygen balanced bulk explosive (5.7% Fuel to 94.3% Oxidiser by weight ratio) with maximum sensitivity, lowest density, should be selected when loading within 500m of the roosting habitat entry points. . If ground conditions are wet a low water content ANE or a Watergel must be used to ensure that the detonation conditions are optimal as possible, not cooled by the excess water added to the bulk explosives.

Post blast fume, Nitrous Oxide (NOx) is an orange to purple in colour gas and can be associated with under fuelled bulk explosives or poor detonation conditions. The gas is toxic as when it encounters moisture it will produces a nitric acid. If NOx is inhaled by the PLNB or GB death or serious lung injury could occur. As discussed with the control of CO production from blasting, an oxygen balanced bulk explosive should be selected with the density being selected to ensure maximum sensitivity, which will ensure optimal detonation conditions. Most rock masses display no improvement in fragmentation increasing the bulk explosives density past 1.1 gcm^{-3}, therefore to maintain bulk explosive detonation conditions, a density of 1.1 gcm^{-3} or less must be selected to reduce the potential of NOx gasses being generated. Figure 8 displays an example of post detonating fume (NOx) at a mine site.

Figure 8 Example of a Post Blast Fume Event (NOx)

The prediction of post blast dust and controlling the generation of post blast dust has proven a very difficult task. Applying water, misting the blast, applying membranes and chemical retardants has been tried with minimal benefits. A proven method of control, which is used by all blasting operations located near residential areas, is to monitor weather conditions and only fire the blast when the prevailing winds are blowing away from sensitive structure. This will also assist in restricting any post blast gasses moving toward the roosting habitat entry points. . Figure 9 displays an example of a post blast dust event.

Figure 9 Example of Post Blast Dusts

Blast Flyrock Evaluation

Australian Standard 2187.2-2006 Appendix E highlights considerations for blast design to minimise the generation of flyrock. AS2187.2-2006 Appendix E (E2.1) - contributing factors, outlines the key contributing factors that must be considered when addressing controls to minimise the effects of flyrock and developing a safe and productive Blast Exclusion Zone (BEZ).

Many industry experts have developed site prediction methodologies for determining a safe BEZ to protect quarry personnel, equipment, infrastructure and the public. The causes of flyrock have been well studied and documented. The three main mechanisms are rifling, cratering and face bursting. The equations show in Figure 10 (Richards & Moore) address the three mechanisms of flyrock generation and will be used to determine the safe blast exclusion distances.

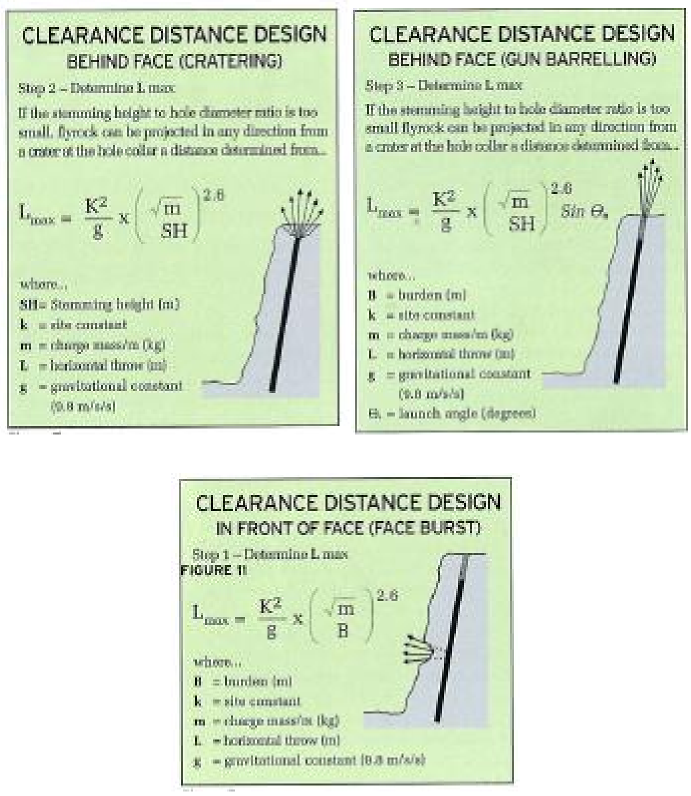


Figure 10 (Richards & Moore) Flyrock Equations

The above equations include a site constant "K", which requires calibration to site conditions to improve the accuracy of the factor of safety calculation, and in some cases, improve productivity by ensuring good energy confinement. This can be achieved by measuring actual blast parameters and recording the maximum fly rock projection distance from each blast on site, thus ensuring specificity to the site's drill and blast parameters and geology. In this case the absence of any site data dictates that a value of 27 should be used for "K" to maximise the factor of safety. Industry standard K values are from 13 in soft rock, to 27 in hard rocks such as granite.

The cratering mechanism can be eliminated by ensuring that the correct stemming length is used in relation to the blast hole diameter. Flyrock caused through a cratering scenario is typically associated with poor blast design. The empirical rule that determines the correct stemming length, as documented in Equation 3, and depicted in Figure 11.

$$SD = D/W^{0.333}$$

Where:

SD	= Scaled Depth ($m/\sqrt[3]{kg}$)
W	= Charge weight contained in 10 hole diameters (kg)
D	= Distance from point of interest (m)

Equation 3: Scaled Depth of Burial equation

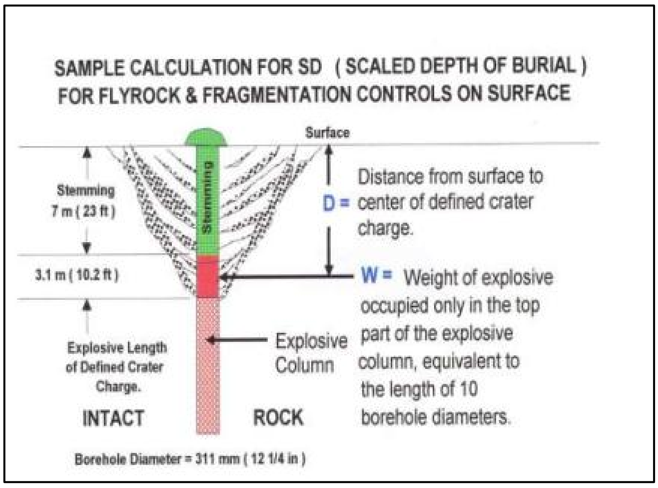


Figure 11 Scale Depth of Burial Dimensions Defined (Chiappetta)

To determine the trajectory of the flyrock, a launch velocity must be calculated using the following equation:

$$V_0 = \sqrt{\frac{L_{\max} g}{Sin 2\theta}}$$

Where:

θ	= Flyrock launch angle
L_{max}	= maximum flyrock range
V_0	= Launch velocity (ms^{-1})
g	= gravitational constant (9.81 ms^{-2})

Equation 4: Launch velocity

The above equations and techniques were used to determine safe blast exclusion zone and maximum theoretical flyrock throw distances.

Table 7 lists the blast parameters that have been used to predict the expected blast vibration and airblast overpressure levels in the previous sections of this report, along with the maximum calculated flyrock distances and Scaled Depth of Burial (SDoB). The worst-case scenarios were modelled using the equations documented in the in this section of this report. A flyrock constant (K) of 27 was used in all calculations to maximise the factor of safety in the absence of any site data. Where the SDoB is greater than 1.3 the "Maximum Horizontal Distance Crater" value was not used.

Parameters	Standard Blast Parameters	Alternate # 1	Alternate #2 Ore Mine to Mill	Alternate #3	Alternate # 4
Bench Height (m)	5	5	5	7.5	10
Hole Diameter (mm)	102	115	115	127	165
Face Burden (m)	3.0	3.2	3.2	3.8	4.4
Burden (m)	2.8	3.0	2.5	3.5	4.4
Spacing (m)	3.2	3.4	2.9	4.0	5.0
Stemming (m)	2.0	2.3	2.0	2.3	3.3
Subdrill (m)	0.7	0.7	0.5	0.8	1.0
Explosive Density (g/cm3)	1.10	1.10	1.10	1.10	1.10
Charge Weight (kg)	31.5	38.8	40.0	80.8	181.1
Max Horizontal Distance Face Burst (m)	74	86	86	48	96
Max Horizontal Distance Cratering (m)	213	202	291	202	202
Max Horizontal Distance Stem Ejection (m)	106	101	145	101	101
SDoB	1.20	1.22	1.15	1.22	1.22

Table 7: Calculated Worse Case Flyrock Projection Distances (Rock Density = 2.7 gcm^{-3})

A graphical plot of the expected flyrock trajectories is displayed in Appendix 1. As none of the blast parameters scenarios comply with a no flyrock within 50m of the PLNB/GB roosting habitat areas, the stemming length will have to be adjusted to ensure compliance.

Parameters	Standard Blast Parameters	Alternate # 1	Alternate #2 Ore Mine to Mill	Alternate #3	Alternate # 4
Bench Height (m)	5	5	5	7.5	10
Hole Diameter (mm)	102	115	115	127	165
Face Burden (m)	3.0	3.2	3.2	3.8	4.4
Burden (m)	2.8	3.0	2.5	3.5	4.4
Spacing (m)	3.2	3.4	2.9	4.0	5.0
Stemming (m)	2.4	2.7	2.7	3.0	3.9
Subdrill (m)	0.7	0.7	0.5	0.8	1.0
Explosive Density (g/cm3)	1.10	1.10	1.10	1.10	1.10
Charge Weight (kg)	29.7	34.3	34.3	73.8	167.0
Max Horizontal Distance Face Burst (m)	74	86	86	71	96
Max Horizontal Distance Cratering (m)	133	133	133	135	135
Max Horizontal Distance Stem Ejection (m)	66	67	67	68	67
SDoB	1.39	1.38	1.38	1.38	1.4

Table 8: Calculated Worse Case Flyrock Projection Distances Increased Stemming (Rock Density = 2.7 gcm^{-3})

Without a calibrated Flyrock Model using the conservative Flyrock Constant of 27, when blasting within 350m of the closest PLNB/GB roosting habitat the stemming length documented in Table 8 must be used to control flyrock projection. Once the blasting is greater than 350m from the PLNB/GB roost the blast parameters documented in Table 1 can be used.

Additional stemming will control the flyrock projection, although must be noted that additional stemming will increase the maximum particle size and concentration of large rock fragments. If free face firing the actual face must be scanned and used to review actual face burden prior to firing the blast if the blast is facing towards the PLNB/GB roosting habitats.

Initiation Systems Evaluation

To ensure that the PLNB/GB is not disturbed by airblast only non-electric initiation systems or electronic initiation systems could be used, as detonating cord systems create high amplitude low frequency airblast overpressure, which could disturb the bats. Airblast overpressure that can be controlled by initiation sequencing can equally be controlled using either a non-electric or electronic initiation system.

Blast vibration would require the use of an electronic initiation system or a non-electric system. Prior to commencing full scale production blasting it would be suggested that a seed hole firing program be planned and fired to evaluate actual site blast vibration attenuation constants. Determination of the blast vibration constant will enable the selection of the most economic initiation system to be able to control the blast vibration.

An electronic initiation system will allow the users to control blast vibration with greater ease, although both system can be used to control vibration by experienced blasting professionals. If a scientifically determined, with high confidence, site blast vibration equation is not determined, then it would be suggested that within 50m of the PLNB/GB roosting habitat electronic detonators are used.

Environmental Blast Monitoring

Due to the location of the project to the sensitive PLNB/GB roosting habitat, a permanent blast monitoring location must be established. A key criterion is that a permanent blast vibration monitoring block is located as close to the PLNB/GB roosting habitat as possible (within 10 m), and located between the roosting habitat and the proposed drill and blast locations.

Monitoring of the blast for both airblast overpressure and blast vibration must be conducted for all blasting events, within 1000 m of the PLNB/GB roosting habitat. Figure 12 displays an example of a blast monitor set up with a permanent monitoring block, the blast monitor is only placed out on the day of the blast. Other costlier permanent blast monitor installations can be established that use remote dial in to download data or even notify of exceedances.

Figure 12 Blast Monitor - Microphone and Geophone Installation

Recommendations

Based on the results of airblast overpressure, blast vibration and flyrock modelling for blasting at the Warrawoona Gold Project, the following recommendations are suggested:

- Select conservative blast parameters, similar to parameter that have been modelled in this report to be compliant with airblast overpressure, blast vibration and flyrock projection until measurement and competence in expected blast results has been established;
- Select suitable explosives that have a low probability of producing toxic post blast fume events;
- Establish controls in the Blast Management Plan for blasting when wind conditions will drive post blast dust and potential fume towards the PLNB/GB roosting habitat entry point(s);
- Permanent blast monitoring stations should be established at close proximity to the PLNB/GB roosting habitat. The monitor must record both air overpressure and ground vibration for all nearby blasts. The resultant data plus blast parameters should be used to develop site prediction equations;
- Initial site blasting should commence a minimum of 1000m from both the Accommodation Village and the PLNB roosting habitat, until the site prediction equations are established with a high level of confidence;
- All blasting practices should have procedures and designs that are adhered to and ensure above average confinement of the explosives charges; and
- Blasting should commence at safe distances from the closest sensitive sites to ensure that techniques are well established, and the air overpressure site equation can be established.

By implementing the recommendations, Calidus Resources will achieve industry best practice to ensure blasting environmental compliance at the identified sensitive sites.

Conclusion

If the Drill & Blast design parameters modelled in this report are utilised, Drill & Blast activities can safely occur to within 185m of the Klondyke Queen and will not result in vibration exceeding that of human comfort levels, or result in collapse of this sensitive receiver (Klondyke Queen).

To ensure compliance of the blast results with reference to sites suggested blasting limits, the following conditions should be implemented:

a) The recommendations in this report are followed; and
b) Best practice blasting processes and procedures are implemented and adhered to.

By implementing the recommendations, Calidus Resources will achieve industry best practice to ensure blasting environmental compliance at the identified sensitive sites and ensure sustainable mining practices.

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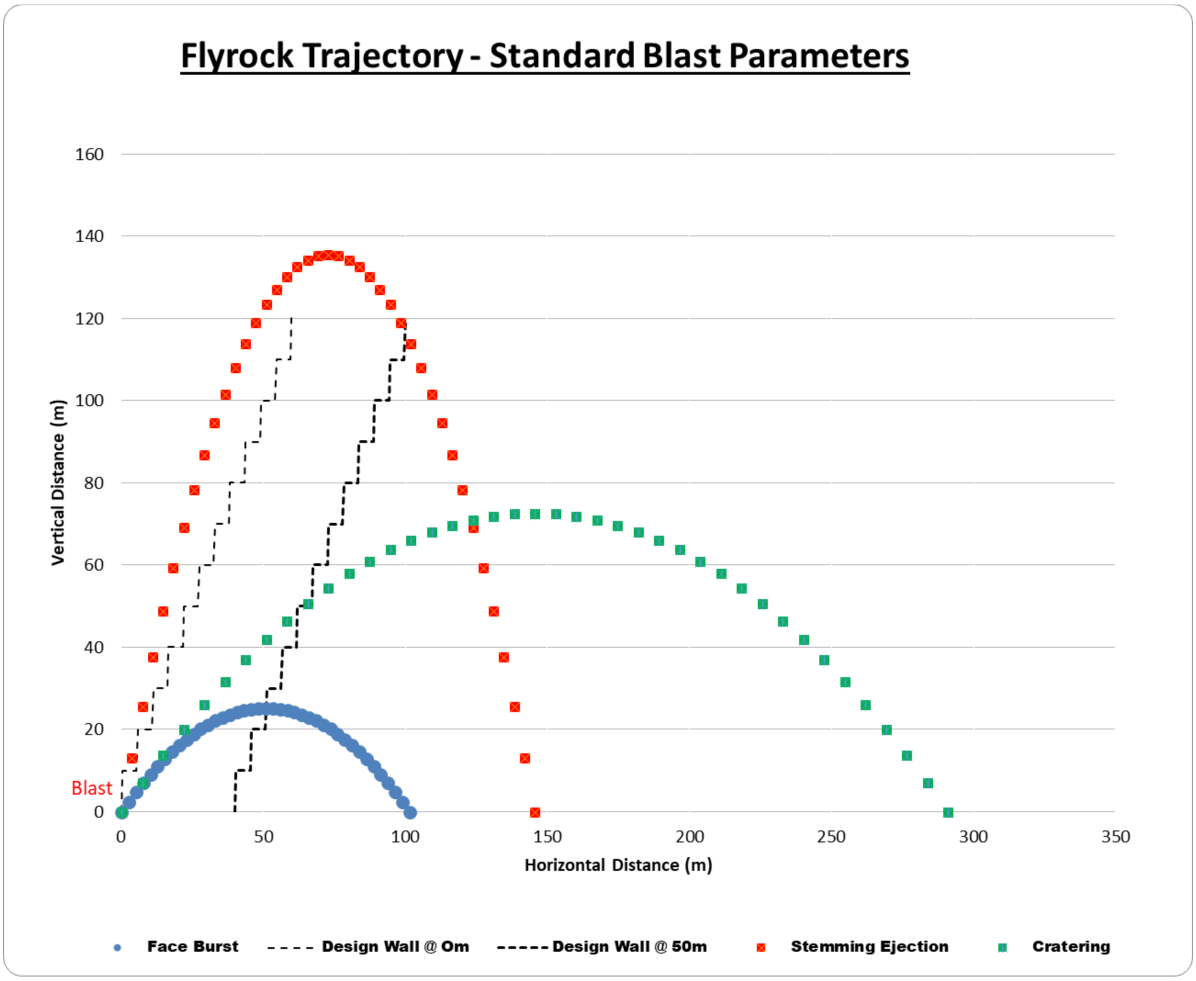
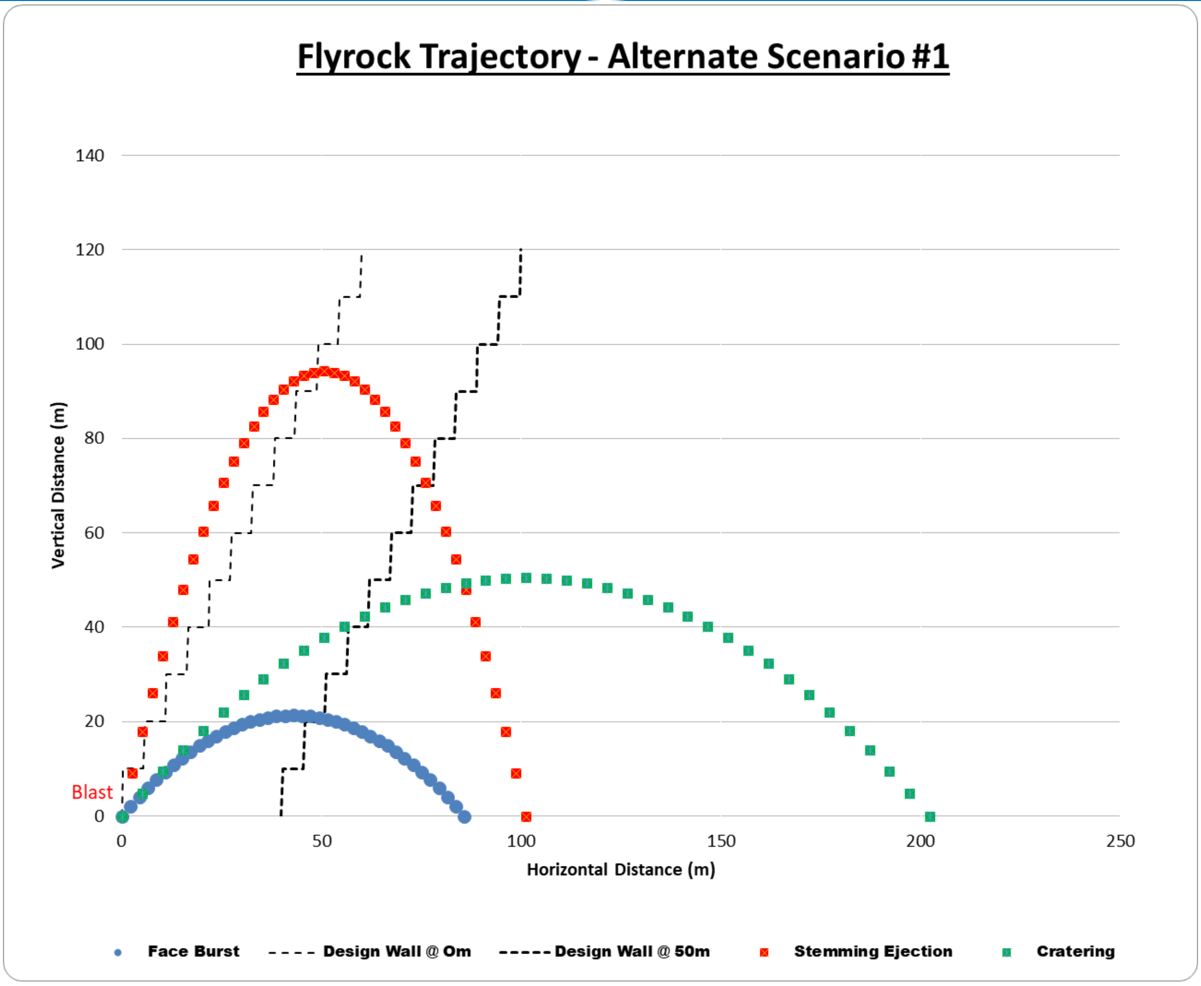
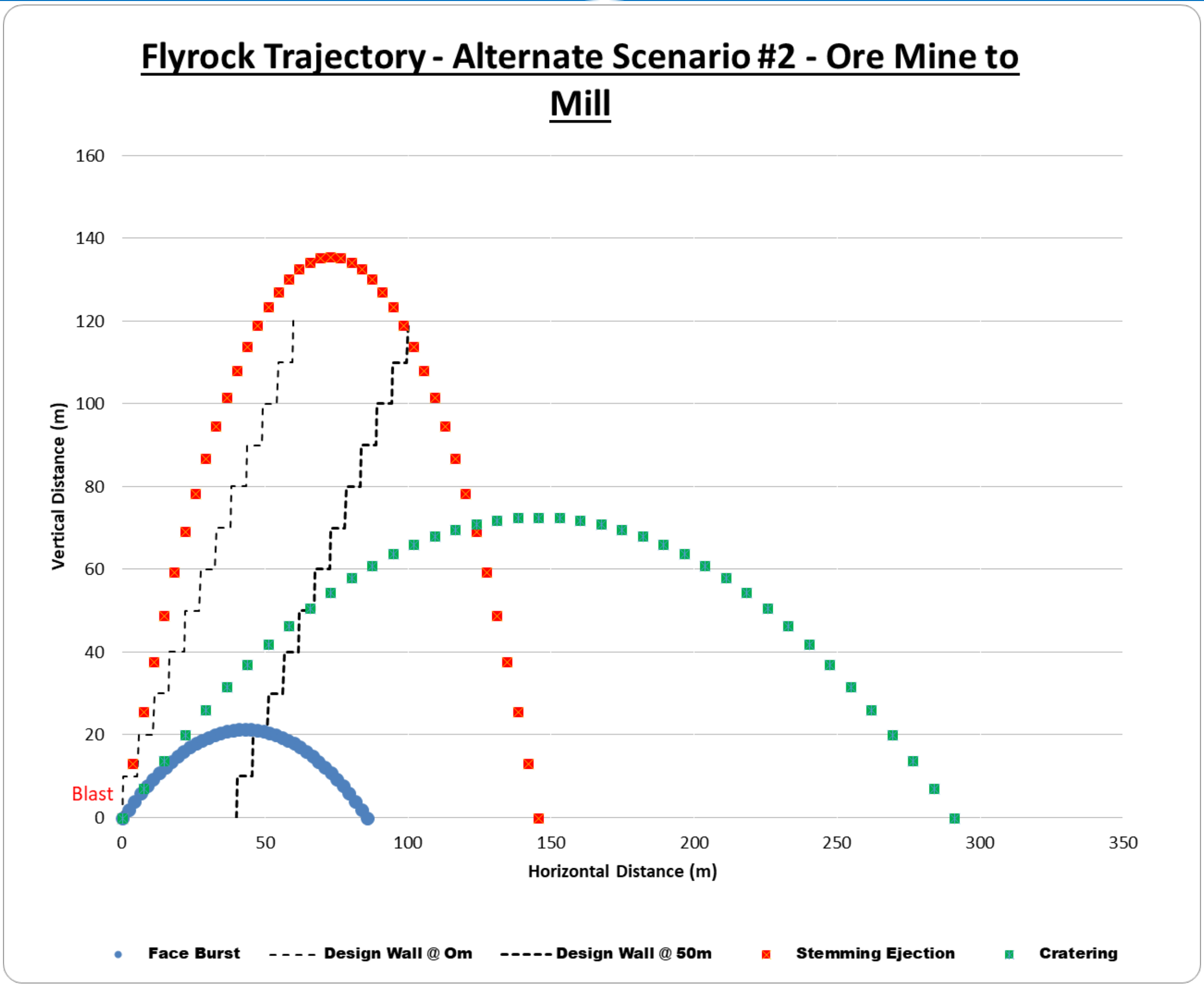
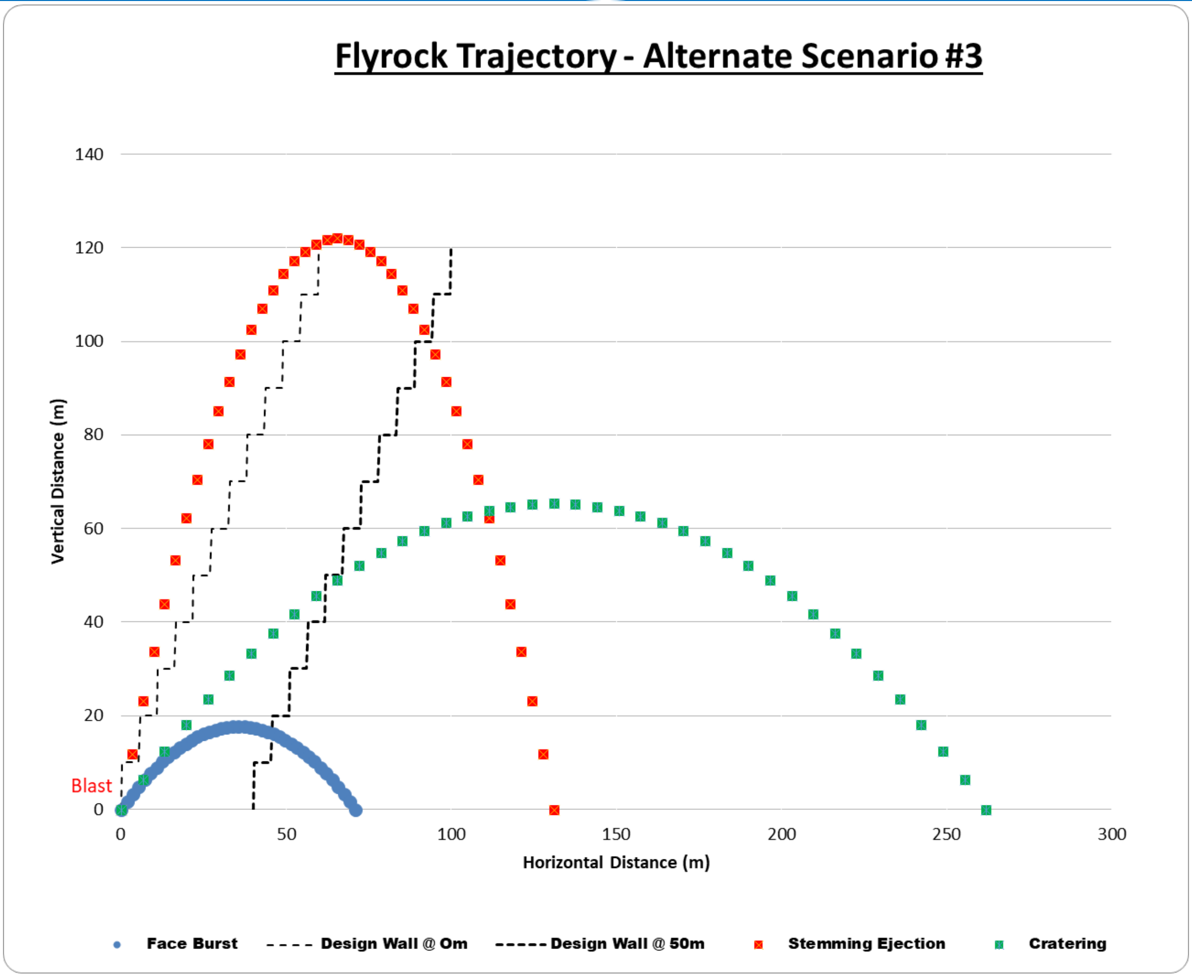
Appendices

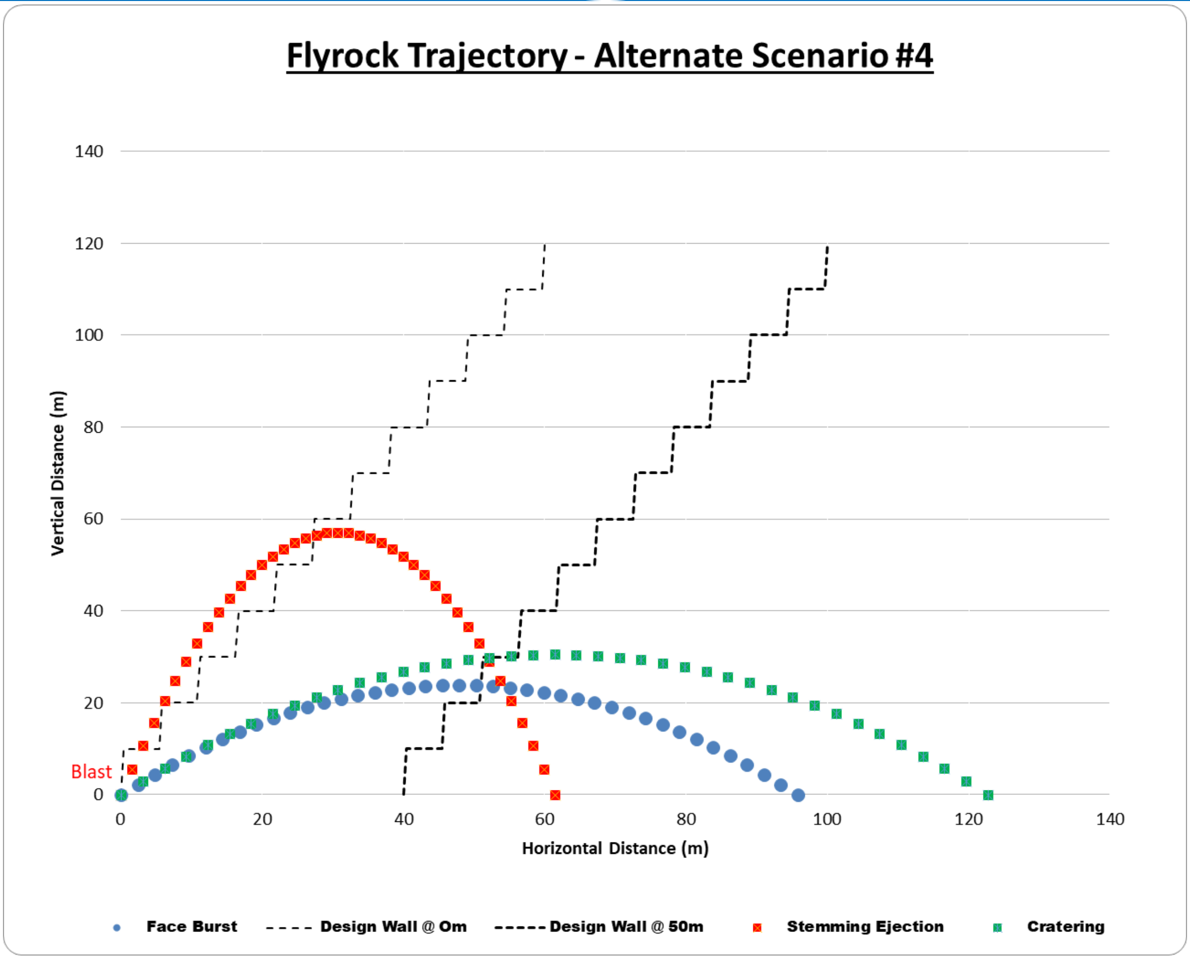
Appendix 1 Flyrock Projection Distance for Each Scenarios Blast Parameters

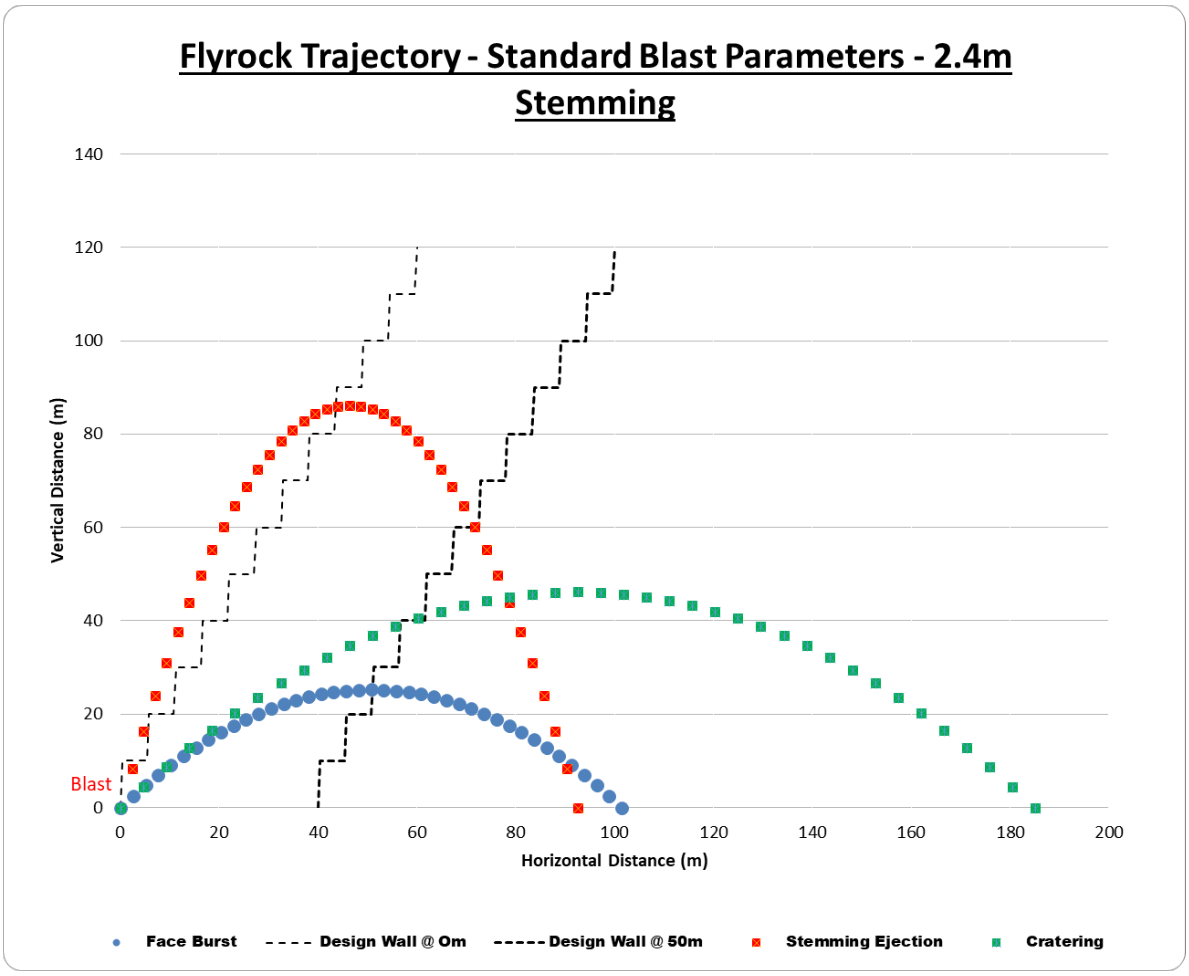


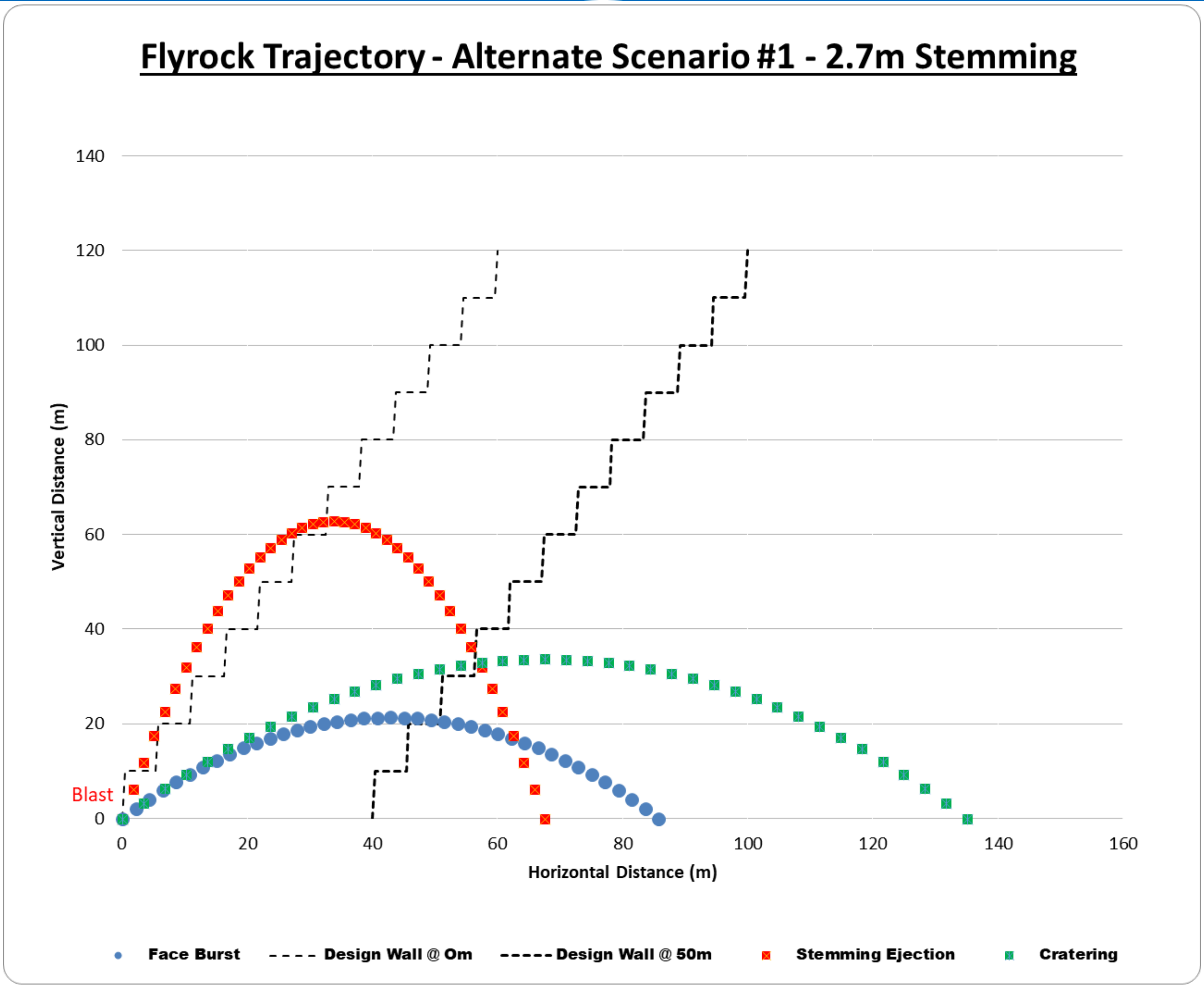

Flyrock Trajectory - Alternate Scenario #1
Vertical Distance (m)
140
120
100
80
60
40
20
0
Blast
0
50
100
150
200
250
Horizontal Distance (m)
Face Burst
Design Wall @ 0m
Design Wall @ 50m
Stemming Ejection
Cratering


Flyrock Trajectory - Alternate Scenario #2 - Ore Mine to Mill
160
140
120
100
80
60
40
20
0
Blast
Vertical Distance (m)
0
50
100
150
200
250
300
350
Horizontal Distance (m)
Face Burst
Design Wall @ 0m
Design Wall @ 50m
Stemming Ejection
Cratering

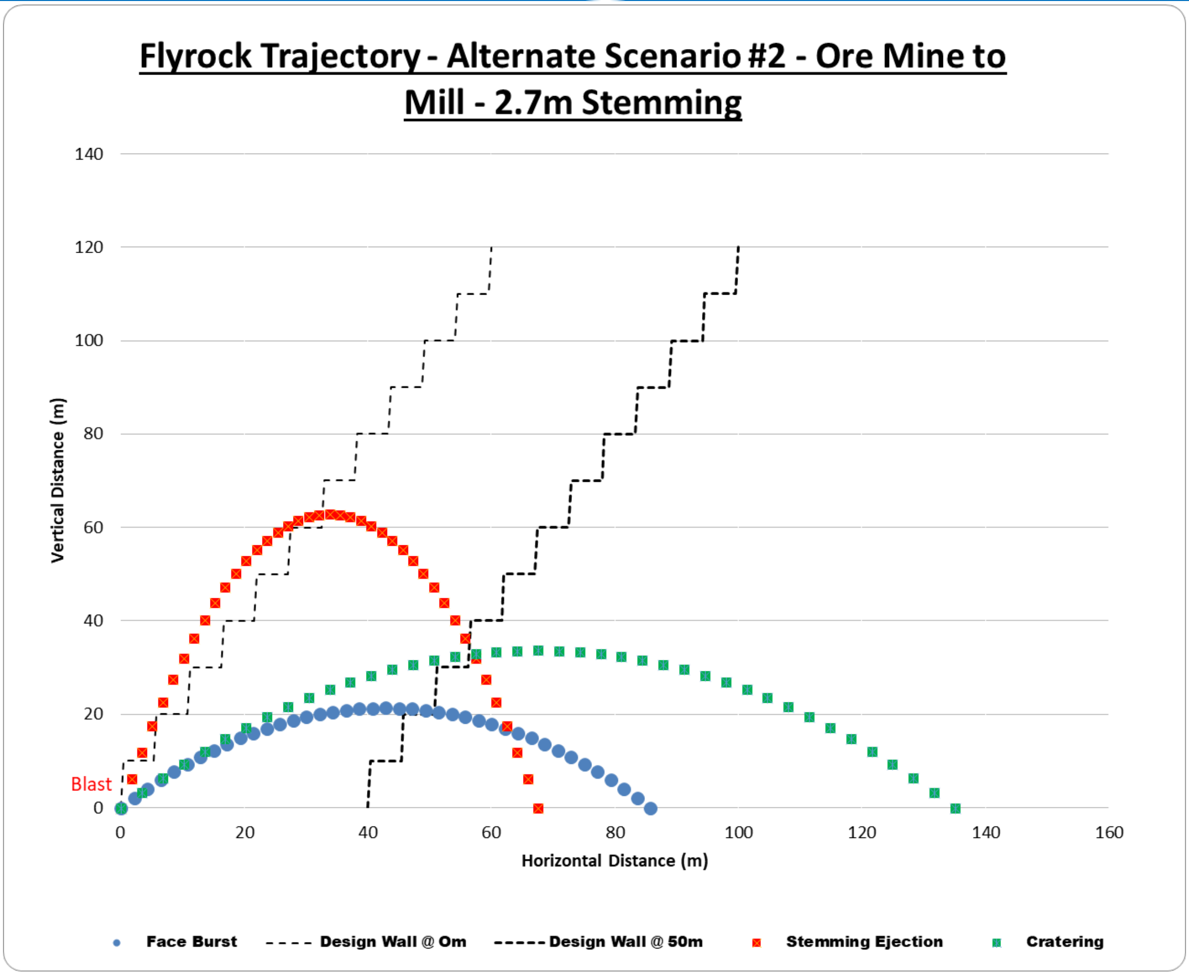

Flyrock Trajectory - Alternate Scenario #3
Vertical Distance (m)
Horizontal Distance (m)
Blast
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
Face Burst
Design Wall @ 0m
Design Wall @ 50m
Stemming Ejection
Cratering

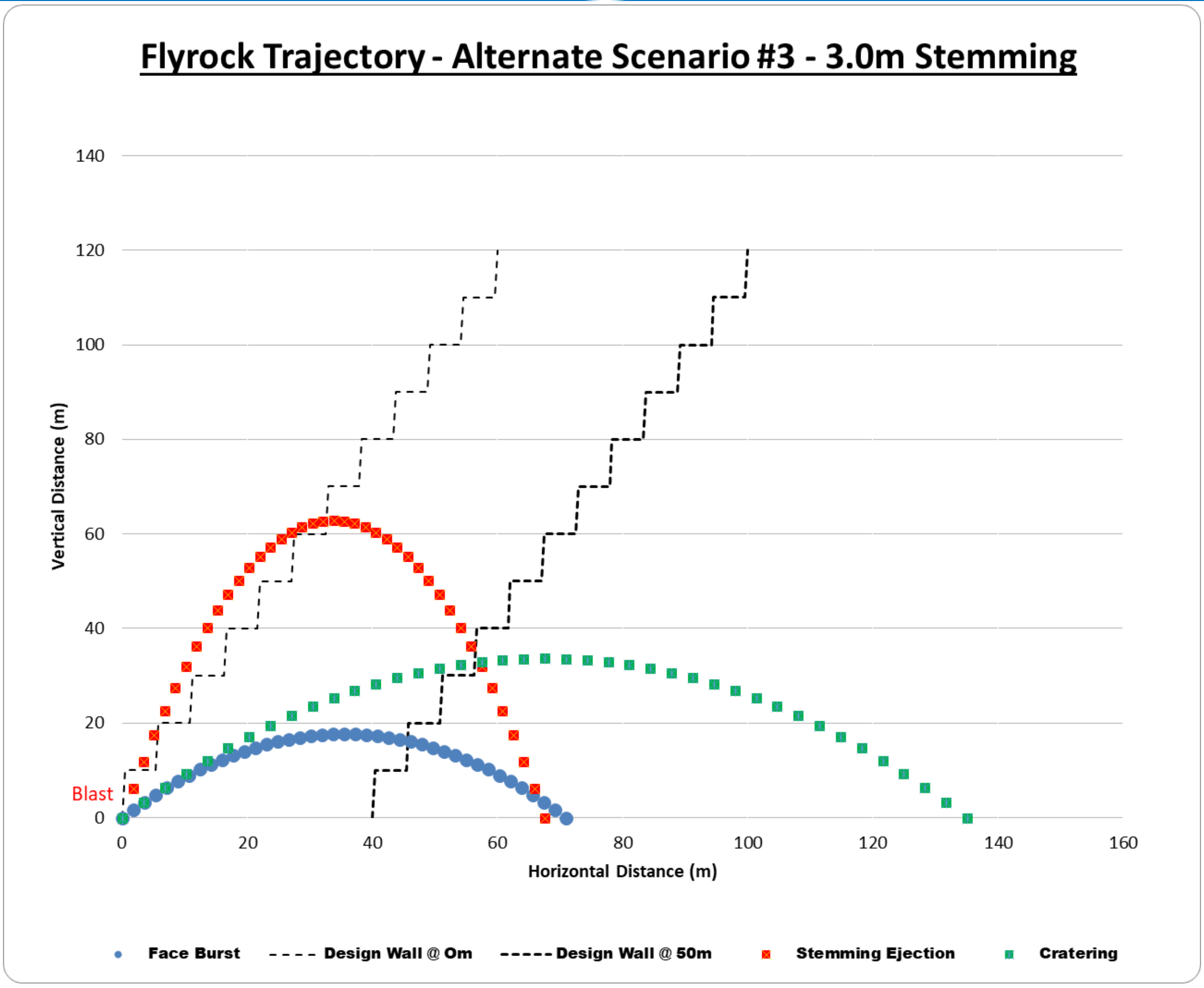

Flyrock Trajectory - Alternate Scenario #4
Vertical Distance (m)
Horizontal Distance (m)
Blast
0
20
40
60
80
100
120
140
Face Burst
Design Wall @ 0m
Design Wall @ 50m
Stemming Ejection
Cratering

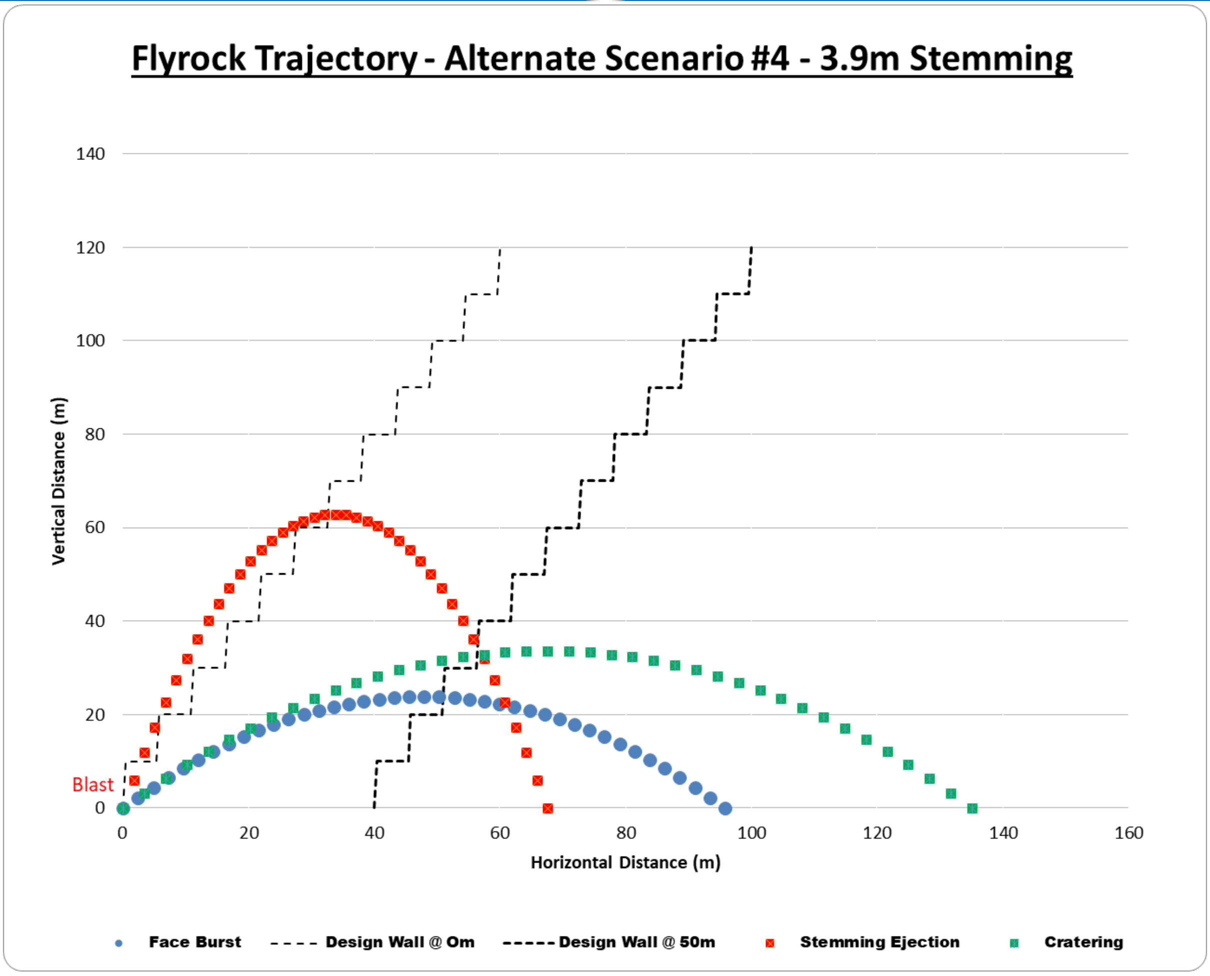

Flyrock Trajectory - Standard Blast Parameters - 2.4m Stemming
Vertical Distance (m)
Horizontal Distance (m)
Blast
0
20
40
60
80
100
120
140
160
180
200
Face Burst
Design Wall @ 0m
Design Wall @ 50m
Stemming Ejection
Cratering



Flyrock Trajectory - Alternate Scenario #1 - 2.7m Stemming
Vertical Distance (m)
140
120
100
80
60
40
20
0
Blast
0
20
40
60
80
100
120
140
160
Horizontal Distance (m)
Face Burst
Design Wall @ 0m
Design Wall @ 50m
Stemming Ejection
Cratering

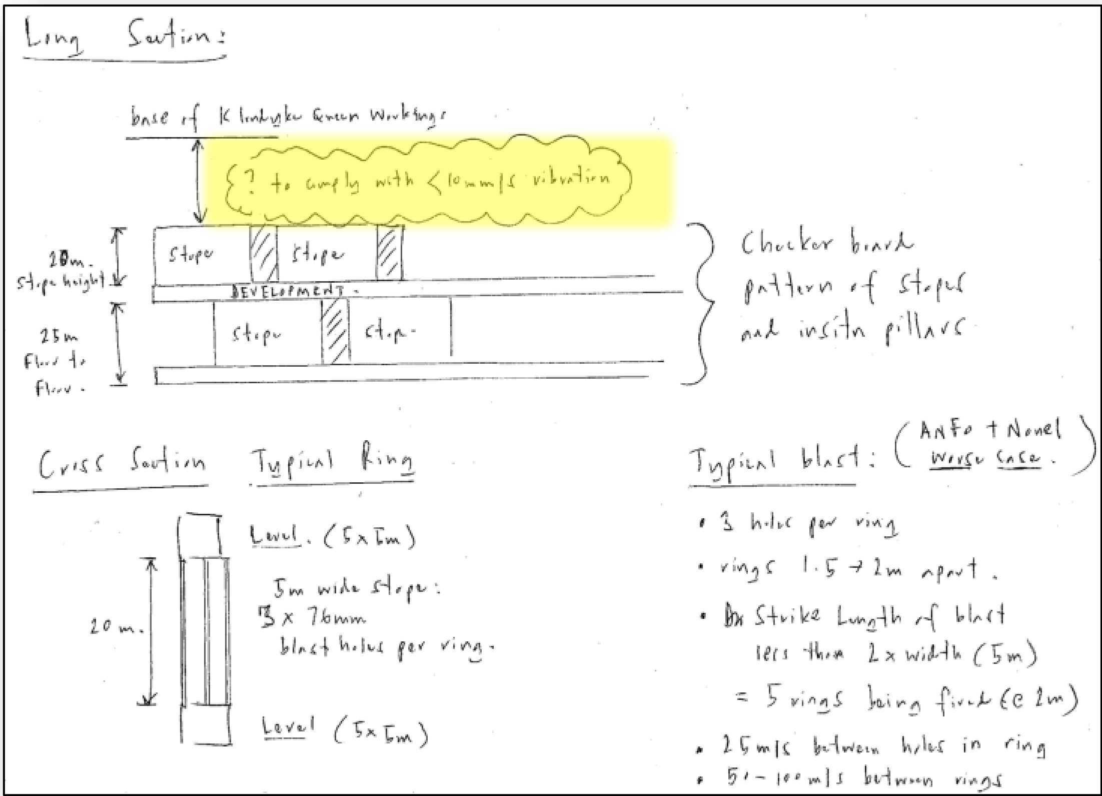

Flyrock Trajectory - Alternate Scenario #2 - Ore Mine to Mill - 2.7m Stemming
Vertical Distance (m)
Horizontal Distance (m)
Blast
0
20
40
60
80
100
120
140
160
Face Burst
Design Wall @ Om
Design Wall @ 50m
Stemming Ejection
Cratering


Flyrock Trajectory - Alternate Scenario #3 - 3.0m Stemming
Vertical Distance (m)
140
120
100
80
60
40
20
0
Blast
0
20
40
60
80
100
120
140
160
Horizontal Distance (m)
Face Burst
Design Wall @ 0m
Design Wall @ 50m
Stemming Ejection
Cratering


Flyrock Trajectory - Alternate Scenario #4 - 3.9m Stemming
140
120
100
80
60
40
20
0
Blast
Vertical Distance (m)
0
20
40
60
80
100
120
140
160
Horizontal Distance (m)
Face Burst
Design Wall @ 0m
Design Wall @ 50m
Stemming Ejection
Cratering

Calidus Resources

Underground Blast Vibration Calculations for the Klondyke Gold Deposit



22 October 2019

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Brief

Calculate the standoff distance required to be maintained between the new workings and the previous Klondyke Queen workings such that;

- Blasting in the new workings does not produce vibration levels greater than 10 mm/s at the base of the old workings (on a 95% confidence interval basis), and;
- Said calculations are based on the method described in AS2187.2-2006 Appendix J section J7.3, employing K=2000 and B=1.6 factors as recommended in the report "Assessment of Blasting on the Klondyke Queen. A roost site for Pilbara-Leaf-nosed Bat and Ghost Bat" (Martin 2018), and where;
- Proposed Drill and Blast parameters are as per the diagram presented on the cover page of this report, based on use of 76 mm diameter blast holes.

In addition, repeat the above calculations for alternate scenarios of 89mm and 64 mm blast hole diameters.

D&B Parameters and Calculations

The table overleaf contains the supplied Drill and Blast parameters together with necessary assumptions to calculate the Maximum Instantaneous Charge (MIC).

The explosives loading method selected was Blow Loaded ANFO. (Calculations have also been performed for loose-poured ANFO which, having a lower density, would result in a lower MIC and potentially lower estimated vibration levels).

Based on the calculations and assumptions, the minimum required stand-off distance to the old workings is 255 metres using 76mm diameter blast holes and 200m using 64mm diameter blast holes.

Recommendations

The required standoff distance is primarily dependent on the MIC and the assumed values for K and B used in the AS2187.2 equation.

- Installation of a blast vibration monitor early in the underground blasting program would facilitate the measurement of actual vibration levels.
- Collection of actual vibrations levels and comparison to each blast's actual MIC would enable the development of site-specific values for K and B. This is known as a 'Site Law'.
- A well-developed Site Law would permit significantly improved accuracy in estimating vibration levels, allowing the required standoff distances to be more accurately defined and potentially reduced.
- Alternate blast design practices may be able to reduce the standoff distances, once an accurate Site Law has been established. An example would be decking the ring charges in order to reduce the MIC.

Table 1.0

89mm Blast Holes

Standard Stope Design Drill and Blast Parameters			ANFO BLOW-LOADED
Item	*Value*	*Unit*	*Comment*
<u>Stope Design</u>			
Stope height	20	m	
Stope width	5	m	
Rings fired per blast	5		
Distance between Rings	1.8	m	*Diagram says 1.5 - 2.0*
Blasted Volume	900	m3	
Rock Density	2.9	t/m3	*Assumed value*
Blasted Tonnage	2610	t	
<u>Drilling Parameters</u>			
Hole diameter	89	mm	
Dip angle	90	°	
Hole length	20	m	*All holes breakthrough*
Drill holes per ring	3		
<u>Loading Parameters</u>			
Bulk Explosives product	ANFO		
Density	0.95	g/cm3	*Assumed value for blow-loading*
Charge per metre	5.9	kg/m	
Uncharged collar	0	m	*Worst case: fully loaded holes*
Uncharged base	0	m	*Worst case: fully loaded holes*
Total charge length	20	m	
Charge per hole	118	kg	
Total Charge per blast	1773	kg	
Powder Factor	**0.68**	**t/m3**	
<u>Timing Design</u>			
Delay between holes in ring	25	ms	*Sufficient value cf. inhole delay scatter*
Delay between rings	100	ms	
Holes per delay	1		*25 ms between all holes ensures single hole firing*
MIC	118	kg	
<u>Vibration Estimate</u>			
K Factor	2000		
B Factor	1.6		
Minimum Distance to Old Workings	**298**	**m**	
Estimated Vibration	10.0	mm/s	*Not exceeding (95% Confidence Level)*

Table 2.0

76mm Blast Holes

Standard Stope Design Drill and Blast Parameters			ANFO BLOW-LOADED
Item	*Value*	*Unit*	*Comment*
Stope Design			
Stope height	20	m	
Stope width	5	m	
Rings fired per blast	5		
Distance between Rings	1.5	m	*Diagram says 1.5 - 2.0*
Blasted Volume	750	m3	
Rock Density	2.9	t/m3	*Assumed value*
Blasted Tonnage	2175	t	
Drilling Parameters			
Hole diameter	76	mm	
Dip angle	90	°	
Hole length	20	m	*All holes breakthrough*
Drill holes per ring	3		
Loading Parameters			
Bulk Explosives product	ANFO		
Density	0.95	g/cm3	*Assumed value for blow-loading*
Charge per metre	4.3	kg/m	
Uncharged collar	0	m	*Worst case: fully loaded holes*
Uncharged base	0	m	*Worst case: fully loaded holes*
Total charge length	20	m	
Charge per hole	86	kg	
Total Charge per blast	1293	kg	
Powder Factor	**0.59**	**t/m3**	
Timing Design			
Delay between holes in ring	25	ms	*Sufficient value cf. inhole delay scatter*
Delay between rings	100	ms	
Holes per delay	1		*25 ms between all holes ensures single hole firing*
MIC	86	kg	
Vibration Estimate			
K Factor	2000		
B Factor	1.6		
Minimum Distance to Old Workings	**255**	**m**	
Estimated Vibration	10.0	mm/s	*Not exceeding (95% Confidence Level)*

Table 3.0

64mm Blast Holes

Standard Stope Design Drill and Blast Parameters			ANFO BLOW-LOADED
Item	*Value*	*Unit*	*Comment*
Stope Design			
Stope height	20	m	
Stope width	5	m	
Rings fired per blast	5		
Distance between Rings	1.4	m	*Diagram says 1.5 - 2.0*
Blasted Volume	700	m3	
Rock Density	2.9	t/m3	*Assumed value*
Blasted Tonnage	2030	t	
Drilling Parameters			
Hole diameter	64	mm	
Dip angle	90	°	
Hole length	20	m	*All holes breakthrough*
Drill holes per ring	3		
Loading Parameters			
Bulk Explosives product	ANFO		
Density	0.95	g/cm3	*Assumed value for blow-loading*
Charge per metre	3.1	kg/m	
Uncharged collar	2.7	m	*Worst case: fully loaded holes*
Uncharged base	0	m	*Worst case: fully loaded holes*
Total charge length	17.3	m	
Charge per hole	53	kg	
Total Charge per blast	793	kg	
Powder Factor	**0.39**	**t/m3**	
Timing Design			
Delay between holes in ring	25	ms	*Sufficient value cf. inhole delay scatter*
Delay between rings	100	ms	
Holes per delay	1		*25 ms between all holes ensures single hole firing*
MIC	53	kg	
Vibration Estimate			
K Factor	2000		
B Factor	1.6		
Minimum Distance to Old Workings	**200**	**m**	
Estimated Vibration	10.0	mm/s	*Not exceeding (95% Confidence Level)*