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# Prediction of Blast-Induced Ground Vibration and Air Overpressure

# Fimiston Open Pit – Fimiston South Project Study

## Kalgoorlie WA

## KCGM

## July 2022

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# Table of Contents

# 1. Introduction

At the request of Kalgoorlie Consolidated Gold Mines Pty Ltd (KCGM), George Boucher Consulting (GBC) conducted a review of previous KCGM Open Pit mine environmental data and developed predictive models for blast-induced ground vibration and air overpressure. These models were used to predict the likely blast-induced ground vibration amplitude (and minimum distances for compliance with established limits) for the different types of blasts planned for the Fimiston South Project.

# 2. Blast-Induced Ground Vibration and Air Overpressure

## 2.1 Prediction of Ground Vibration

Best Practice for blasting operations is defined within the Australian Standard AS2187.2(2006) which describes the phenomena of blast-induced ground vibration in the following way:

"*Ground vibration from blasting is the radiation of mechanical energy within a rock mass or soil. It comprises various vibration phases travelling at different velocities. These phases are reflected, refracted, attenuated and scattered within the rock mass or soil, so that the resulting ground vibration at any particular location will have a complex character with various peaks and frequency content.*"

The magnitude of the ground vibration, together with ground vibration frequency, is commonly used to define likelihood of annoyance of near neighbours and potential for damage criteria. Studies and experience show that well designed and controlled blasts are unlikely to create ground vibrations of a magnitude that causes damage to structures. AS2187.2(2006) – Appendix J further states:

"*It is recognised that ground vibration and airblast produced by blasting falls into two categories-*

*(a) Those causing human discomfort; and*

*(b) Those with the potential for causing damage to structures, architectural elements and services.*

*Generally, human discomfort levels set by authorities are less than the levels that are likely to cause damage to structures, architectural elements and services. Ground vibration and airblast levels are influenced by a number of factors, some of which are not under the control of the shotfirer.*"

Cracks in buildings may be attributable to causes other than ground vibration, including ground or foundation movements (settlement and swell) associated with natural progressive deterioration of buildings over time and/or cyclical expansion/contraction of reactive clay soils during periods of prolonged dry or wet weather.

Many site-based factors including rock type, structure, topography, explosive type, blast design and geometry determine the vibration level that will be transmitted to a particular location remote from the blast location. Consequently the accurate prediction of ground vibration by calculation requires the use of site measurements to quantify the site factors represented in the prediction formula.

The Australian Standard AS2187.2 (2006) Appendix J provides a prediction equation in the form:

$$\mathbf{V = K\,(R/Q^{1/2})^{-b}}$$

Where:

V = peak particle velocity (ppv) in mm/sec

K & b = Site Constants (specific to the attenuation character of the rock between the blast and monitoring locations)

R = Range (distance) to structure (m)

Q = Charge mass per delay (Often expressed as Maximum Instantaneous Charge or MIC) (kg)

AS2187 states that, where no data from previous blasting is available, K=1140 and b=-1.6 are applicable to prediction of mean ppv (i.e. 50% Confidence Limit) for "Free face-average rock" (Refer to paragraph J7.3).

However, the compliance limits set for ground vibration in Western Australia are usually specified in terms of 90% compliance.

Condition 9-5 of Ministerial Statement No. 782, issued to KCGM 29 January 2009, stipulates the following vibration limits for KCGM's Fimiston Operations:

1. the peak particle velocity shall not exceed 5 millimetres per second for 90% of blasts per year;

2. the peak particle velocity shall not exceed 10 millimetres per second for any blast; and

3. no more than one in ten consecutive blasts shall exceed 5 millimetres per second peak particle velocity.

KCGM is required to comply with these vibration limits, measured or calculated in accordance with section J4.2 of Australian Standard AS2187.2(2006), for the protection of human comfort at any houses and low rise buildings, theatres, schools and other similar buildings occupied by people and not owned by KCGM. Essentially, the vibration limits apply to sensitive premises.

The Fimiston South Project is adjacent to the South Boulder Light Industrial area which is predominantly made up of commercial and light industrial buildings/premises/land use; which are generally not considered to be sensitive premises.

The Australian Standard AS2187.2(2006) Appendix J specifies that the limit applicable to such premises/land use is much higher at 25mm/s for all blasts (as shown in the following table taken from the standard):

**TABLE J4.5(A)**

**GROUND VIBRATION LIMITS FOR HUMAN COMFORT CHOSEN BY SOME REGULATORY AUTHORITIES (see Note to Table J4.5(B))**

| Category | Type of blasting operations | Peak component particle velocity (mm/s) |
|---|---|---|
| Sensitive site* | Operations lasting longer than 12 months or more than 20 blasts | 5 mm/s for 95% blasts per year 10 mm/s maximum unless agreement is reached with the occupier that a higher limit may apply |
| Sensitive site* | Operations lasting for less than 12 months or less than 20 blasts | 10 mm/s maximum unless agreement is reached with occupier that a higher limit may apply |
| Occupied non-sensitive sites, such as factories and commercial premises | All blasting | 25 mm/s maximum unless agreement is reached with occupier that a higher limit may apply. For sites containing equipment sensitive to vibration, the vibration should be kept below manufacturer's specifications or levels that can be shown to adversely effect the equipment operation |

*A sensitive site includes houses and low rise residential buildings, theatres, schools, and other similar buildings occupied by people.

NOTE: The recommendations in Table J4.5(A) are intended to be informative and do not override statutory requirements with respect to human comfort limits set by various authorities. They should be read in conjunction with any such statutory requirements and with regard to their respective jurisdictions.

## 2.2 Prediction of Air Overpressure

The publication "ICI – Handbook of Blasting Tables" describes a method for prediction of air overpressure. This method is described in the equation below:

$$P = C\,(R/Q^{1/3})^{-1.2}$$

P = pressure (kPa)
C = Constant (determined mainly by level of confinement and atmospheric conditions)
R = Range (metres)
Q = Quantity of explosives (kg per unit time)

Most limits applied to air overpressure are expressed in terms of decibels linear (dBL) (as is the case for the limits applied at KCGM). To convert kPa to dBL the following equation is used:

$$dBL = 20\,\log_{10}(P/2.0265\times10^{-8})$$

The main challenge inherent to the numerical prediction of air overpressure is determination of the constant C. This value must be determined from the degree of confinement of the charge combined with consideration of the atmospheric conditions at the time of firing.

Industry experience has shown that atmospheric conditions exert a high level of dominance upon actual air overpressure results making prediction of air overpressure very difficult.

The publication "ICI – Handbook of Blasting Tables" suggests that for "fully confined blasthole charges" in average atmospheric conditions, the constant C = 3.3 (See Appendix D) while for unconfined charges (such as the proposed pilot charge) the constant C = 185.

# 3. KCGM Blast Monitoring System

Compliance with ground vibration and air overpressure limits are measured/verified using ground vibration (geophone) and air overpressure (microphone) sensors that are connected to data logger and transmission instruments.

The purposes of each of these monitors includes:

- To measure the blast-induced ground vibration and air overpressure that would be experienced by the nearest neighbours to the mining operation or from which the experienced ground vibration and air overpressure may be calculated by extrapolation
- To avoid measurement of ground vibration and air overpressure from other sources (i.e. ambient vibration and air overpressure/noise)
- To resist degradation of instrumentation due to exposure to outdoors conditions
- To resist accidental and other damage/interference from human activity
- To avoid any interference with normal activities by other land users

It is the experience of KCGM, that these criteria are most well met when monitoring sites are located on land that it owns.

## 3.1 Current Open Pit Blast Monitors

Open Pit blast monitoring is undertaken at six permanent blast monitoring locations (Alpha, Bravo, Charlie, Delta, Echo and Foxtrot) that are located between the Fimiston Open Pit and the City of Kalgoorlie-Boulder.

**Figure 3.1: Typical Environmental Monitoring Station West of the KCGM Fimiston Open Pit**

Within each monitor "cage" there is a triaxial geophone which is well coupled to the ground - like that shown below

**Figure 3.2: Typical Vibration Geophone setup adjacent to the KCGM Fimiston Open Pit**

Within each monitor "cage" there is also a microphone like that shown below

**Figure 3.3: Typical Air Overpressure Microphone adjacent to the KCGM Fimiston Open Pit**

The locations of the open pit blast monitors are shown in the figure below.

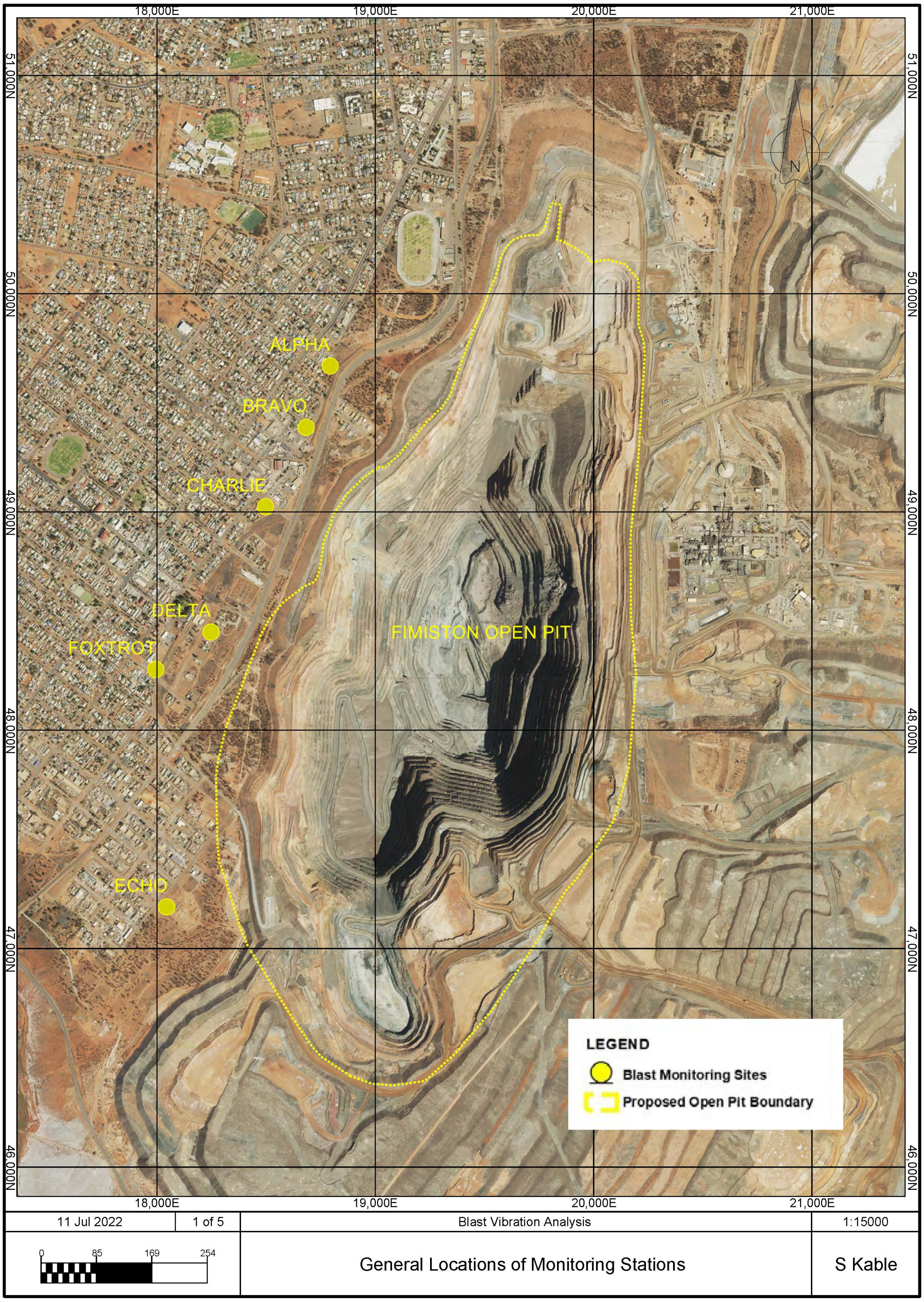



**Figure 3.4: General Locations of the monitoring stations Alpha to Foxtrot**

## 3.2 Review of Current Monitoring Network

As part of these analyses, the location of all current monitors were reviewed against the criteria listed in Section 3 to ensure each location would be appropriate for blasting activities within the Fimiston South Project area.

All monitors did meet these requirements.

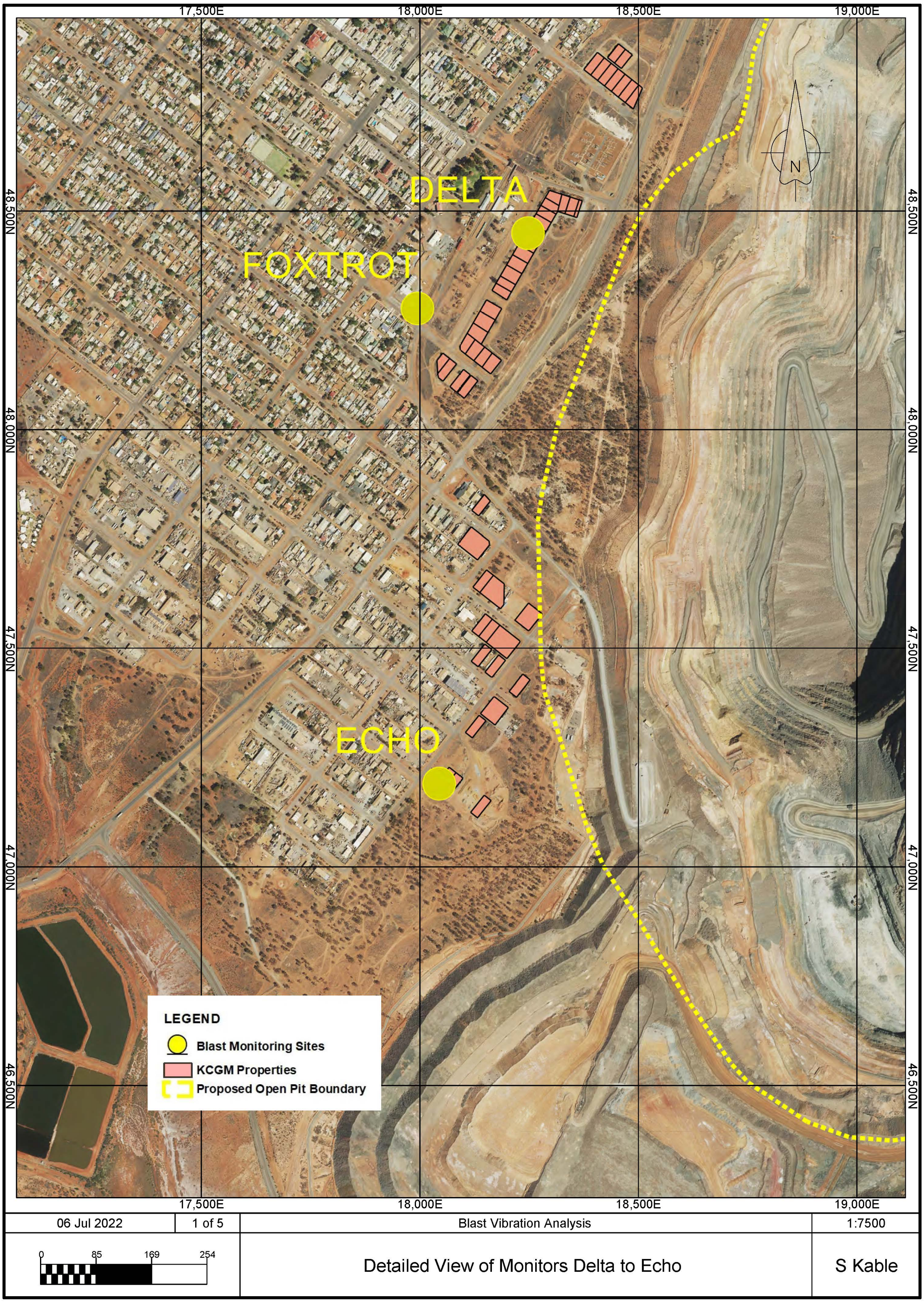



**Figure 3.5: Detailed view of monitors Delta to Foxtrot**

Note that the blasting in the oxide and fresh zones of the Fimiston South Project area will be more distant relative to the adjacent light industrial area due to the pit wall inclination.

## 3.3 Proposed New Monitoring Station

Regression analyses (like those conducted as part of the core process in this review), rely upon a range of scaled distance values being correlated to ground vibration and air overpressure data.

KCGM currently has two types of monitoring stations:

- Pit perimeter compliance stations – Monitors Alpha to Echo
- Monitoring stations located deep into Boulder and Kalgoorlie

While the Pit perimeter stations are relied upon to monitor compliance with environmental limits, the other stations are used to better understand how vibration and air overpressure are attenuated at distance across the adjacent town(s) and to diversify the scaled distance at which vibration and air overpressure has been measured.

As part of this review, it was found that an additional monitoring station located inside the South Boulder light industrial area may provide additional information about attenuation at distance.

Physical inspection of the light industrial area showed that selection of a site that meets all the criteria listed at the beginning of this section, would be challenging. However, such a site may be able to identified, land tenure obtained and installed sufficiently remote from structures/sources of ambient ground vibration and air overpressure.

Such a new site may be named Echo 2 (due to proximity to the current Echo monitoring station) and may be located in one of the following general locations:

- Corner of Goldfields Highway and Vivian Street – Cleanaway South Boulder site
- Elsewhere on Vivian Street between Goldfields Highway and Shannon Street

# 4. Prediction of Ground Vibration for the Fimiston South Project

Analysis of KCGM Ground Vibration Records

GBC conducted a review of actual blast vibration measurements from the Fimiston Open Pit operation since early 2000. Data from all blasting monitored during 2000-2021 was supplied by KCGM and this constituted 45,346 vibration measurements over this 21 year period. The data was reviewed and collated into a structure/form suitable for the analyses.

The data most relevant to the blasting which will be conducted in the Fimiston South Project area was that from blasts located 900m or less from the monitors adjacent to both the mining planned for the Fimiston South Project and the adjacent town/light industrial area. Consequently the data used in the regressions denoted as "Less than 900m", was filtered to include only these records.

The data was then split by monitoring location and then used to establish attenuation coefficients for the prediction equations (for 50% and 90% confidence limits). The monitoring locations for which data was provided include those listed in Section 3.

The data provided to GBC by KCGM for this study included parameters and environmental measurements for production, wall control, presplit and secondary blasts. Some filtering of data was necessary to exclude data from blasts that were fired together making the source of the environmental measurements uncertain.

Data used included environmental measurements from blasts initiated with both Nonel and Electronic Detonators. It is widely accepted that the higher accuracy and precision of Electronic Detonators results in their ability to achieve greater control of actual firing times of primers and hence main charge columns.

The Maximum Instantaneous Charge (MIC) used in the regression calculations was the same as that used in routine blast design by KCGM's engineers and calculated from:

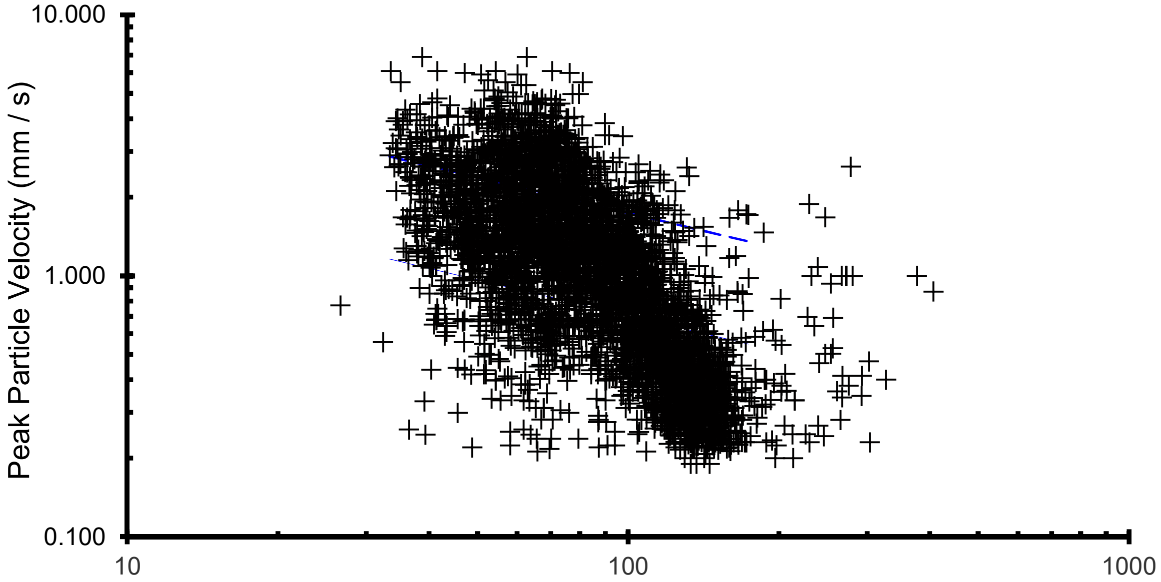
- Nonel Detonator Blasts - The charge in the most heavily charged three holes
- Electronic Detonator Blasts – The charge in the most heavily charged single hole

For the purposes of these analyses, KCGM provided data that the typical charge mass per production blast hole (in Fresh Rock) was 175kg.

## 4.1 Analysis of KCGM Ground Vibration Records – Full Data Set

### 4.1.1 Vibration Regression - Monitor Alpha

Fimiston South Stg 2 - Full Data Set, Vibration Regression, Monitor Location: Alpha




| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Alpha |
| **Slope** | -1.02 |
| **K (avg)** | 91.670 |
| **Design percentile** | |
| **K (90%)** | 204.657 |
| **Quality of Fit ($r^2$)** | 0.349 |
| **No of points** | 4327 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

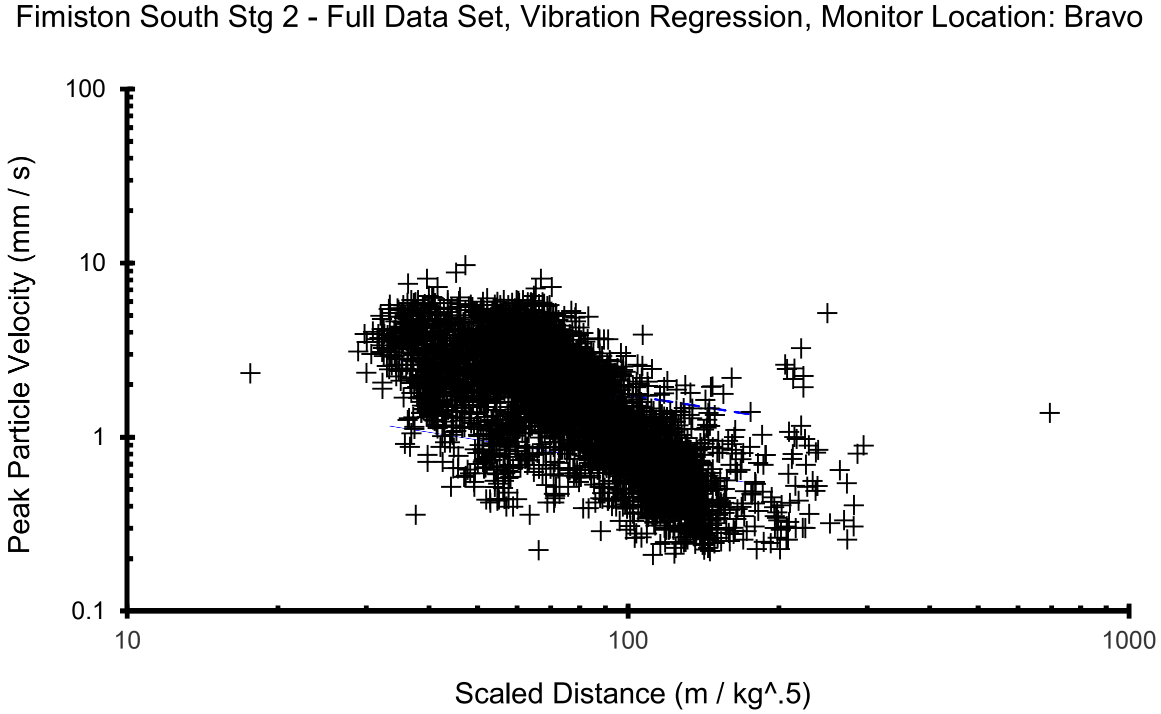
50% Confidence Limit $\mathbf{V= 91.670(R/Q^{1/2})^{-1.02}}$

90% Confidence Limit $\mathbf{V= 204.657(R/Q^{1/2})^{-1.02}}$

The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.349 which is moderate. This was most likely due to:

- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different vibration attenuation paths (with presumably different techniques, geology and attenuation characteristics)
- The data set being so large (4327 data points)

### 4.1.2 Vibration Regression - Monitor Bravo




| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Bravo |
| **Slope** | -1.06 |
| **K (avg)** | 145.252 |
| **Design percentile** | |
| **K (90%)** | 317.442 |
| **Quality of Fit ($r^2$)** | 0.393 |
| **No of points** | 4386 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit $\mathbf{V = 145.252(R/Q^{1/2})^{-1.06}}$

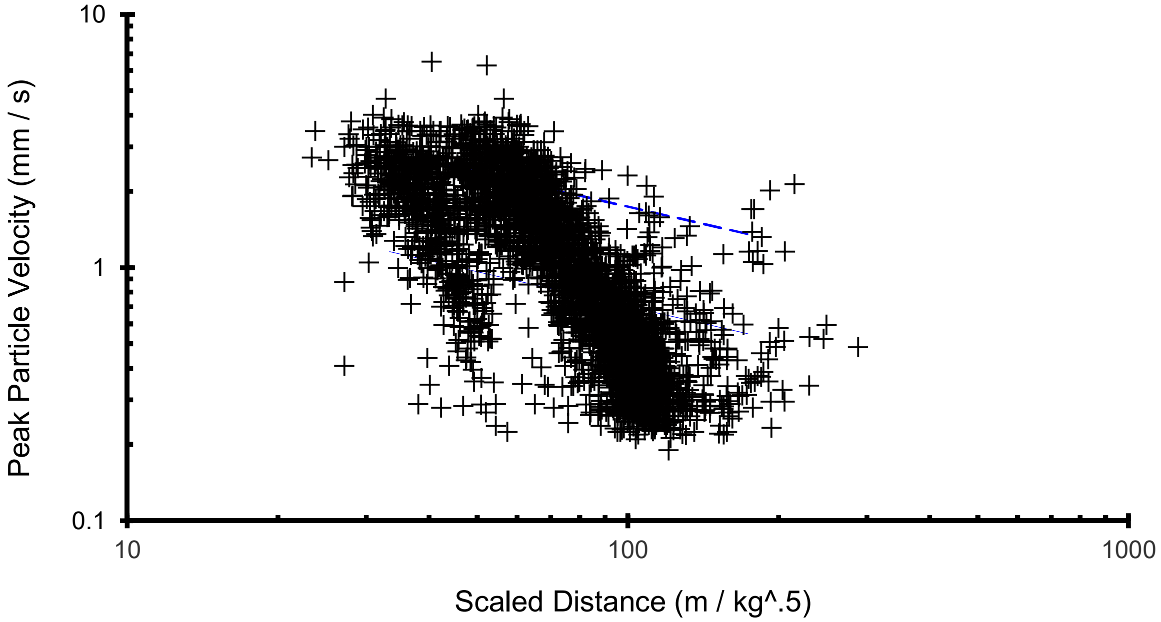
90% Confidence Limit $\mathbf{V = 317.442(R/Q^{1/2})^{-1.06}}$

The r squared, correlation coefficient or “goodness of fit” value for this data set was 0.393 which is moderate. This was most likely due to:

- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different vibration attenuation paths (with presumably different techniques, geology and attenuation characteristics)
- The data set being so large (4386 data points)

### 4.1.3 Vibration Regression - Monitor Charlie

Fimiston South Stg 2 - Full Data Set, Vibration Regression, Monitor Location: Charlie




| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Charlie |
| **Slope** | -0.94 |
| **K (avg)** | 51.454 |
| **Design percentile** | |
| **K (90%)** | 107.295 |
| **Quality of Fit ($r^2$)** | 0.339 |
| **No of points** | 4774 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit $\mathbf{V= 51.454(R/Q^{1/2})^{-0.94}}$

90% Confidence Limit $\mathbf{V= 107.295(R/Q^{1/2})^{-0.94}}$

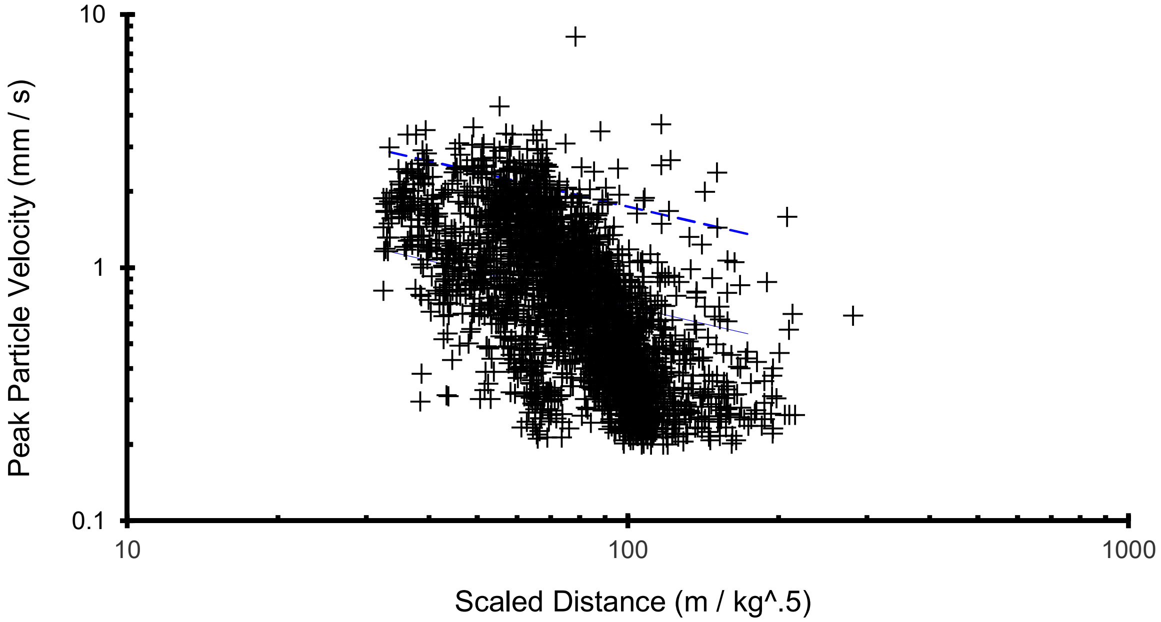
Note that these regression equations are remarkably similar to the guidelines provide in AS2187.2 for average and free faced blasting.

The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.339 which is moderate. This was most likely due to:

- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different vibration attenuation paths (with presumably different techniques, geology and attenuation characteristics)
- The data set being so large (4774 data points)

## 4.1.4 Vibration Regression - Monitor Delta

Fimiston South Stg 2 - Full Data Set, Vibration Regression, Monitor Location: Delta




| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Delta |
| **Slope** | -0.83 |
| **K (avg)** | 26.576 |
| **Design percentile** | |
| **K (90%)** | 53.395 |
| **Quality of Fit ($r^2$)** | 0.248 |
| **No of points** | 3764 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit $\mathbf{V= 26.576(R/Q^{1/2})^{-0.83}}$

90% Confidence Limit $\mathbf{V= 53.395(R/Q^{1/2})^{-0.83}}$

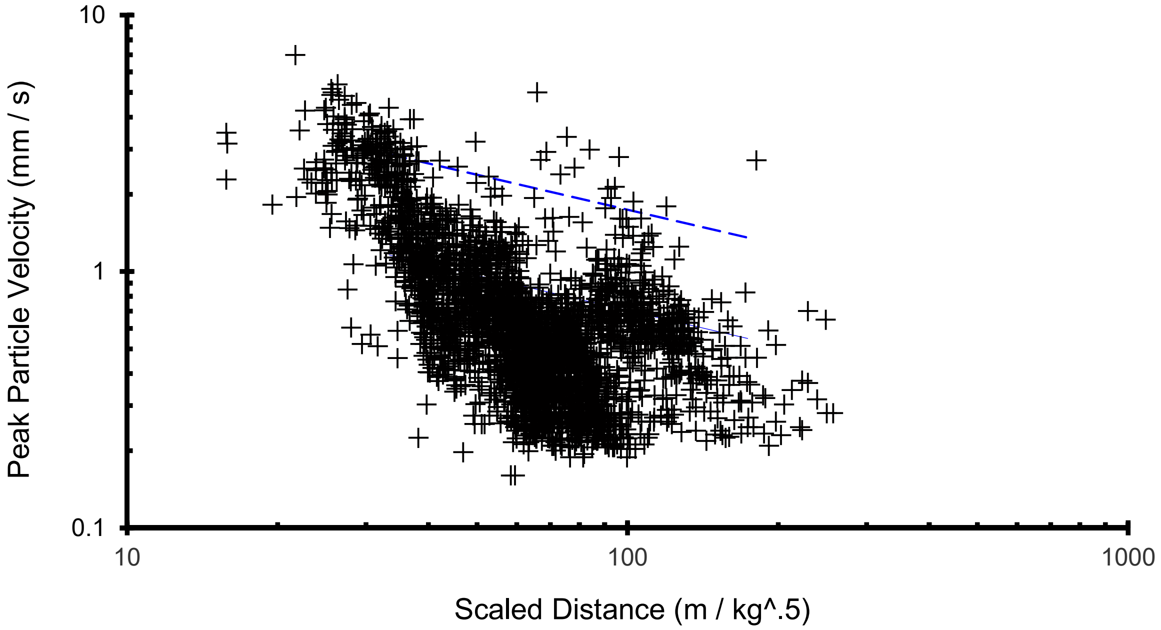
Note that these regression equations are somewhat similar to the guidelines provide in AS2187.2 for average and free faced blasting.

The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.248 which is moderate to low. This was most likely due to:

- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different vibration attenuation paths (with presumably different techniques, geology and attenuation characteristics)
- The data set being so large (3674 data points)

### 4.1.5 Vibration Regression - Monitor Echo

Fimiston South Stg 2 - Full Data Set, Vibration Regression, Monitor Location: Echo




| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Echo |
| **Slope** | -0.89 |
| **K (avg)** | 25.154 |
| **Design percentile** | |
| **K (90%)** | 50.033 |
| **Quality of Fit ($r^2$)** | 0.326 |
| **No of points** | 2945 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit $\mathbf{V= 25.154(R/Q^{1/2})^{-0.89}}$

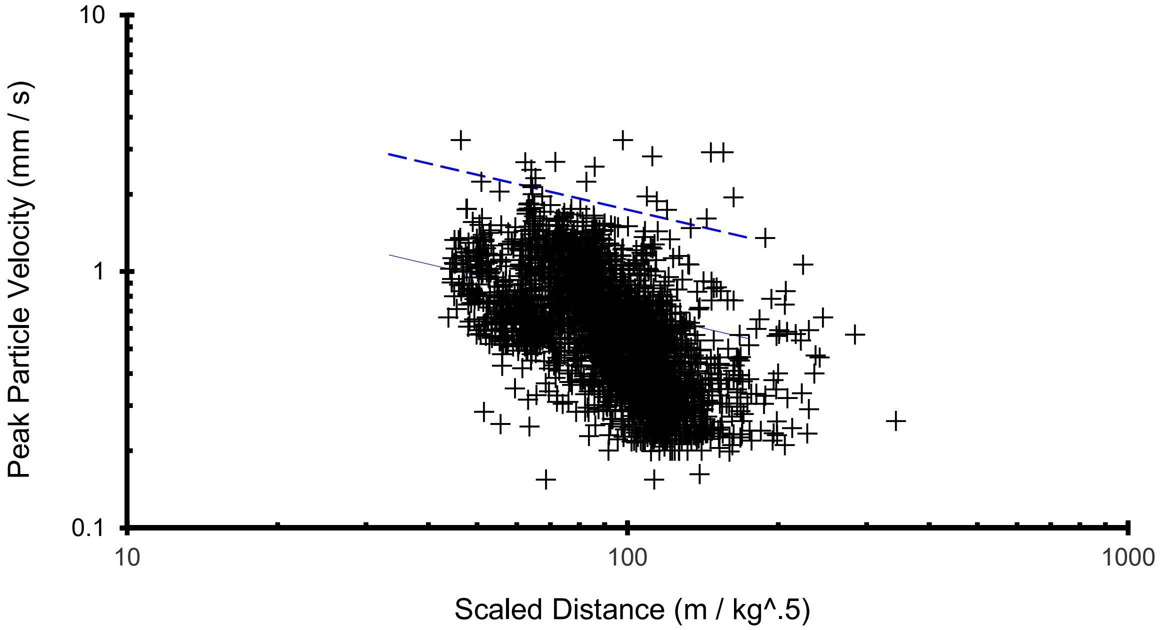
90% Confidence Limit $\mathbf{V= 50.033(R/Q^{1/2})^{-0.90}}$

Note that these regression equations are quite similar to the guidelines provide in AS2187.2 for average and free faced blasting.
The r squared, correlation coefficient or “goodness of fit” value for this data set was 0.326 which is moderate. This was most likely due to:

- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different vibration attenuation paths (with presumably different techniques, geology and attenuation characteristics)
- The data set being so large (2945 data points)

### 4.1.6 Vibration Regression - Monitor Foxtrot

Fimiston South Stg 2 - Full Data Set, Vibration Regression, Monitor Location: Foxtrot




| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Foxtrot |
| **Slope** | -0.88 |
| **K (avg)** | 31.743 |
| **Design percentile** | |
| **K (90%)** | 56.155 |
| **Quality of Fit ($r^2$)** | 0.279 |
| **No of points** | 2676 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit $\mathbf{V= 31.743(R/Q^{1/2})^{-0.88}}$

90% Confidence Limit $\mathbf{V= 56.155(R/Q^{1/2})^{-0.88}}$

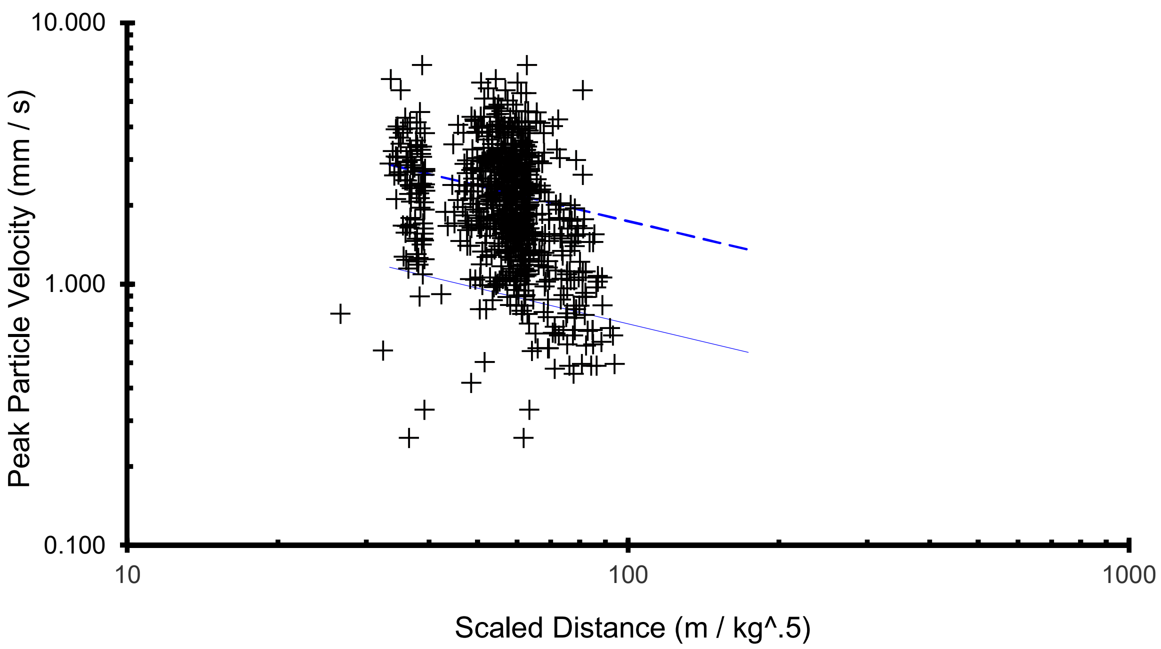
The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.279 which is moderate to low. This was most likely due to:

- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different vibration attenuation paths (with presumably different techniques, geology and attenuation characteristics)
- The data set being so large (2676 data points)

## 4.2 Analysis of KCGM Ground Vibration Records – 900m Data Set

### 4.2.1 Vibration Regression - Monitor Alpha

Fimiston South Stg 2 - 900m Dataset, Vibration Regression, Monitor Location: Alpha




| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Alpha |
| **Slope** | -0.84 |
| **K (avg)** | 57.715 |
| **Design percentile** | |
| **K (90%)** | 110.605 |
| **Quality of Fit ($r^2$)** | 0.106 |
| **No of points** | 745 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit $\mathbf{V= 57.715(R/Q^{1/2})^{-0.84}}$

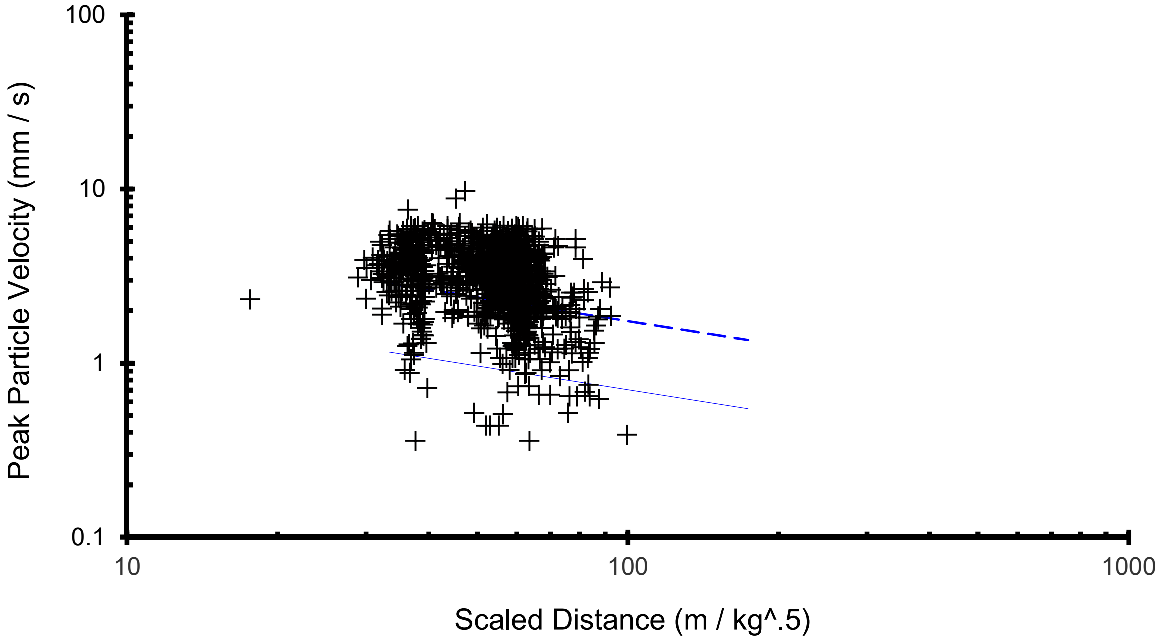
90% Confidence Limit $\mathbf{V= 110.605(R/Q^{1/2})^{-0.84}}$

The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.106 which is low. This was most likely due to:

- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different vibration attenuation paths (with presumably different techniques, geology and attenuation characteristics)
- The data set being of moderate size (745 data points)

### 4.2.2 Vibration Regression - Monitor Bravo

Fimiston South Stg 2 - 900m Dataset, Vibration Regression, Monitor Location: Bravo




| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Bravo |
| **Slope** | -0.56 |
| **K (avg)** | 27.682 |
| **Design percentile** | |
| **K (90%)** | 50.020 |
| **Quality of Fit ($r^2$)** | 0.074 |
| **No of points** | 1089 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit $\mathbf{V= 27.682(R/Q^{1/2})^{-0.56}}$

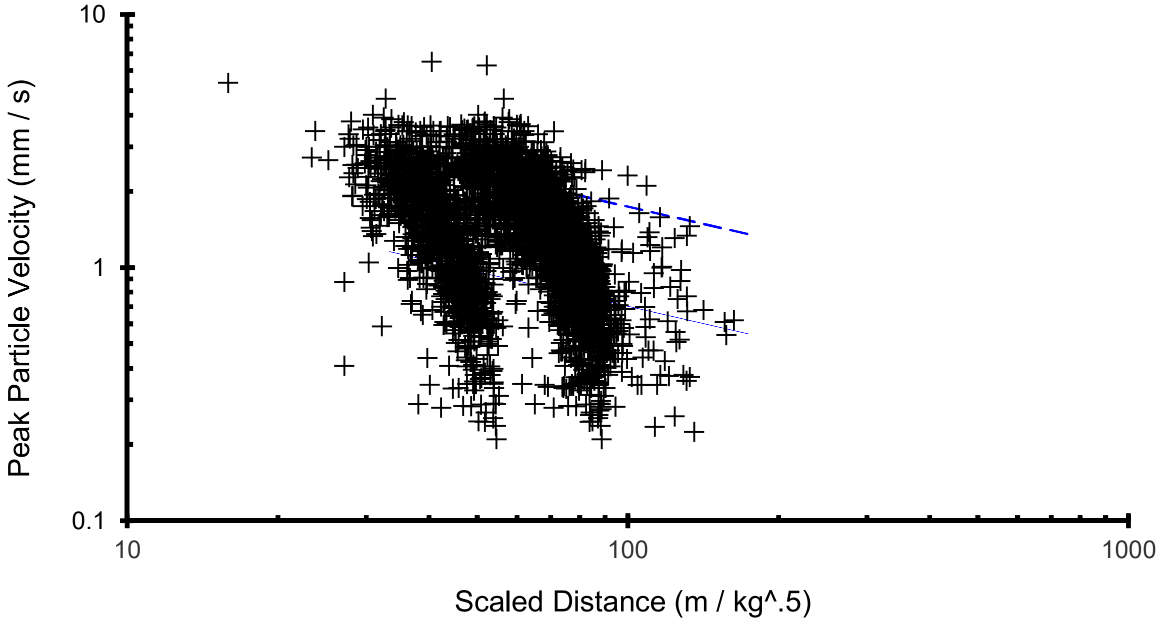
90% Confidence Limit $\mathbf{V= 50.020(R/Q^{1/2})^{-0.56}}$

The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.074 which is low. This was most likely due to:

- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different vibration attenuation paths (with presumably different techniques, geology and attenuation characteristics)
- The data set being of moderate size (1089 data points)

### 4.2.3 Vibration Regression - Monitor Charlie

Fimiston South Stg 2 - 900m Dataset, Vibration Regression, Monitor Location: Charlie




| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Charlie |
| **Slope** | -0.31 |
| **K (avg)** | 6.619 |
| **Design percentile** | |
| **K (90%)** | 10.347 |
| **Quality of Fit ($r^2$)** | 0.048 |
| **No of points** | 1247 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit $\mathbf{V= 6.619(R/Q^{1/2})^{-0.31}}$

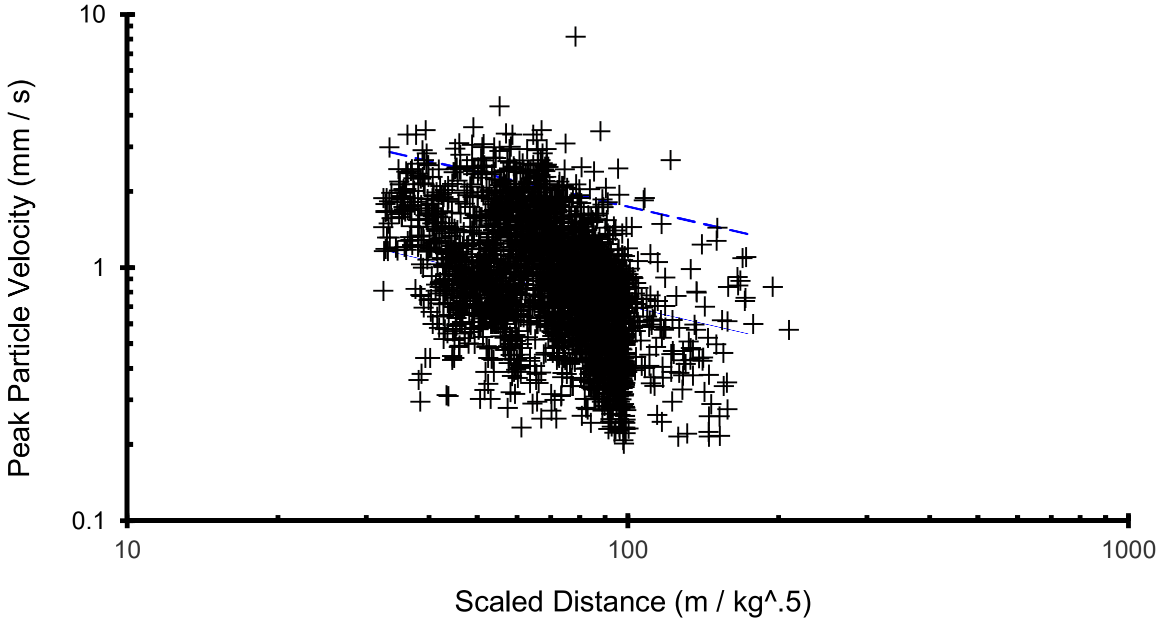
90% Confidence Limit $\mathbf{V= 10.347(R/Q^{1/2})^{-0.31}}$

Note that these regression equations are remarkably similar to the guidelines provide in AS2187.2 for average and free faced blasting.
The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.048 which is low. This was most likely due to:

- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different vibration attenuation paths (with presumably different techniques, geology and attenuation characteristics)
- The data set being of moderate size (1247 data points)

### 4.2.4 Vibration Regression - Monitor Delta

Fimiston South Stg 2 - 900m Dataset, Vibration Regression, Monitor Location: Delta




| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Delta |
| **Slope** | -0.41 |
| **K (avg)** | 7.593 |
| **Design percentile** | |
| **K (90%)** | 12.840 |
| **Quality of Fit ($r^2$)** | 0.053 |
| **No of points** | 526 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit $\mathbf{V= 7.593(R/Q^{1/2})^{-0.41}}$

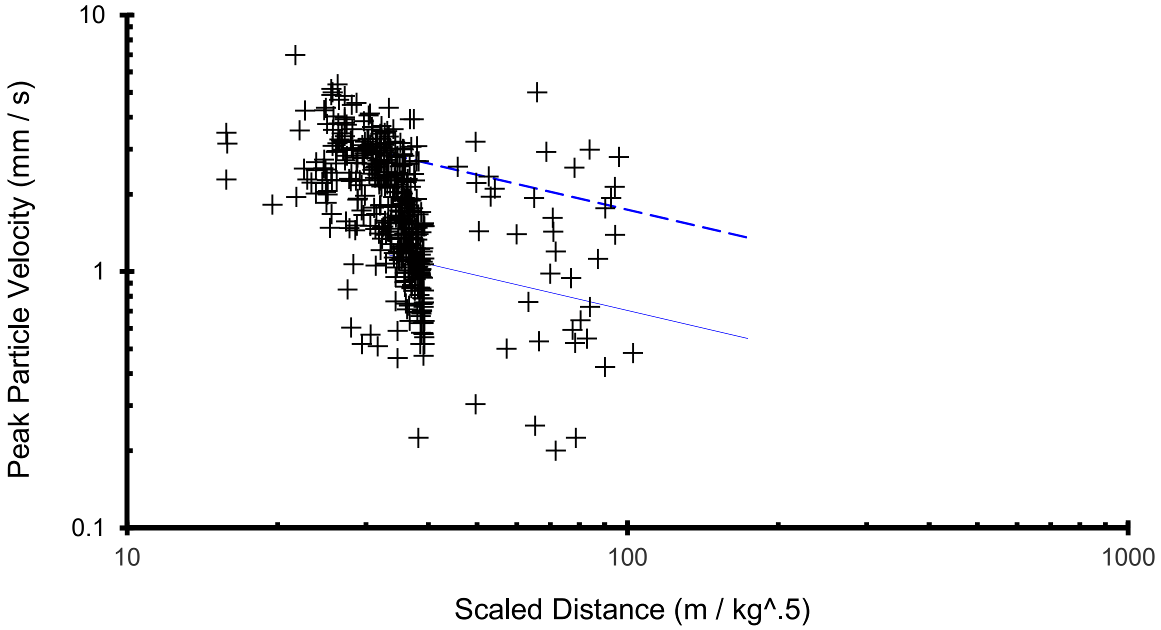
90% Confidence Limit $\mathbf{V= 12.840(R/Q^{1/2})^{-0.41}}$

Note that these regression equations are somewhat similar to the guidelines provide in AS2187.2 for average and free faced blasting.
The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.053 which is low. This was most likely due to:

- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different vibration attenuation paths (with presumably different techniques, geology and attenuation characteristics)
- The data set being of moderate size (526 data points)

### 4.2.5 Vibration Regression - Monitor Echo

Fimiston South Stg 2 - 900m Dataset, Vibration Regression, Monitor Location: Echo




| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Echo |
| **Slope** | -1.03 |
| **K (avg)** | 64.909 |
| **Design percentile** | |
| **K (90%)** | 126.898 |
| **Quality of Fit ($r^2$)** | 0.220 |
| **No of points** | 432 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit **$V= 64.909(R/Q^{1/2})^{-1.03}$**

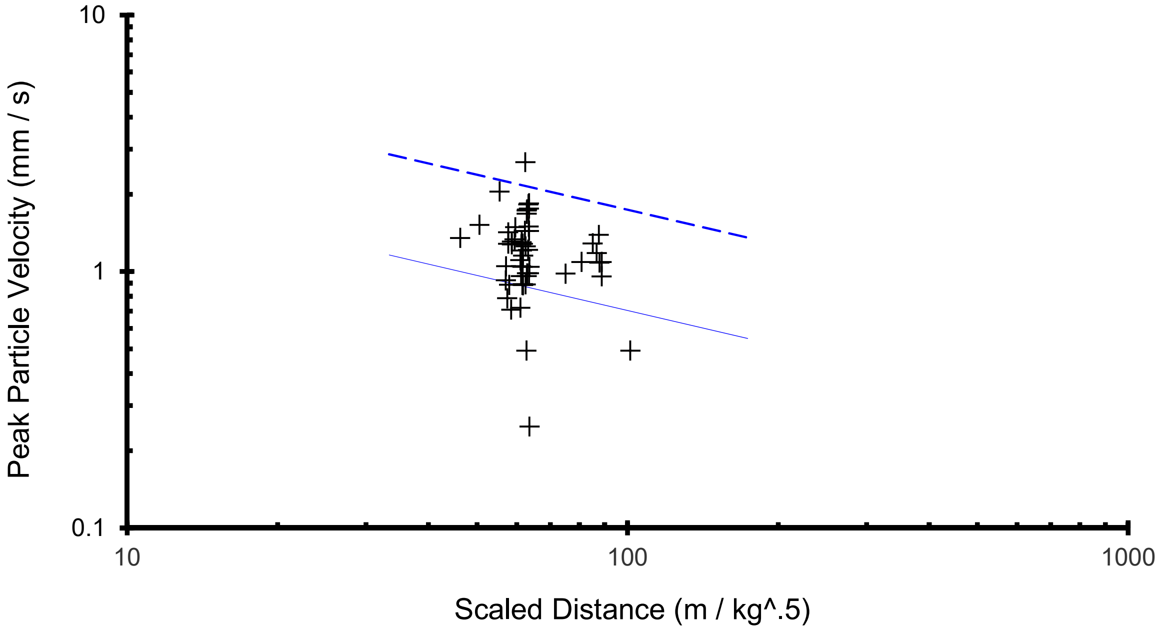
90% Confidence Limit **$V= 126.898(R/Q^{1/2})^{-1.03}$**

Note that these regression equations are quite similar to the guidelines provide in AS2187.2 for average and free faced blasting.
The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.220 which is moderate. This was most likely due to:

- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different vibration attenuation paths (with presumably different techniques, geology and attenuation characteristics)
- The data set being of moderate size (432 data points)

### 4.2.6 Vibration Regression - Monitor Foxtrot

Fimiston South Stg 2 - 900m Dataset, Vibration Regression, Monitor Location: Foxtrot




| Vib'n Regression Parameters | |
|---|---|
| Location Filter | Foxtrot |
| Slope | -0.47 |
| K (avg) | 8.118 |
| Design percentile | |
| K (90%) | 12.111 |
| Quality of Fit ($r^2$) | 0.048 |
| No of points | 54 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit $\mathbf{V= 8.118(R/Q^{1/2})^{-0.47}}$

90% Confidence Limit $\mathbf{V= 12.111(R/Q^{1/2})^{-0.47}}$

The r squared, correlation coefficient or “goodness of fit” value for this data set was 0.048 which is moderate to low. This was most likely due to:

- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different vibration attenuation paths (with presumably different techniques, geology and attenuation characteristics)
- The data set being small (54 data points)

## 4.3 Summary of Vibration Prediction Equations

For prediction equations in the form:

$$\mathbf{V = K\ (R/Q^{1/2})^{-b}}$$

Where:

V = peak particle velocity (ppv) in mm/sec

K & b = Site Constants (specific to the attenuation character of the rock between the blast and monitoring locations)

R = Range (distance) to structure (m)

Q = Charge mass per delay (Often expressed as Maximum Instantaneous Charge or MIC) (kg)

The following parameters have been analysed to apply by monitor location:

**Table 4.1: Regression equation parameters calculated from KCGM Full data set**

| | K factor by Confidence Limit Complete Data Set | | |
|---|---|---|---|
| **Monitor** | **50%** | **90%** | **b** |
| Alpha | 91.7 | 204.7 | -1.02 |
| Bravo | 145.3 | 317.4 | -1.06 |
| Charlie | 51.5 | 107.3 | -0.94 |
| Delta | 26.6 | 53.4 | -0.83 |
| Echo | 25.2 | 50.0 | -0.89 |
| Foxtrot | 31.7 | 56.2 | -0.88 |

**Table 4.2: Regression equation parameters calculated from KCGM 900m data set**

| | K factor by Confidence Limit 900m Data Set | | |
|---|---|---|---|
| **Monitor** | **50%** | **90%** | **b** |
| Alpha | 57.7 | 110.6 | -0.84 |
| Bravo | 27.7 | 50.0 | -0.56 |
| Charlie | 6.6 | 10.3 | -0.31 |
| Delta | 7.6 | 12.8 | -0.41 |
| Echo | 64.9 | 126.9 | -1.03 |
| Foxtrot | 8.1 | 12.1 | -0.47 |

## 4.4 Vibration Attenuation – Geologic Considerations

The process by which blast-induced ground vibration waves are attenuated as they travel hundreds of metres is complex. Waves will be subject to interference from rock characteristics including rock discontinuities/structures that do the following to blast-induced vibrations:

- Reflect
- Refract
- Step attenuate

Rock inconsistencies can also “channel” vibration waves making wave amplitude vary considerably at the same distance from the same blast event. This inconsistency is part of the reason why operations like KCGM use multiple monitoring stations to assess compliance with limits based upon multiple and more locally representative vibration wave paths.

As part of this review, the presence of specific structures that could produce substantial inconsistencies were examined.

The following Figure 4.1 shows the major geologic structures identified between the mining locations planned for the Fimiston South Project mining operations and the adjacent Soth Boulder industrial area.

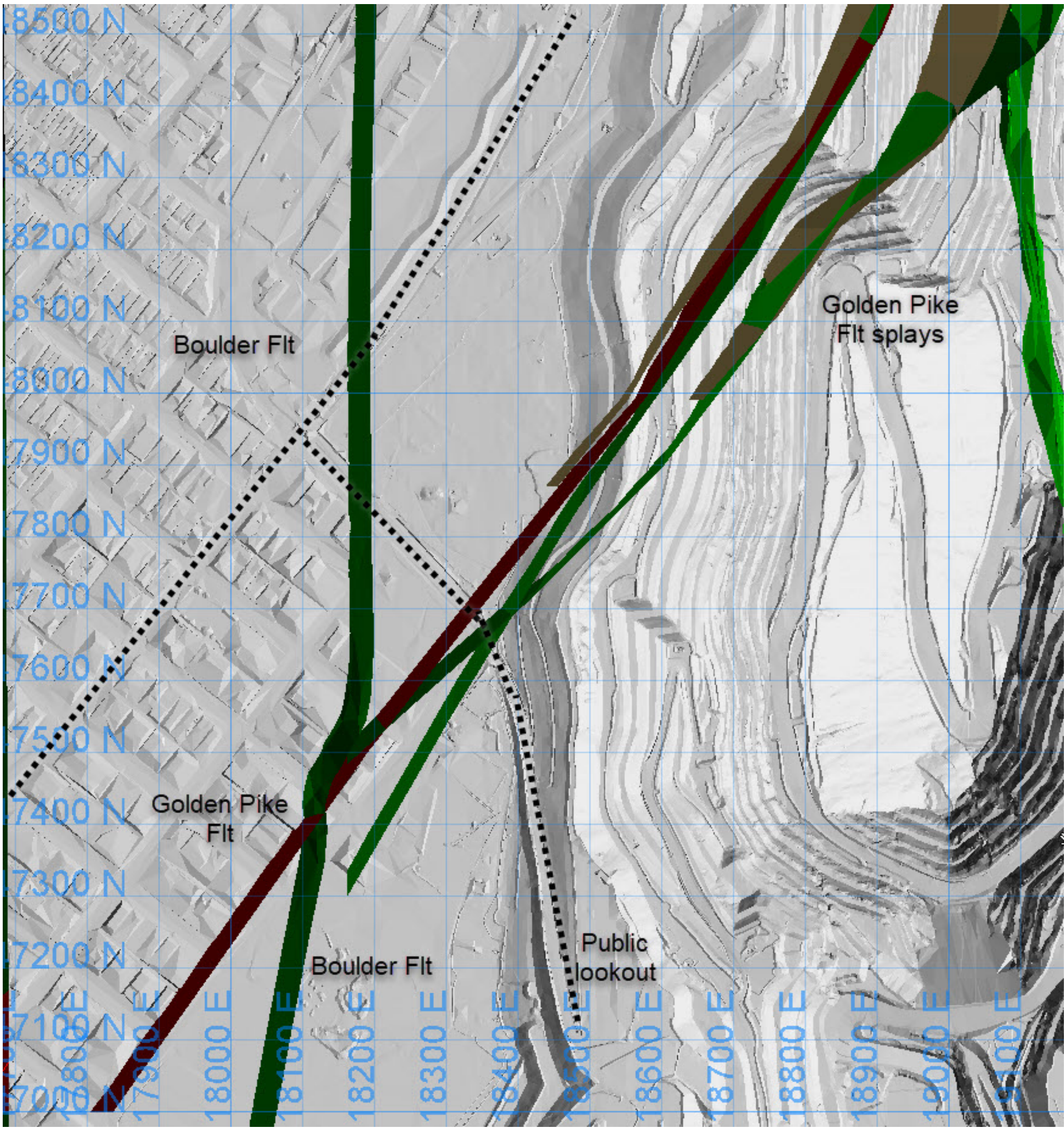



**Figure 4.1: Main geologic structures adjacent to the Fimiston South Project mining operations.**

Structural mapping of the rock underneath the industrial area has not been assessed. However, the structures shown above close to the pit (that have been identified as part of analyses to ensure the safety/stability of pit walls), are orientated roughly North-South and NNE-SSW. These orientations are unlikely to complicate attenuation character as much as more East-West oriented structures would be expect to do so.

# 5. Prediction of Air Overpressure for the Fimiston South Project

As discussed in Section 2.2, regression analyses of air overpressure data does not usually yield formulae from which accurate predictions of over pressure level can be derived. This is due to the strong influence that ambient environmental conditions at the time of each blast (which are not included in the prediction equations) exert of actual air overpressure levels that will be measured at any particular distance.

However, to eliminate doubt, regression analyses were conducted upon the KCGM data to assess the usefulness of prediction equations.

## 5.1 KCGM Empirical Approach to Air Overpressure Compliance

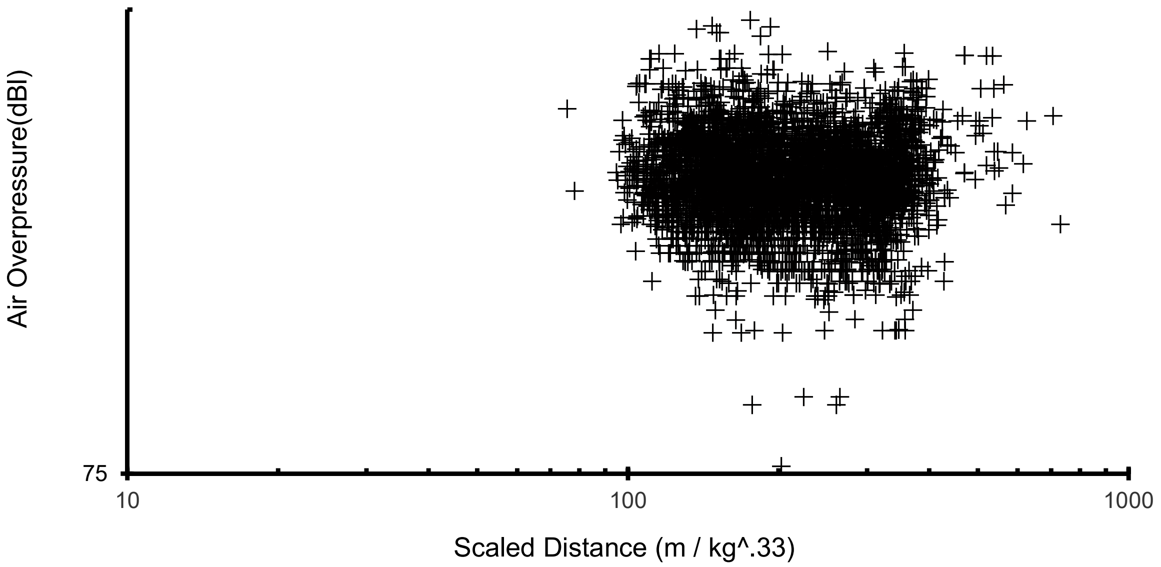
In practice, KCGM controls air overpressure from blasting using empirical methods that include:

- Understanding of the anecdotal influence of wind direction and velocity upon air overpressure measured at the monitors and near residences
- Anticipation of reflection and refraction effects associated with indirect air overpressure pathways due to the location of blasts and the shape of the pit
- Familiarity with the air overpressure outputs of different types of blasts
- Air overpressure mitigation techniques within blast designs and implementation
- Avoidance of blasting during combinations of ambient atmospheric conditions and blast designs/types that result in elevated air overpressure at the monitors and near residences

## 5.2 Analysis of KCGM Air Overpressure Records – Full Data Set

### 5.2.1 Air Overpressure Regression - Monitor Alpha

Fimiston South Stg 2 - Full Data Set, Air Overpressure Regression, Monitor Location: Alpha



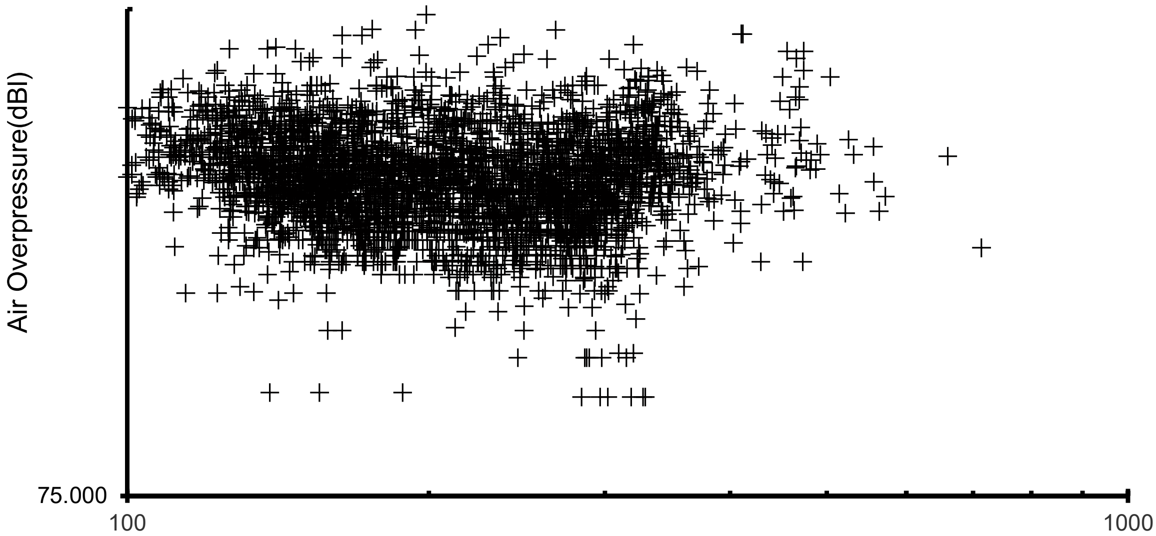

Note: The top of the vertical axis of the above graphic is 125dBl

| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Alpha |
| **Slope** | 0.00 |
| **K (avg)** | 104.384 |
| **Design percentile** | |
| **K (90%)** | 116.179 |
| **Quality of Fit ($r^2$)** | 0.000 |
| **No of points** | 4318 |

There was no correlation between Air Overpressure and Cube Root Scaled distance for Monitor Alpha.

### 5.2.2 Air Overpressure Regression – Monitor Bravo

Fimiston South Stg 2 - Full Data Set, Air Overpressure Regression, Monitor Location: Bravo




Note: The top of the vertical axis of the above graphic is 125dBl

| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Bravo |
| **Slope** | -0.019 |
| **K (avg)** | 115.523 |
| **Design percentile** | |
| **K (90%)** | 125.052 |
| **Quality of Fit ($r^2$)** | 0.01089 |
| **No of points** | 3540 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit $\mathbf{V= 115.523(R/Q^{1/3})^{-0.019}}$

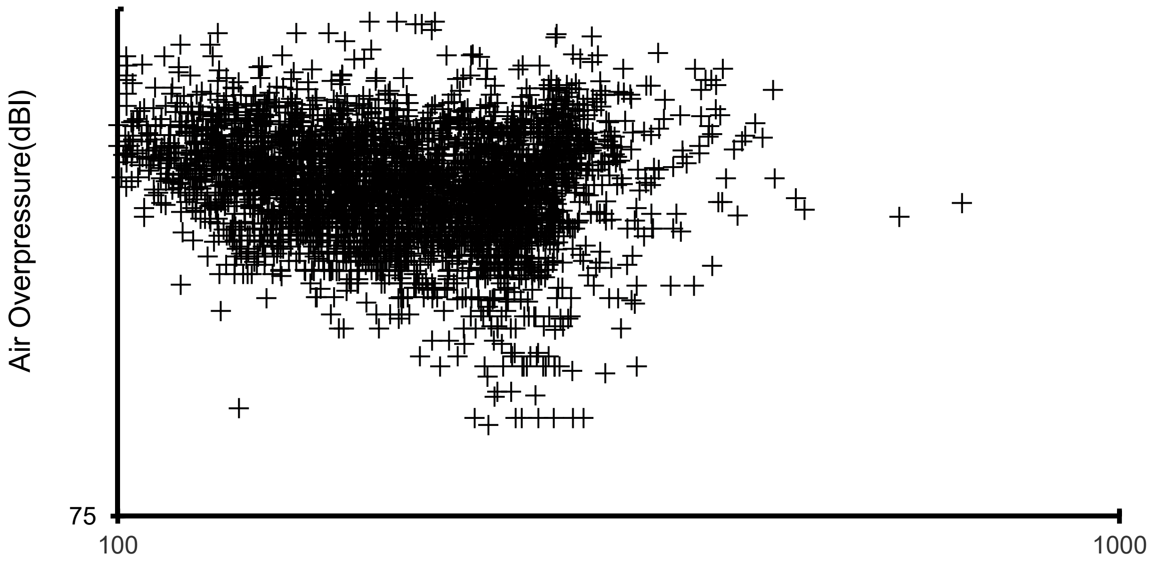
90% Confidence Limit $\mathbf{V= 125.052(R/Q^{1/3})^{-0.019}}$

The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.0.01089 which is extremely low. This was most likely due to:

- The dependency of air overpressure levels upon ambient environmental conditions
- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different air overpressure attenuation paths (with presumably different techniques, topography and attenuation characteristics)

### 5.2.3 Air Overpressure Regression – Monitor Charlie

Fimiston South Stg 2 - Full Data Set, Monitor Location: Charlie




Note: The top of the vertical axis of the above graphic is 125dBl

| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Charlie |
| **Slope** | -0.032 |
| **K (avg)** | 123.634 |
| **Design percentile** | |
| **K (90%)** | 132.630 |
| **Quality of Fit ($r^2$)** | 0.0303 |
| **No of points** | 3550 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit **$V = 123.634(R/Q^{1/3})^{-0.032}$**

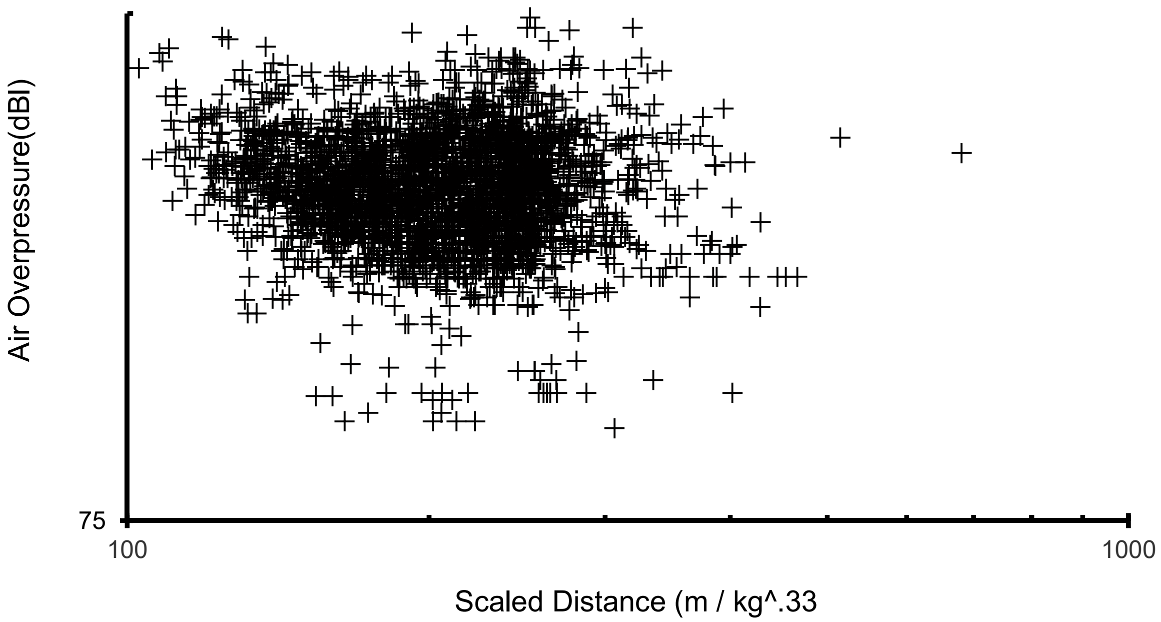
90% Confidence Limit **$V = 132.630(R/Q^{1/3})^{-0.032}$**

The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.0303 which is very low. This was most likely due to:

- The dependency of air overpressure levels upon ambient environmental conditions
- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different air overpressure attenuation paths (with presumably different techniques, topography and attenuation characteristics)

### 5.2.4 Air Overpressure Regression – Monitor Delta

Fimiston South Stg 2 - Full Data Set, Monitor Location: Delta




Note: The top of the vertical axis of the above graphic is 125dBl

| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Delta |
| **Slope** | -0.01 |
| **K (avg)** | 112.989 |
| **Design percentile** | |
| **K (90%)** | 121.435 |
| **Quality of Fit ($r^2$)** | 0.004 |
| **No of points** | 3034 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

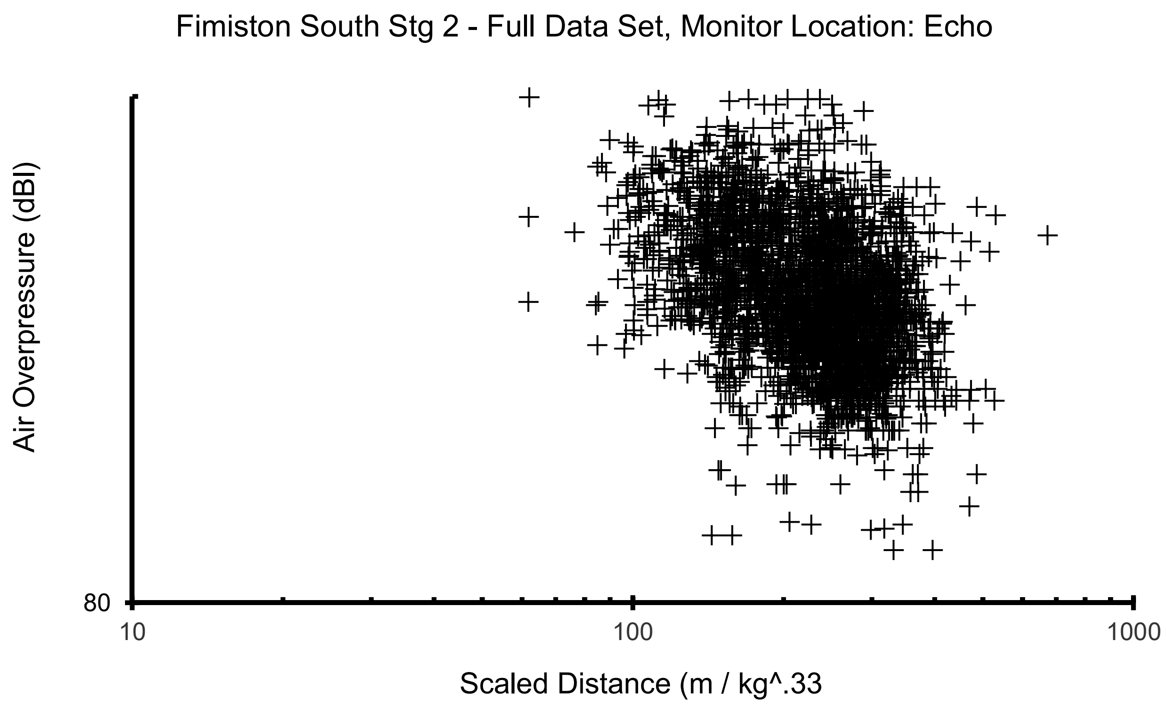
50% Confidence Limit $\mathbf{V= 112.989(R/Q^{1/3})^{-0.01}}$

90% Confidence Limit $\mathbf{V= 121.435(R/Q^{1/3})^{-0.01}}$

The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.004 which is extremely low. This was most likely due to:

- The dependency of air overpressure levels upon ambient environmental conditions
- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different air overpressure attenuation paths (with presumably different techniques, topography and attenuation characteristics)

### 5.2.5 Air Overpressure Regression – Monitor Echo




Note: The top of the vertical axis of the above graphic is 125dBl

| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Echo |
| **Slope** | -0.067 |
| **K (avg)** | 150.429 |
| **Design percentile** | |
| **K (90%)** | 171.583 |
| **Quality of Fit ($r^2$)** | 0.047 |
| **No of points** | 2941 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

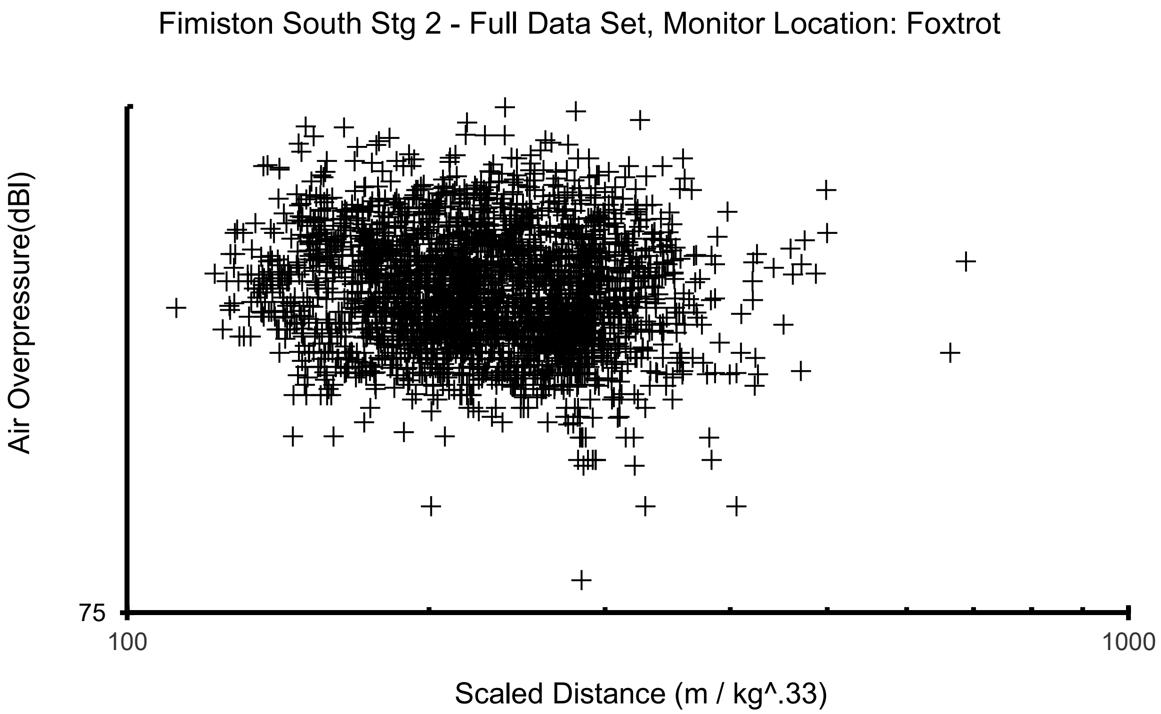
50% Confidence Limit $\mathbf{V = 150.429(R/Q^{1/3})^{-0.067}}$

90% Confidence Limit $\mathbf{V = 171.583(R/Q^{1/3})^{-0.067}}$

The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.047 which is very low. This was most likely due to:

- The dependency of air overpressure levels upon ambient environmental conditions
- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different air overpressure attenuation paths (with presumably different techniques, topography and attenuation characteristics)

### 5.2.6 Air Overpressure Regression – Monitor Foxtrot




Note: The top of the vertical axis of the above graphic is 125dBl

| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Foxtrot |
| **Slope** | -0.02 |
| **K (avg)** | 117.193 |
| **Design percentile** | |
| **K (90%)** | 126.471 |
| **Quality of Fit ($r^2$)** | 0.009 |
| **No of points** | 2672 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit **$V= 117.193(R/Q^{1/3})^{-0.02}$**

90% Confidence Limit **$V= 126.471(R/Q^{1/3})^{-0.02}$**

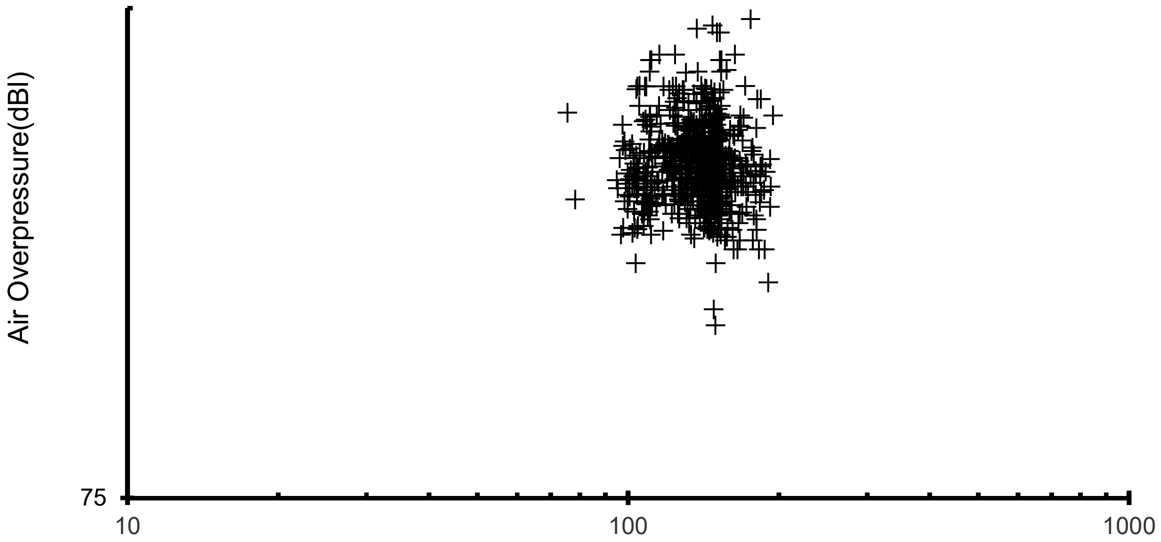
The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.009 which is extremely low. This was most likely due to:

- The dependency of air overpressure levels upon ambient environmental conditions
- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different air overpressure attenuation paths (with presumably different techniques, topography and attenuation characteristics)

## 5.3 Analysis of KCGM Air Overpressure Records – 900m Data Set

### 5.3.1 Air Overpressure Regression - Monitor Alpha

Fimiston South Stg 2 - 900m Data, Air Overpressure Regression, Monitor Location: Alpha



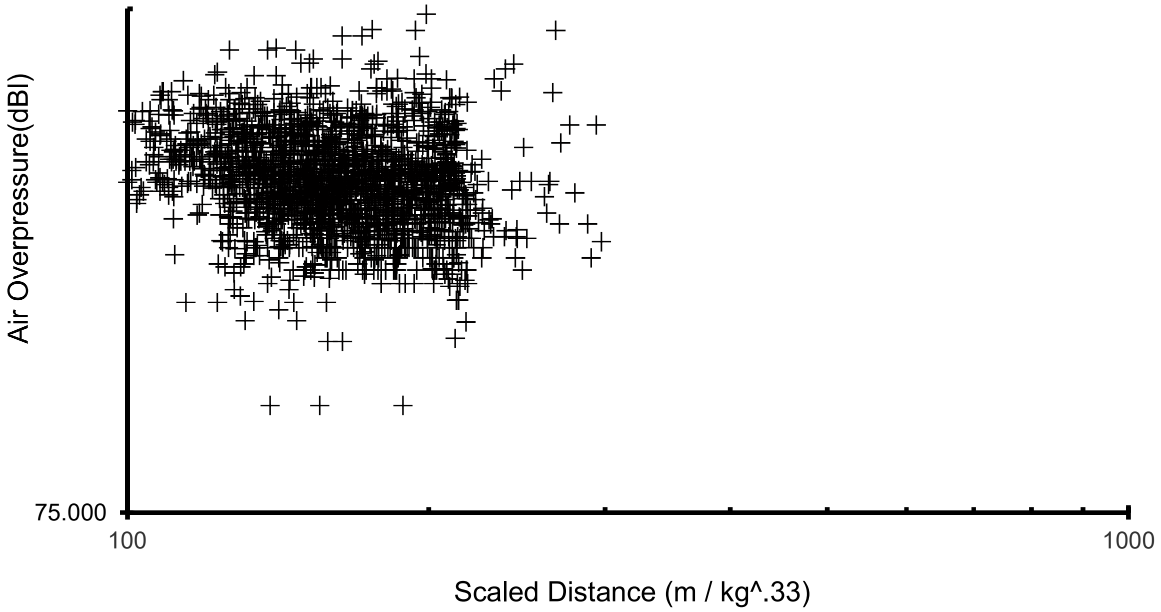

Note: The top of the vertical axis of the above graphic is 125dBl

| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Alpha |
| **Slope** | 0.06 |
| **K (avg)** | 79.913 |
| **Design percentile** | |
| **K (90%)** | 98.979 |
| **Quality of Fit ($r^2$)** | 0.002 |
| **No of points** | 744 |

There was no correlation between Air Overpressure and Cube Root Scaled distance for Monitor Alpha.

### 5.3.2 Air Overpressure Regression – Monitor Bravo

Fimiston South Stg 2 - 900m Data, Air Overpressure Regression, Monitor Location: Bravo




Note: The top of the vertical axis of the above graphic is 125dBI

| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Bravo |
| **Slope** | -0.062 |
| **K (avg)** | 144.011 |
| **Design percentile** | |
| **K (90%)** | 156.814 |
| **Quality of Fit ($r^2$)** | 0.03439 |
| **No of points** | 1957 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

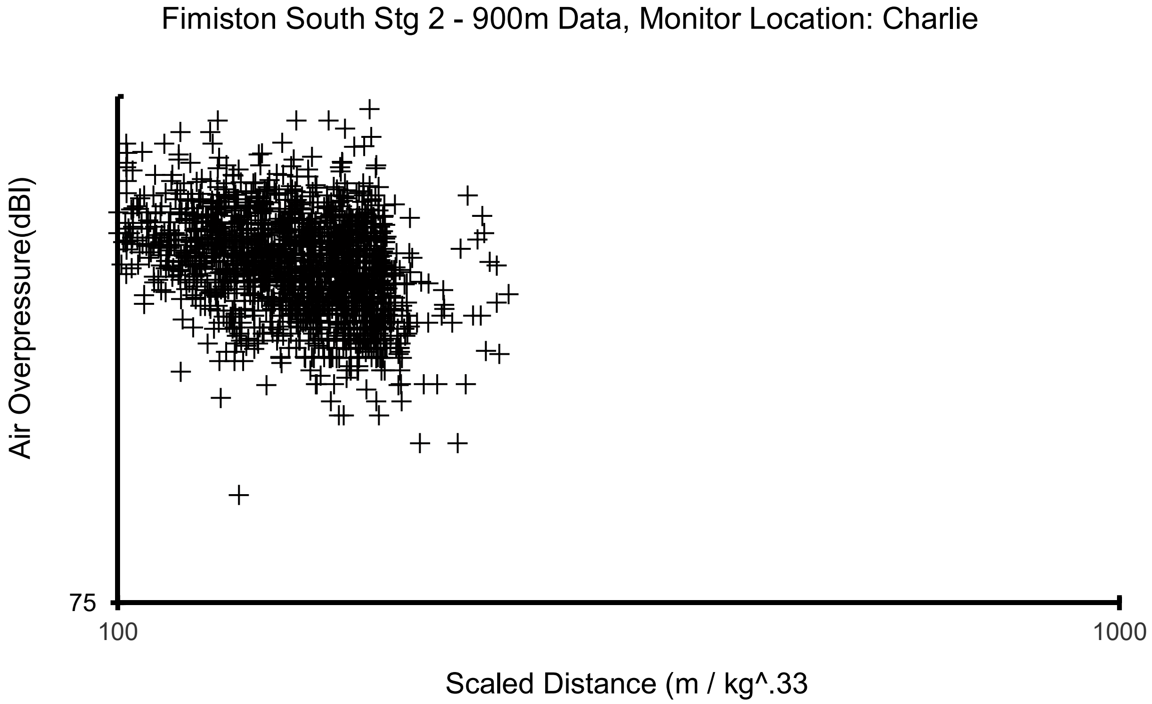
50% Confidence Limit $\mathbf{V= 144.011(R/Q^{1/3})^{-0.062}}$

90% Confidence Limit $\mathbf{V= 156.814(R/Q^{1/3})^{-0.062}}$

The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.0.03439 which is extremely low. This was most likely due to:

- The dependency of air overpressure levels upon ambient environmental conditions
- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different air overpressure attenuation paths (with presumably different techniques, topography and attenuation characteristics)

### 5.3.3 Air Overpressure Regression – Monitor Charlie




Note: The top of the vertical axis of the above graphic is 125dBl

| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Charlie |
| **Slope** | -0.098 |
| **K (avg)** | 171.714 |
| **Design percentile** | |
| **K (90%)** | 182.265 |
| **Quality of Fit ($r^2$)** | 0.1318 |
| **No of points** | 1654 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

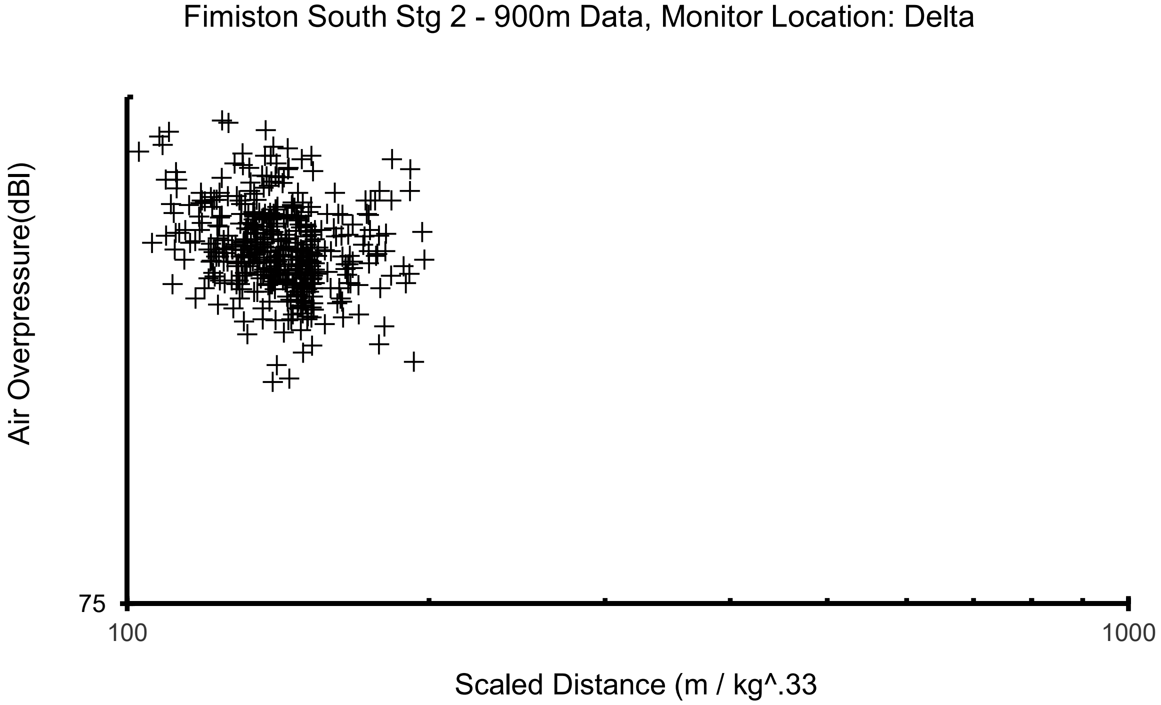
50% Confidence Limit **$V= 171.714(R/Q^{1/3})^{-0.098}$**

90% Confidence Limit **$V= 182.265(R/Q^{1/3})^{-0.098}$**

The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.1318 which is very low. This was most likely due to:

- The dependency of air overpressure levels upon ambient environmental conditions
- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different air overpressure attenuation paths (with presumably different techniques, topography and attenuation characteristics)

### 5.3.4 Air Overpressure Regression – Monitor Delta




Note: The top of the vertical axis of the above graphic is 125dBl

| Vib'n Regression Parameters | |
|---|---|
| Location Filter | Delta |
| Slope | -0.08 |
| K (avg) | 156.925 |
| Design percentile | |
| K (90%) | 165.755 |
| Quality of Fit ($r^2$) | 0.043 |
| No of points | 430 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit $\mathbf{V= 156.925(R/Q^{1/3})^{-0.08}}$

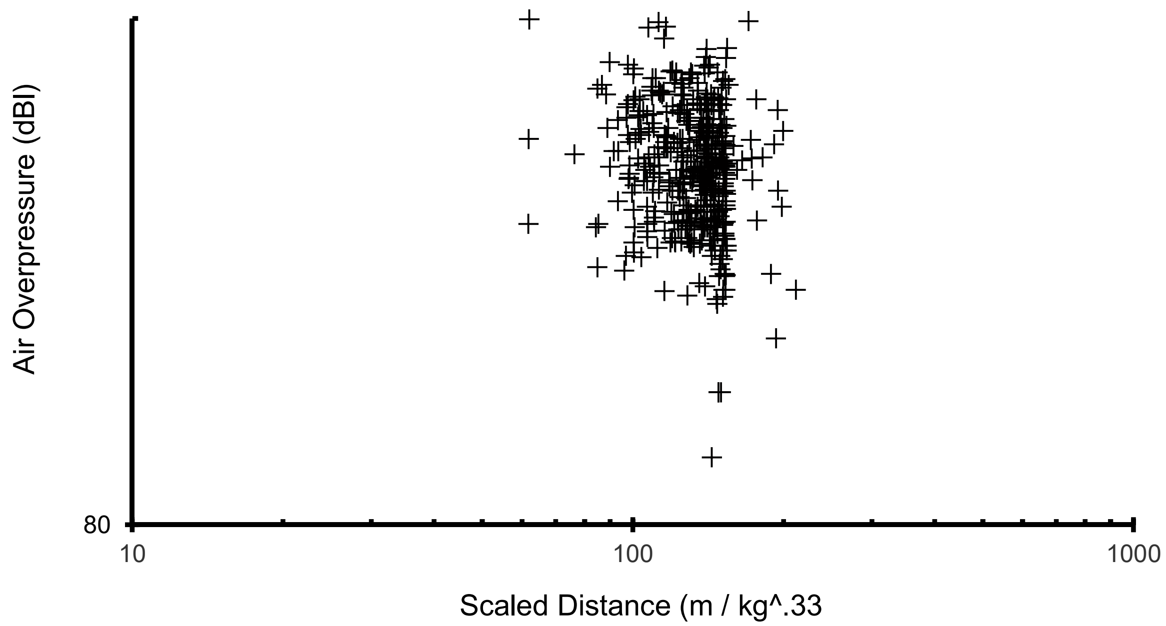
90% Confidence Limit $\mathbf{V= 165.755(R/Q^{1/3})^{-0.08}}$

The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.043 which is extremely low. This was most likely due to:

- The dependency of air overpressure levels upon ambient environmental conditions
- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different air overpressure attenuation paths (with presumably different techniques, topography and attenuation characteristics)

### 5.3.5 Air Overpressure Regression – Monitor Echo

Fimiston South Stg 2 - 900m Data, Monitor Location: Echo




Note: The top of the vertical axis of the above graphic is 125dBl

| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Echo |
| **Slope** | -0.060 |
| **K (avg)** | 146.855 |
| **Design percentile** | |
| **K (90%)** | 157.441 |
| **Quality of Fit ($r^2$)** | 0.035 |
| **No of points** | 433 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

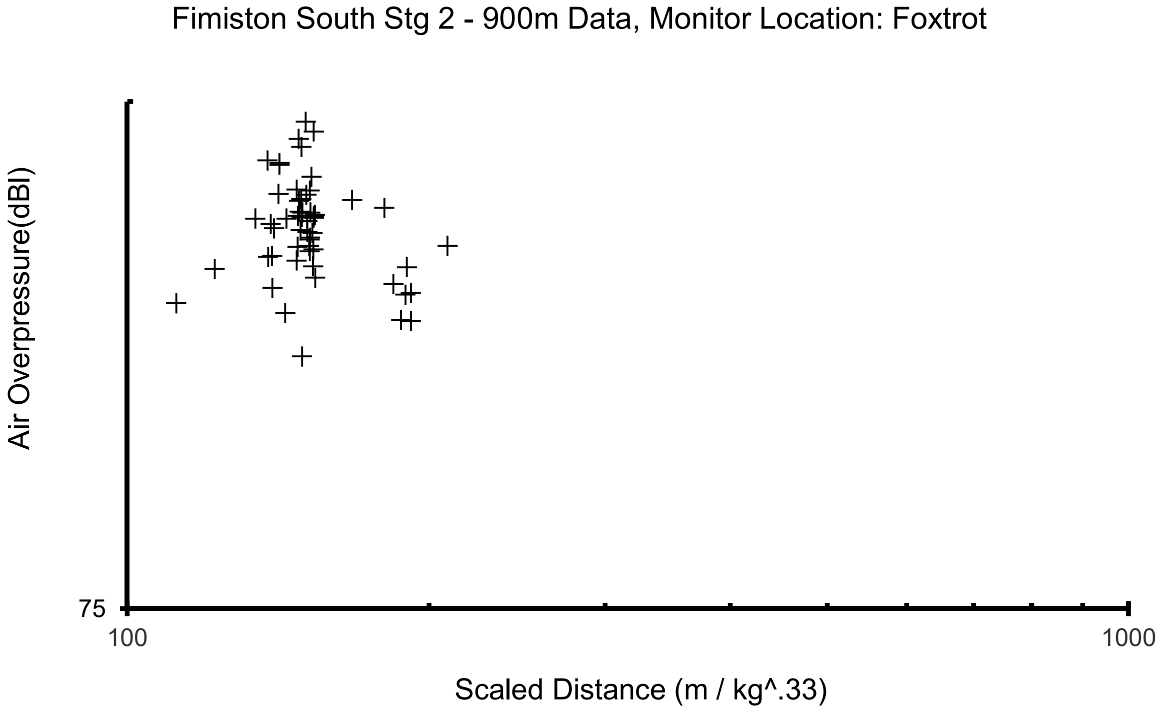
50% Confidence Limit $\mathbf{V= 146.855(R/Q^{1/3})^{-0.060}}$

90% Confidence Limit $\mathbf{V= 157.441(R/Q^{1/3})^{-0.060}}$

The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.035 which is very low. This was most likely due to:

- The dependency of air overpressure levels upon ambient environmental conditions
- The data set including several different types of blast (with various MIC, timing, confinement and other factors)
- The data from many years of blasting activity and numerous blast locations – resulting in numerous different air overpressure attenuation paths (with presumably different techniques, topography and attenuation characteristics)

### 5.3.6 Air Overpressure Regression – Monitor Foxtrot




Note: The top of the vertical axis of the above graphic is 125dBl

| Vib'n Regression Parameters | |
|---|---|
| **Location Filter** | Foxtrot |
| **Slope** | -0.10 |
| **K (avg)** | 182.915 |
| **Design percentile** | |
| **K (90%)** | 194.862 |
| **Quality of Fit ($r^2$)** | 0.050 |
| **No of points** | 55 |

The 50% and 90% lines of best fit for the data were calculated and then represented by square root scaled distance equations (as per AS2187.2). These equations were:

50% Confidence Limit **$V = 185.915(R/Q^{1/3})^{-0.10}$**

90% Confidence Limit **$V = 194.862(R/Q^{1/3})^{-0.10}$**

The r squared, correlation coefficient or "goodness of fit" value for this data set was 0.05 which is extremely low. This was most likely due to:

- The dependency of air overpressure levels upon ambient environmental conditions
- The data set including several different types of blast (with various MIC, timing, confinement and other factors)

The data from many years of blasting activity and numerous blast locations – resulting in numerous different air overpressure attenuation paths (with presumably different techniques, topography and attenuation characteristics)

# 6. Prediction of Minimum Distance for Compliance with Vibration and Air Overpressure Limit – By Monitor and Initiation Type

## 6.1 Prediction of Minimum Distance for Compliance with Vibration Limits

The 90% confidence limit vibration prediction equations were used to analyse the predicted minimum distance between the monitor locations and the proposed Fimiston South Project area to assess probability of compliance with a peak particle velocity of 5mm/s.

The following table details the predicted minimum distance based upon the full data set.

**Table 6.1: Predicted minimum slope distance for 90% probability of compliance with 5mm/s limit for each adjacent monitor – Full Data Set**

| | Nonel Initiation | Electronic Initiation | Minimum Distances for Planned Mining (m) | | |
|---|---|---|---|---|---|
| **Monitor** | **Minimum Distance for 90% Probability of Compliance with 5mm/s (m)** | **Minimum Distance for 90% Probability of Compliance with 5mm/s (m)** | **Minimum Slope Distance from Oxide Rock (m) - Free Dug** | **Minimum Slope Distance from Transitional Rock (m) – Lower MIC Blasting** | **Minimum Slope Distance from Fresh Rock (m) – Normal MIC Blasting** |
| Alpha | 911 | 526 | 504 | 579 | 608 |
| Bravo | 1372 | 792 | 350 | 426 | 448 |
| Charlie | 242 | 140 | 307 | 426 | 447 |
| Delta | 232 | 134 | 221 | 368 | 377 |
| Echo | 536 | 309 | 296 | 411 | 430 |
| Foxtrot | 153 | 88 | 396 | 526 | 526 |

The following table details the predicted minimum distance based upon the 900m data set.

**Table 6.2: Predicted minimum slope distance for 90% probability of compliance with 5mm/s limit for each adjacent monitor – 900m Data Set**

| | Nonel | Electronic | Minimum Distances for Planned Mining (m) | | |
|---|---|---|---|---|---|
| **Monitor** | **Minimum Distance for 90% Probability of Compliance with 5mm/s (m)** | **Minimum Distance for 90% Probability of Compliance with 5mm/s (m)** | **Minimum Slope Distance from Oxide Rock (m) - Free Dug** | **Minimum Slope Distance from Transitional Rock (m) – Lower MIC Blasting** | **Minimum Slope Distance from Fresh Rock (m) – Normal MIC Blasting** |
| Alpha | 868 | 501 | 504 | 579 | 608 |
| Bravo | 1144 | 661 | 350 | 426 | 448 |
| Charlie | 604 | 349 | 307 | 426 | 447 |
| Delta | 394 | 227 | 221 | 368 | 377 |
| Echo | 301 | 174 | 296 | 411 | 430 |
| Foxtrot | 352 | 203 | 396 | 526 | 526 |

## 6.2 Prediction of Air Overpressure

None of the regression relationships developed from the database were of sufficiently reliable character to derive predictions. As noted in Section 2, this was unsurprising/expected.

Through the history of mining at KCGM (including the present), an empirical approach to achievement of air overpressure compliance has been applied. This approach involves awareness of which combinations of blast parameters/location and ambient atmospheric/environmental conditions can be relied upon to control air overpressure measured at the monitors (and the even more distant town) to below the limits specified in the ministerial approval. While this system relies upon experience/knowledge of the blast designers and effective preservation (and passing on) of that knowledge, the effectiveness of this approach suggests it's continuation is the most appropriate way to ensure continued air overpressure compliance.

## 6.3 Location of Planned Mining, Monitoring Stations and the adjacent South Boulder Light Industrial Area

The following figures show the planned proximity of oxide and fresh rock mining to the adjacent monitoring stations and South Boulder light industrial area.

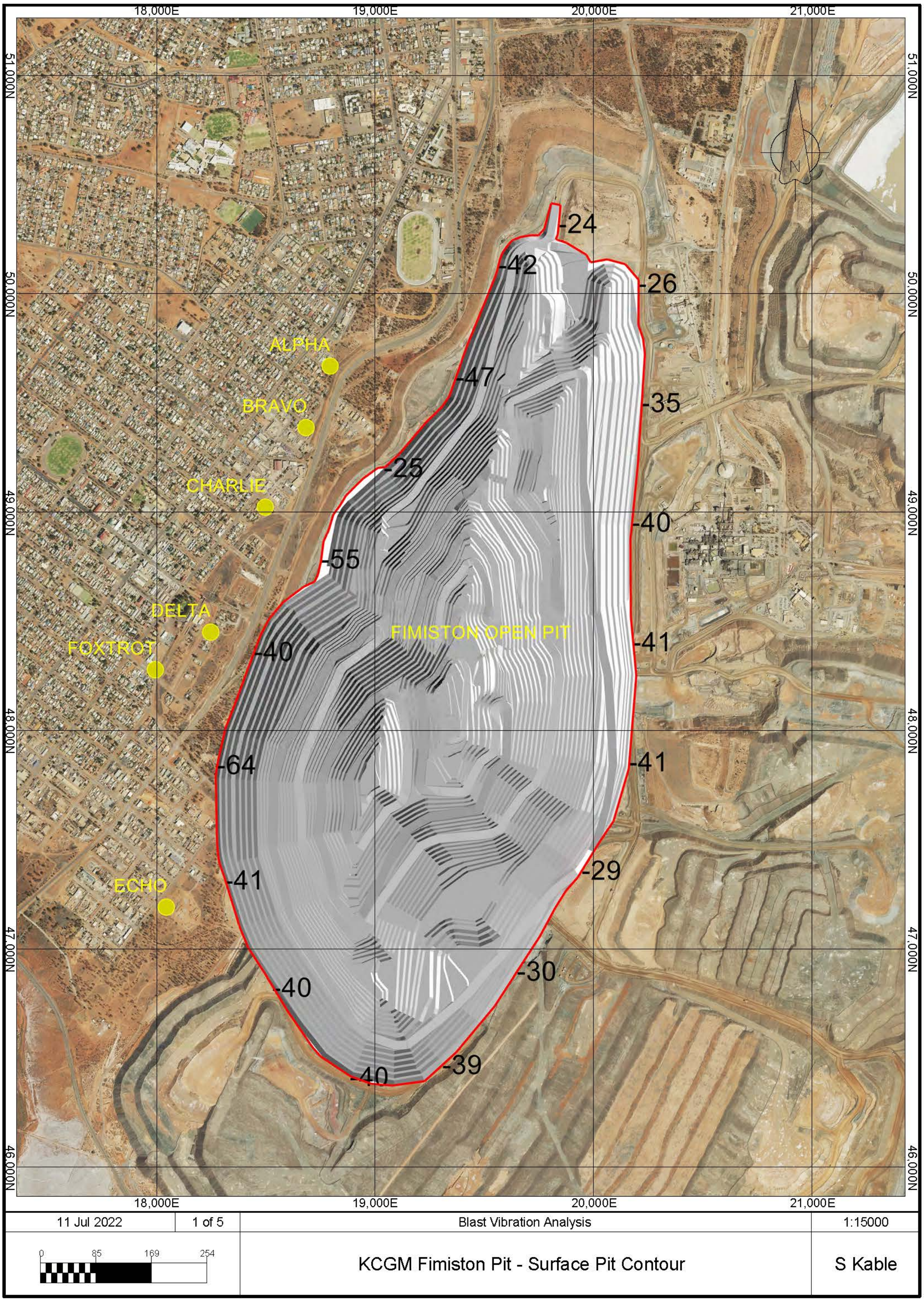
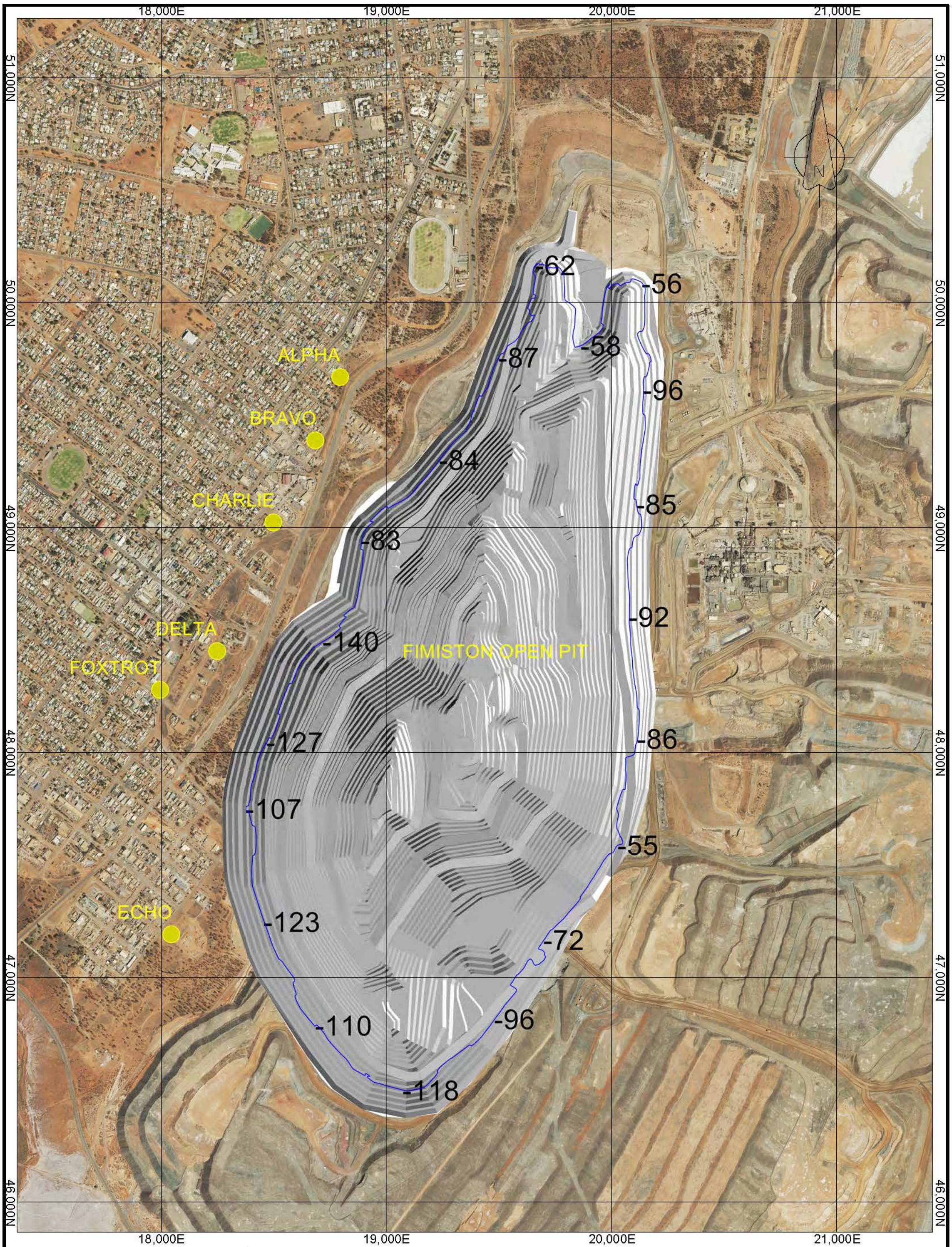



**Figure 6.1: Planned surface pit contour for Fimiston South Project Mining**




| 11 Jul 2022 | 1 of 5 | Blast Vibration Analysis | 1:15000 |
|---|---|---|---|
| 0 85 169 254 | | KCGM Fimiston Pit - Oxide to Transitional Pit Contour | S Kable |

**Figure 6.2: Planned oxide to transition pit contour (ie commencement of blasting) for Fimiston South Project Mining**

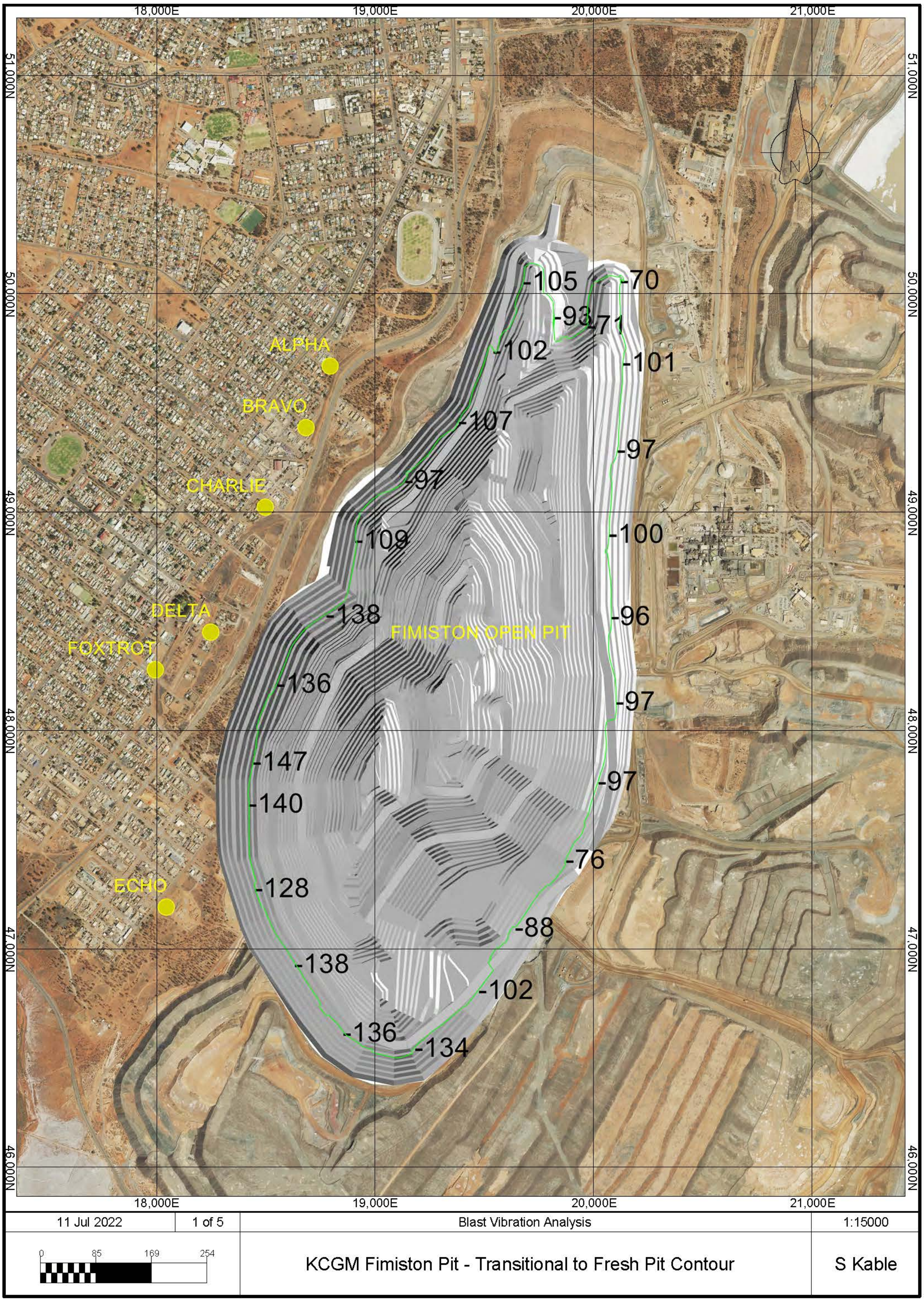



**Figure 6.3: Planned transitional to fresh transition pit contour (ie commencement of fresh rock blasting) for Fimiston South Project Mining**

# 7. Conclusions

1. The predominant land use in the South Boulder light industrial area is light industry. Industry practice and the Australian Standard AS2187 both recognise the lower blast annoyance sensitivity of industrial land users. It could be argued that the ground vibration limits specified in the Ministerial Approval are inappropriately low and should conform to those found in Table J4.5(A) of AS2187.2 for "Occupied non-sensitive sites such as factories and commercial premises", i.e. 25mm/s.

2. A substantial proportion of the new data collected since the last review of KCGM vibration records, was found to have originated from blasting events where several blasts were fired together without adequate time between distinct vibration sources for monitors to reset. The lack of distinct source and measurement link for this data required that it be excluded from these analyses.

3. Analysis of the vibration data from the complete and 900m data sets measured at monitoring locations Alpha to Foxtrot were both relevant and useful in prediction of the ground vibration that may be produced by blasting in the Fimiston South Project area.

4. Calculated minimum distances for compliance for some monitors relevant to the planned mining were found to be quite different when the data set was restricted to blasts 900m or less distant from each monitor.

5. The analyses showed that blasting in the Fimiston South Project area will very probably achieve compliance with ground vibration limits as stipulated in Condition 9-5 of Ministerial Statement No. 782. This assessment is predicated upon the use of similar techniques to those previously applied to blasting at KCGM over the last 20 years and hence inherent to the vibration data gathered over that time.

6. The analyses showed that Oxide Rock blasts and Fresh Rock blasts adjacent to Monitors Bravo and Echo may require selective use of Electronic Detonators to conform to the minimum predicted distances for compliance shown in table 6.1 and 6.2. KCGM currently uses Electronic Detonators selectively for specific purposes such as environmental control.

7. The analyses showed that Oxide Rock blasts and Fresh Rock blasts adjacent to Monitors Bravo may require selective use of deck loading to conform to the minimum predicted distances for compliance shown in table 6.1 and 6.2. KCGM currently uses deck loading selectively when blasting around voids. Application of this technique to vibration control should prove to be technically and operationally unchallenging.

8. Analysis of the air overpressure dataset was not useful in predicting air overpressure for the Fimiston South Project area due to the poor correlation coefficients that result from the influence of ambient environmental conditions that could not be taken into account. Despite this, KCGM has well established empirical techniques derived, refined and proven over two decades of blasting operations, that can mitigate the risks

of air overpressure exceedance. These techniques are summarised in Section 5.1 of this report.

# 8. Recommendations

Pertaining to the data analysed, use of the complete vibration data set and the 900m data set:

1. KCGM should ensure that as far as practical, blasts are fired with sufficient delay between individual blast events to allow the monitors to reset.

2. Blasting during the project should be analysed to assess which data set produces the most effective predictions of ground vibration and minimum distance for compliance

3. KCGM should consider the establishment of a new monitoring location (which could be named Echo 2), located inside the South Boulder light industrial area. This monitor would provide greater diversity to scaled distance values gathered in the progressively refined ground vibration/air overpressure data sets and may provide greater understanding of how vibration and air overpressure are attenuated at distance in the area.

# 9. DISCLAIMER OF LIABILITY

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Before using the information or blast designs contained in this document in a particular situation it is essential that, amongst other things, the following criteria be taken into account:

- whether the particular technique proposed to be used is appropriate for the circumstances;
- whether the persons using it have the necessary competency and experience;
- the environmental conditions in which it is to be used;
- the specific aims intended to be achieved and whether those aims are achievable in the particular circumstances; and
- the sequence of steps which need to be followed in the particular circumstances.

George Boucher
Principal Consultant
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**12th July 2022**