

## FOUNTAIN HEAD GOLD MINE, NORTHERN TERRITORY

### BLASTING IMPACT ON RAILWAY LINE & GAS PIPELINE

#### 1. INTRODUCTION

PNX Metals have requested that Terrock Consulting Engineers undertake an assessment of the impact of blasting in the proposed Fountain Head Gold Mine on the adjacent railway and gas pipeline. The closest points of the planned open pit are approximately 380m from the Bonaparte Gas Pipeline (BGP) and 550m from the Alice Springs-Darwin Railway. Mount Wells Road and a 66 kV powerline are located on the opposite (southern) side of the railway line.

The most significant blasting impacts that must be assessed are the ground vibration levels generated by blasting, and the potential for flyrock. Consideration has also been given to the management of dust and blast fume, and airblast overpressure (blast noise) levels. The positions of the open-pit, railway, gas pipeline, road, and powerline are shown in the site plan, **Figure 1**.

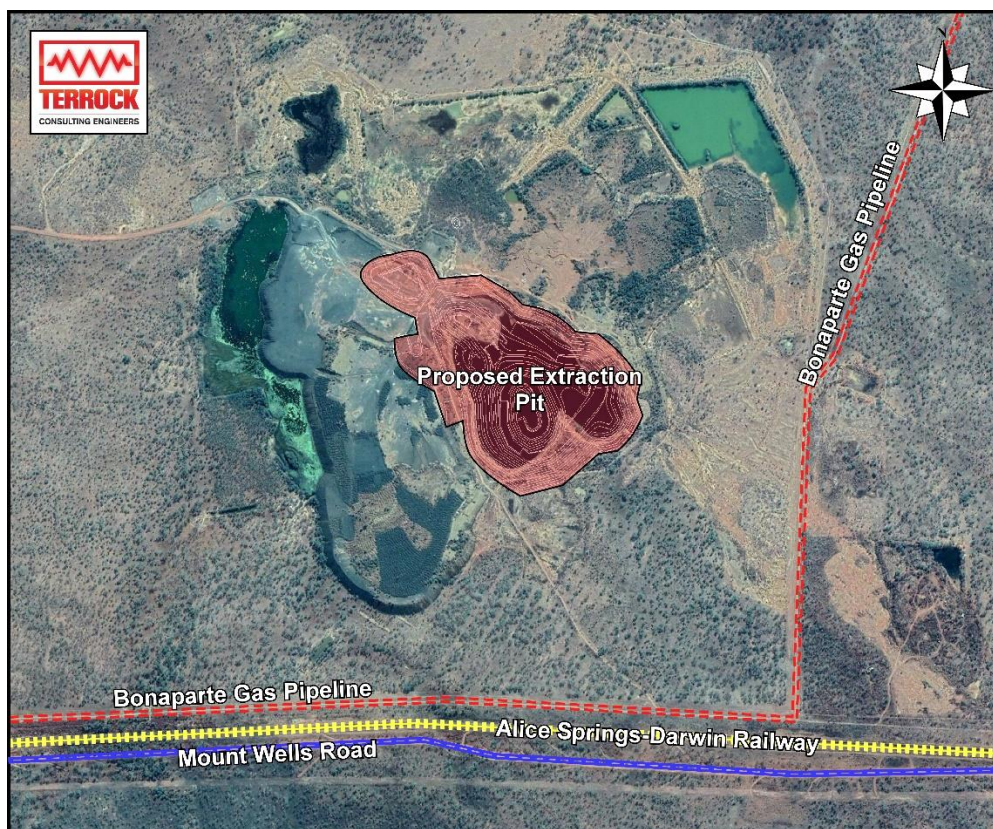


Figure 1 – Fountain Head Gold mine site plan

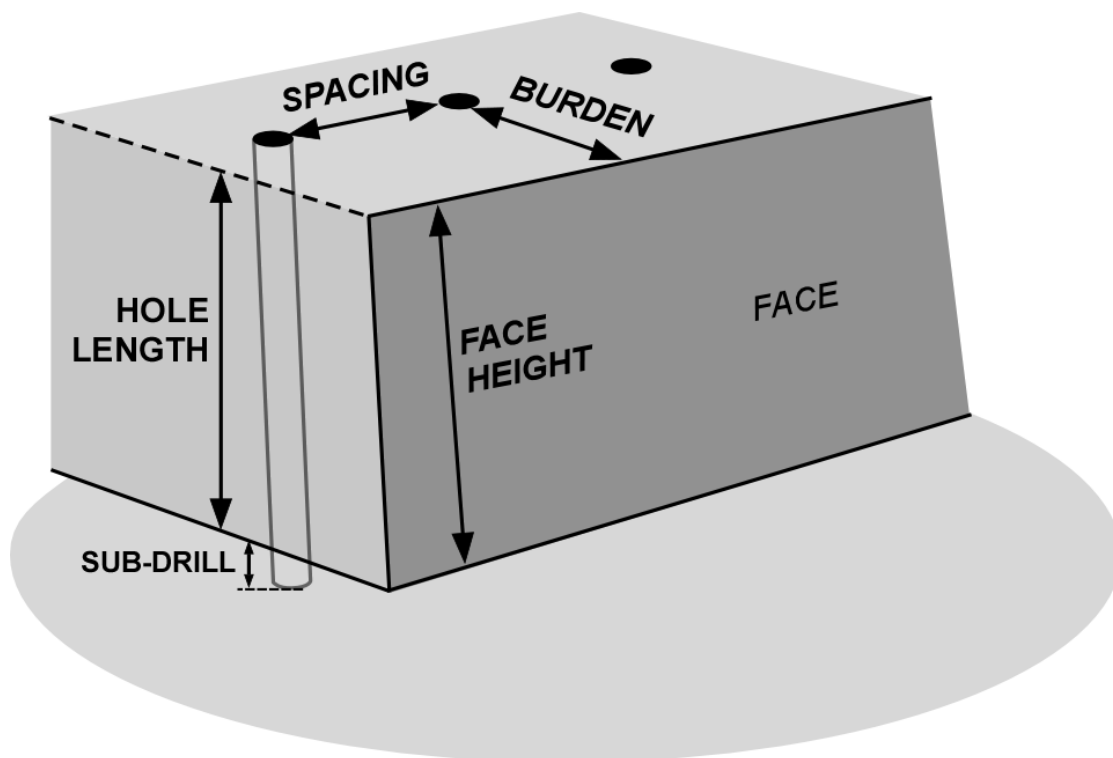
Further details, including the outline of a 500m blast radius exclusion zone, are shown in the plan that is attached as **Appendix 1**.

## 2. BLASTING TERMINOLOGY

The following is a brief explanation of blasting that has been prepared to assist those who are unfamiliar with blasting,

To extract rock in mines it is necessary to use blasting. Blastholes are drilled downwards into the rock in rows, and a quantity of explosives is placed in each blast hole, which is then topped up with inert material such as aggregate to effectively confine the explosives charge.

The distance between the blastholes in each row is called the spacing, and the distance between each row and the free face is called the burden. This is illustrated in **Figure 2.1**.



**Figure 2.1 – Basic blasthole layout**

The inert material used to confine the explosives charge is called stemming, and the length of stemming is called the stemming height. The stemming is used to effectively confine the explosives charge, reduce the amount of energy that would otherwise be released directly out of the open end of the blasthole.

These terms are further illustrated in **Figure 2.2**.

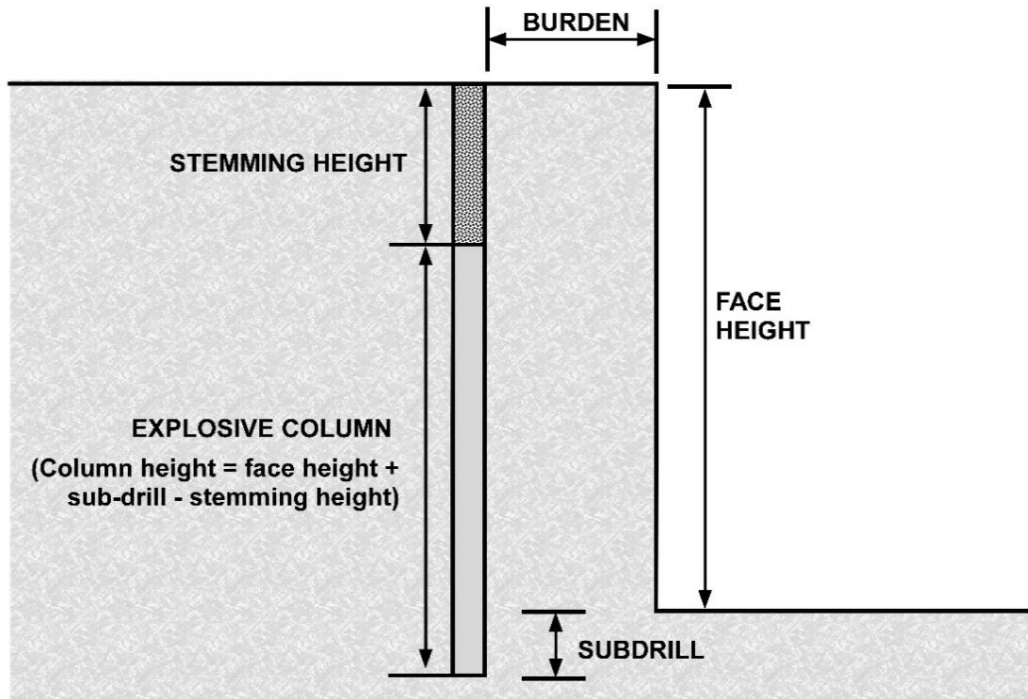


Figure 2.2 – Basic blasting layout continued

### 3. BLASTING SPECIFICATIONS

The blastholes will be loaded either with ANFO explosives (density 0.8 gm/cc), or a waterproof emulsion explosive (max. density 1.2 g/cc). Details of alternative options that may be used at the mine are shown below in **Table 1**

Table 1 – Alternative Options - Blast Design Specifications

PNX Fountain Head	PF 0.8kg/m <sup>3</sup>				PF 0.9kg/m <sup>3</sup>			
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Blasthole diameter (mm)	102		115		102		115	
Explosive density (g/cc)	0.8	1.2	0.8	1.2	0.8	1.2	0.8	1.2
Charge mass per m of blasthole (kg/m)	6.54	9.81	8.17	12.25	6.54	9.81	8.17	12.25
Stemming (m)	2.6	2.7	2.9	3	2.0	2.0	2.3	2.3
Subdrill (m)	1.0	1.0	1.2	1.2	1.0	1.0	1.2	1.2
Burden (m)	2.4	2.8	2.6	3.1	2.4	2.9	2.6	3.2
Spacing (m)	2.4	2.8	2.6	3.1	2.4	2.9	2.6	3.2
Bench height (m)	5	5	5	5	5	5	5	5
Charge weight (kg)	22.7	32.6	26.8	38.6	26.0	39.0	31.5	47.2
Powder factor (kg/m <sup>3</sup> ) (vertical blastholes)	0.79	0.83	0.79	0.80	0.90	0.93	0.93	0.92

Details of the significant blasting specifications for Option 8, which result in the maximum ground vibration levels, are given in **Table 2**:

*Table 2 – Blast Design Specifications (Option 8)*

<b>Blast parameter</b>	<b>Details</b>
Bench height (m)	5
Blasthole diameter (mm)	115
Burden (m)	3.2
Stemming height (m)	2.3
Charge Mass per blasthole (kg)	47.2
Max charge mass per metre (kg/m)	12.25
Powder Factor (kg/cubic metre)	0.92

#### **4. GROUND VIBRATION LEVELS**

Ground vibration levels (PPV) resulting from blasting vary with charge mass and distance from that blast by the relationship shown in the following equation:

$$PPV = K_v \left( \frac{\sqrt{m}}{D} \right)^b$$

Where;

- $PPV$  = Peak Particle Velocity (mm/s)
- $m$  = Charge mass per hole or per delay (kg)
- $D$  = Distance from blast (m)
- $K_v$  = Site constant
- $b$  = Site exponent

The Australian Standard AS2187.2-2006 (Explosives – Storage, Transport & Use) advises that for average conditions the following values should be used for the site constant and exponent.

- Site constant ( $K_v$ ) = 1140
- Site exponent ( $b$ ) = -1.6

When blasts are fired, the individual blastholes detonate in a delayed sequence that reduces the resulting vibration levels.

For small blasts it is possible to limit the charge mass being fired at any instant of time (i.e. maximum instantaneous charge or M.I.C.) to the charge mass per blasthole. For larger blasts several blastholes may be fired at the same time in the delayed sequence.

The estimates of vibration levels that will result from blasting in the Fountain Head open-pit mine have been calculated on the basis that four blastholes will be fired per delay, using the last column in blast design specifications.

For a maximum charge mass of 47.2 kg per blasthole, and four blastholes per delay, the maximum charge mass per delay ( $W$ ) = 189 kg. For  $b = -1.6$ ,  $K_v = 1140$ ,  $W = 188.8$  kg, the resulting vibration levels when blasting at the closest point to the railway and pipeline will be as listed in **Table 3**.

Table 3 – Ground vibration predicted levels ( $K_v$ ) = 1140

Location	Distance	PPV Level
Gas Pipeline	380m	5.6mm/s
Railway	550 m	3.1 mm/s

The actual site constant ( $K_v$ ) is unlikely to be greater than 2000, PPV levels resulting from this site constant are listed in **Table 4**.

Table 4 – Ground vibration predicted levels ( $K_v$ ) = 2000

Location	Distance	PPV Level
Gas Pipeline	380m	9.9 mm/s
Railway	550 m	5.5 mm/s

## 5. CONFORMITY WITH GROUND VIBRATION LIMITS

AS2187.2-2006 advises that limits should be based on structural design methodology but provides no specific limits for gas pipelines or railway lines.

### 5.1. Railways

The Australian Rail Track Corporation (ARTC) commonly applies a PPV limit of 100 mm/s for non-electrified railways such as the railway adjacent to the Fountain Head mine.

The ground vibration estimate given in **Table 2** shows that the vibration level of 3.1 mm/s resulting at the railway from a charge mass per delay of 188.8 kg will be well below permitted limits.

### 5.2. Gas Pipelines

The Australian Pipeline Authority (APA) has advised a PPV limit of 20 mm/s. Previous investigations based on structural design methodology show that this limit is very conservative.

The ground vibration estimate given in **Table 2** shows that the vibration level of 5.6 mm/s resulting at the pipeline from a charge mass per delay of 188.8 kg will be well below the 20 mm/s limit specified by the APA.

### 5.3. Roads and Powerlines

A conservative limit of 100 mm/s is commonly used in cases that do not warrant site specific structural analysis. The actual safe level is well above 100 mm/s

### 5.4. General Statement on Compliance

It is possible that ground conditions at the Fountain Head mine may require vibration levels to be predicted using a site exponent greater than the standard condition figure of  $K_v = 1140$  given in the Australian Standard AS2187.2-2006, but this is unlikely to be greater than 2000.

Hence it can be confidently stated that ground vibration levels resulting at the gas pipeline, railway, adjacent road and 66 kV powerline can be controlled to conform with specified limits.

## 6. FLYROCK DISTANCES

Flyrock distances have been assessed using the Terrock flyrock model, which has been widely used in mines and quarries for many years. The first hard rock application of the model was at the Holcim Oaklands Junction Quarry, which is located adjacent to the flightpath for the north-south runway of Melbourne’s Tullamarine Airport.

The first gold mine application was at the Kalgoorlie Super Pit, where blasting was safely carried out to within 200 metres of occupied premises. Details of the Terrock flyrock model are attached as **Appendix 2**.

The significant specifications affecting flyrock throw distances from blasts are:

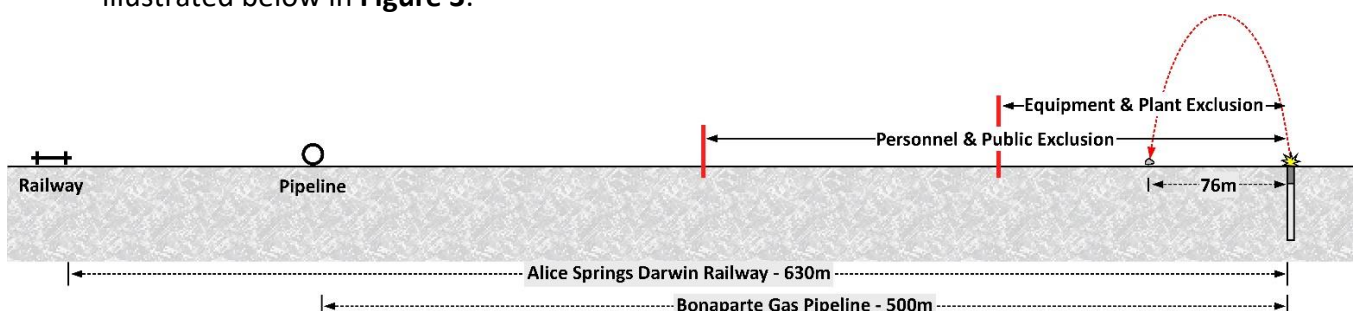
- Charge mass per metre of explosives column
- Stemming height
- Burden
- Site Constant (k)

The site constant (k) is determined by measuring the flyrock distances for various charge masses, burdens, and stemming heights.

Experience over many years has shown that for hard rock mines, the site constant (k) is equal to or less than 27, and hence this constant has been used.

Initial blasting at Fountain Head mine will require that clearance distances be set based on the charge mass per metre of explosives column and stemming height, to control upward flyrock ejection from the stemming column area. For a charge mass per metre of 47.2kg and a stemming height (S.H) of 2.3m, the flyrock distance due to upward ejection from the stemming column area is 76m.

This potential flyrock throw, and details of clearance distances towards the railway, are illustrated below in **Figure 3**.



**Figure 3 – Stemming ejection flyrock throw**

Subsequent blasting will also require that the effect of burden be considered to control outward flyrock ejection from a near vertical free face. For a charge mass per metre of 47.2kg and a burden (B) of 3.2m, the flyrock distance due to the outward face ejection is 111m. This flyrock throw, and details of clearance distances towards the railway, are illustrated below in **Figure 4**.

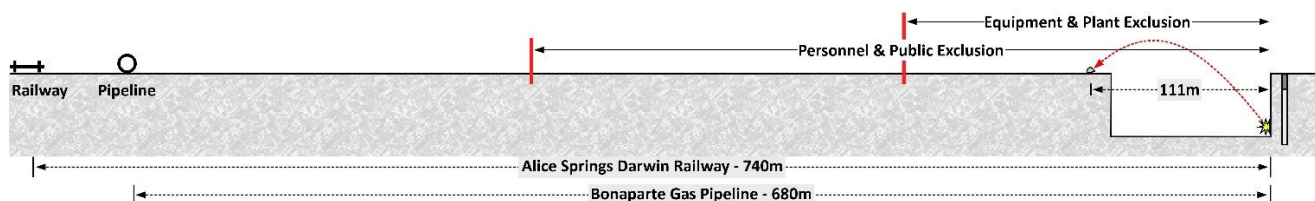


Figure 4 – In front of the face flyrock throw

## 7. FLYROCK CLEARANCE ZONES

The basic Terrock flyrock model permits the flyrock distances for both upward ejection from the stemming column area, and outward ejection from a near vertical free face to be calculated. These distances are then used, with appropriate factors of safety, to establish clearance zones from blast sites. It has been common for the following factors of safety to be used:

Table 5 – Blasting factor of safety clearance zones

Clearance Zone Type	Factor of Safety
Equipment & Plant	In the range 1.5 to 2
Personnel & Public	In the range 3 to 4

For initial operations it would be wise to use a safety factor of 2 for the equipment clearance distance, and a safety factor of 4 for the personnel clearance distance. The initial exclusions zones should be per the values showing **Table 6** below.

Table 6 – Blasting clearance zones

Flyrock Direction	Equipment & Plant	Personnel & Public
Stemming ejection	152m	304m
Blast face ejection	222m	444m

The maximum 'Personnel and Public' clearance distance shown in **Table 6** is less than the 500m Blast Radius shown in **Appendix 1**.

A practical option would be to adopt a standard blast clearance distance of 500m for personnel and plant, and a 250m clearance distance for plant and equipment that is located on the surface.

## 8. AIRBLAST OVERPRESSURE LEVELS

Airblast overpressure levels (sometimes referred to as ‘blast noise’) have been calculated using a model that is widely used for the assessment of airblast overpressure (AOP) in mines and quarries in Australia. The following assessments has been prepared using significant blast parameters from the ‘Option 6’ and ‘Option 8’ blasting specifications, which are shown in **Table 7** below.

*Table 7 – Blast Parameters used in AOP assessment*

	<b>Option 6</b>	<b>Option 8</b>
Explosives density g/cc	0.8	1.2
Blasthole diameter (mm)	115	115
Burden (m)	2.9	3.2
Stemming height (m0	2.0	2.3
Charge mass / blasthole (kg)	39.0	47.2

These parameters result in the maximum AOP emissions which are shown in **Table 8**.

*Table 8 – Airblast Overpressure Levels for ‘Option 6’ and ‘Option 8’*

<b>AOP Level (dBL)</b>	<b>Distance from Blast (m)</b>	
	<b>Option 6</b>	<b>Option 8</b>
130	213	160
120	424	318
115	559	449
110	845	634

The significance of these levels is explained in **Table 9** below.

*Table 9 – Significance of Airblast Overpressure Levels*

<b>AOP Level (dBL)</b>	<b>Details</b>
100	Close to level of human perception
110	Acceptable by most people in a quite housing environment
120	Maximum environmental limit commonly used in Australia
>130	Damage levels to structures are well in excess of 130 dBL

The above figure show that AOP levels resulting outside a 500m blast exclusion zone can be controlled to acceptable environmental limits. The distance at which AOP levels will be close to the level of human perception will be approximately 2km.

### **Note:**

When explosives charges are fired most of the energy in the airblast overpressure emission is sub-audible, and hence AOP must be measured with sound level meters that record the sub-audible low frequencies as well as the audible frequencies that are recorded for normal noise level measurement. This is because sub-audible frequencies that are not heard by humans may affect structures AOP levels are recorded on a dB(Linear) or dBL scale.

Measurements taken with a sound level used to measure noise that is heard by humans is measured on a dBA scale. Comparative measurements have shown that a level of 120 dBL corresponds to a level of 95 dBA (or 25 dB lower).

## **9. GROVE HILL HOTEL.**

Grove Hill Hotel, the closest neighbour, is located 5,675 metres from the closest point of the fountain Head pit. The ground transmitted blast vibration level will be approximately 0.1mm/s, which is below the level of human perception. The air-transmitted vibration level (i.e airblast overpressure, or 'blast noise') will be approximately 85dBL, which is below the general level of human perception.

## **10. OTHER FACTORS**

Dust and blast fume will have no effect on the gas pipeline, railway line, adjacent road and powerline, However, they must be considered for the health and safety of personnel in the area, and if there are any passing trains.

For initial operations, protection to personnel in the area will be provided by not firing when the wind is blowing towards sensitive areas.

As site experience is gained, restraints due to wind direction may be modified if it is found that dust and fume hazards can be contained within specified distances from the blast, and pose no hazard to the railway.

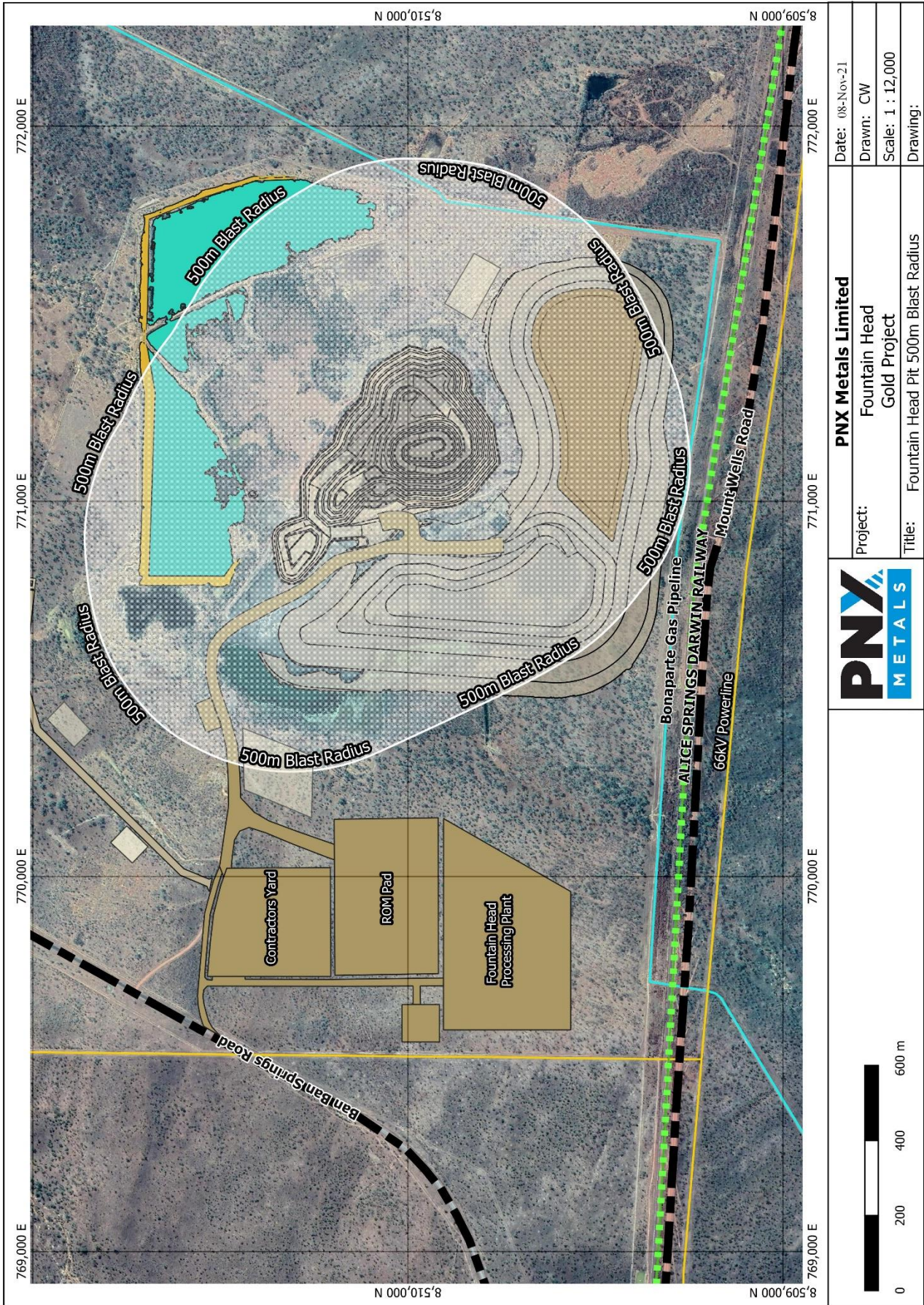
## **11. CONCLUDING COMMENTS.**

The investigation has shown that:

- Ground vibration levels (PPV) will be well below permitted levels.
- Flyrock distances, and flyrock clearance zones will be well within the closest distance to the Alice Springs to Darwin Railway, and the adjacent road and powerline, subject to strict compliance with the blasting specifications.
- Airblast overpressure levels resulting outside a 500m blast exclusion zone can be controlled to acceptable environmental limits and at a distance of 2km will be barely noticeable.
- Dust and blast fume impacts can be managed by procedures that will ensure that blasts are not fired when the wind is blowing towards sensitive areas.

**Alan B. Richards,**  
11<sup>th</sup> November 2021

# APPENDIX 1 – PIPELINE, RAILWAY & ADJACENT ROAD AND POWERLINE



<b>PNX Metals Limited</b>		Date: 08-Nov-21
Project:	Fountain Head Gold Project	Drawn: CW
Title:	Fountain Head Pit 500m Blast Radius	Scale: 1 : 12,000
		Drawing:



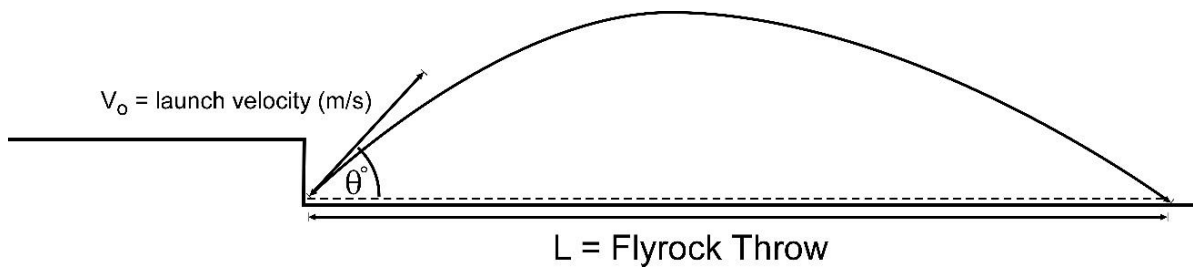
## APPENDIX 2 – TERROCK FLYROCK MODEL

The Terrock flyrock model is based on the following general trajectory formula which is:

$$L = \frac{V_o^2 \times \sin 2\theta_o}{g}$$

Where;

- $L$  = Flyrock throw (m)
- $V_o$  = Launch velocity (m/s)
- $g$  = Acceleration due to gravity ( $9.8\text{m}^2/\text{s}$ )
- $\theta_o$  = Launch angle



The maximum throw will occur when  $\theta_o = 45^\circ$ , ie:

$$L = \frac{V_o^2}{g}$$

The relationship between launch velocity and significant blast parameters has been established by a scaled burden formula developed by Workman et al. The scaled burden formula is:

$$V_o = k \left( \frac{\sqrt{m}}{B} \right)^{1.3}$$

Where;

- $V_o$  = Launch velocity (m/s)
- $m$  = Charge mass per metre (kg/m)
- $B$  = Burden (m)
- $k$  = Site Constant

The Terrock flyrock model has been developed by combining the scaled burden model with the general trajectory formula. By combining the scaled burden formula and the trajectory formula, it gives the following *Terrock flyrock throw* formula (Moore et al, 2004):

$$L_{max} = \frac{k^2}{g} \times \left( \frac{\sqrt{m}}{B} \right)^{2.6}$$

Where;

- $L_{max}$  = Flyrock throw (m)
- $k$  = site constant
- $g$  = Acceleration due to gravity (m/s)
- $m$  = Charge mass (kg)
- $B$  = Front row Burden (m)

It has been found that a site constant of 27 should be used for hard rock mines such as the Fountain Head Gold mine.