Request for approval of details pursuant to conditions 4, 7, 8, 12, 17 and 27 of planning permission TM/88/1002 at Blaise Farm Quarry, Blaise Quarry Road, Kings Hill, West Malling, Kent ME19 4PN – TM/88/1002/RVARA (KCC/TM/0121/2020)

Appendix 9:

- **Appendix 9:** Report R20.10806/2/BG titled "Assessment of Environmental Impact of Blasting at Blaise Farm Quarry, West Malling, Kent" (Vibrock, 2 September 2020)

Assessment of Environmental Impact of Blasting at Blaise Farm Quarry, West Malling, Kent

GALLAGHER GROUP

R20.10806/2/BG
Date of Report: 02 September 2020

QUALITY MANAGEMENT

Report Title: Assessment of Environmental Impact of Blasting at Blaise Farm Quarry, West Malling, Kent

Client: Gallagher Group

Report Number: R20.10806/2/BG

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APPENDIX

1	Instrumentation Used

1.0 INTRODUCTION

1.1 At the request of Gallagher Group, Vibrock Limited were commissioned to undertake a blast induced vibration study to assess the environmental impact of blasting operations at Blaise Farm Quarry, West Malling, Kent.

1.2 This study benefits from site inspections and monitoring of typical production blasts undertaken on 7 July, 13 July, 24 August and 26 August 2020.

2.0 SITE DESCRIPTION

2.1 Blaise Farm Quarry is located some 2.5 kilometres to the south west of the settlement of West Malling.

2.2 The permitted mineral extraction area within which future mineral extraction operations will take place is located to the west and south of the existing quarry void. The closest residential properties lie within the settlement of Offham to the north of the quarry and in the settlement of Kings Hill to the south east of the quarry.

2.3 The optimum blast design may vary from blast to blast and will necessarily be decided by the quarry operator with reference to the site specific conditions and in order to comply with the site vibration criteria.

3.0 EFFECTS OF BLASTING

3.1 When an explosive detonates within a borehole stress waves are generated causing very localised distortion and cracking. Outside of this immediate vicinity, however, permanent deformation does not occur. Instead, the rapidly decaying stress waves cause the ground to exhibit elastic properties whereby the rock particles are returned to their original position following the passage of the stress waves. Such vibration is always generated even by the most well designed and executed of blasts and will radiate away from the blast site attenuating as distance increases.

3.2 With experience and knowledge of the factors which influence ground vibration, such as blast type and design, site geology and receiving structure, the magnitude and significance of these waves can be accurately predicted at any location.

3.3 Vibration is also generated within the atmosphere where the term air overpressure is used to encompass both its audible and sub-audible frequency components. Again, experience and knowledge of blast type and design enables prediction of levels and an assessment of their significance. In this instance, predictions can be made less certain by the fact that air overpressure levels may be significantly influenced by atmospheric conditions. Hence the most effective method of control is its minimisation at source.

3.4 It is important to realise that for any given blast it is very much in the operator's interest to always reduce vibration, both ground and airborne to the minimum possible in that this substantially increases the efficiency and hence economy of blasting operations.

4.0 BLAST VIBRATION TERMINOLOGY

4.1 Ground Vibration

4.1.1 Vibration can be generated within the ground by a dynamic source of sufficient energy. It will be composed of various wave types of differing characteristics and significance collectively known as seismic waves.

4.1.2 These seismic waves will spread radially from the vibration source decaying rapidly as distance increases.

4.1.3 There are four interrelated parameters that may be used in order to define ground vibration magnitude at any location. These are:-

Displacement - the distance that a particle moves before returning to its original position, measured in millimetres (mm).

Velocity - the rate at which particle displacement changes, measured in millimetres per second (mms^{-1}).

Acceleration - the rate at which the particle velocity changes, measured in millimetres per second squared (mms^{-2}) or in terms of the acceleration due to the earth's gravity (g).

Frequency - the number of oscillations per second that a particle undergoes measured in Hertz (Hz).

4.1.4 Much investigation has been undertaken, both practical and theoretical, into the damage potential of blast induced ground vibration. Among the most eminent of such research authorities are the former United States Bureau of Mines (USBM), Langefors and Kihlström, and Edwards and Northwood. All have concluded that the vibration parameter best suited as a damage index is particle velocity.

4.1.5 Studies by the USBM have clearly shown the importance of adopting a monitoring approach that also includes frequency.

4.1.6 Thus the parameters most commonly used in assessing the significance of an impulsive vibration are those of particle velocity and frequency which are related for sinusoidal motion as follows:-

$$PV = 2 \pi f a$$

where PV = particle velocity
π = pi
f = frequency
a = amplitude

4.1.7 It is the maximum value of particle velocity in a vibration event, termed the peak particle velocity, that is of most significance and this will usually be measured in three independent, mutually perpendicular directions at any one location in order to ensure that the true peak value is captured. These directions are longitudinal (or radial), vertical and transverse.

4.1.8 Such maximum of any one plane measurements is the accepted standard worldwide and as recommended by the British Standards Institution and the International Standards Institute amongst others. It is also the basis for all the recognised investigations into satisfactory vibration levels with respect to damage of structures and human perception.

4.1.9 British Standard 7385 states that there is little probability of fatigue damage occurring in residential building structures due to blasting. The increase of the component stress levels due to imposed vibration is relatively nominal and the number of cycles applied at a repeated high level of vibration is relatively low. Non-structural components (such as plaster) should incur dynamic stresses which are typically well below, i.e. only 5% of, component yield and ultimate strengths.

4.1.10 All research and previous work undertaken has indicated that any vibration induced damage will occur immediately if the damage threshold has been exceeded and that there is no evidence of long term effects.

4.2 Airborne Vibration

4.2.1 Whenever an explosive is detonated transient airborne pressure waves are generated.

4.2.2 As these waves pass a given position, the pressure of the air rises very rapidly to a value above the atmospheric or ambient pressure. It then falls more slowly to a value below atmospheric before returning to the ambient value after a series of oscillations. The maximum pressure above atmospheric is known as the peak air overpressure.

4.2.3 These pressure waves will comprise of energy over a wide frequency range. Energy above 20 Hz is perceptible to the human ear as sound, whilst that below 20 Hz is inaudible, however, it can be sensed in the form of concussion. The sound and concussion together is known as air overpressure which is measured in terms of decibels (dB) or pounds per square inch (p.s.i.) over the required frequency range.

4.2.4 The decibel scale expresses the logarithm of the ratio of a level (greater or less) relative to a given base value. In acoustics, this reference value is taken as 20×10^{-6} Pascals, which is accepted as the threshold of human hearing.

4.2.5 Air overpressure (AOP) is therefore defined as:-

$$\text{AOP, dB} = 20 \text{ Log} \frac{\text{(Measured pressure)}}{\text{(Reference pressure)}}$$

4.2.6 Since both high and low frequencies are of importance no frequency weighting network is applied, unlike in the case of noise measurement when an A - weighted filter is employed.

4.2.7 All frequency components, both audible and inaudible, can cause a structure to vibrate in a way which can be confused with the effects of ground vibrations.

4.2.8 The lower, inaudible, frequencies are much less attenuated by distance, buildings and natural barriers. Consequently, air overpressure effects at these frequencies can be significant over greater distances, and more readily excite a response within structures.

4.2.9 Should there be perceptible effects they are commonly due to the air overpressure inducing vibrations of a higher, audible frequency within a property and it is these secondary rattles of windows or crockery that can give rise to comment.

4.2.10 In a blast, airborne pressure waves are produced from five main sources:-

(i) Rock displacement from the face
(ii) Ground induced airborne vibration
(iii) Release of gases through natural fissures
(iv) Release of gases through stemming
(v) Insufficiently confined explosive charges

4.2.11 Meteorological factors over which an operator has no control can influence the intensity of air overpressure levels at any given location. Thus, wind speed and direction, temperature and humidity at various altitudes can have an effect upon air overpressure.

5.0 VIBRATION CRITERIA

5.1 Introduction

5.1.1 When defining damage to residential type structures the following classifications are used:-

Cosmetic or threshold	-	the formation of hairline cracks or the growth of existing cracks in plaster, drywall surfaces or mortar joints.
Minor	-	the formation of large cracks or loosening and falling of plaster on drywall surfaces, or cracks through bricks/concrete blocks.
Major or structural	-	damage to structural elements of a building.

5.1.2 Published damage criteria will not necessarily differentiate between these damage types but rather give levels to preclude cosmetic damage and therefore automatically prevent any more severe damage.

5.2 United States Bureau of Mines

5.2.1 The comprehensive research programme undertaken by the United States Bureau of Mines (USBM) (R.I. 8507, 1980) determined that vibration values well in excess of 50 mms^{-1} are necessary to produce structural damage to residential type structures. The onset of cosmetic damage can be associated with lower vibration levels, especially at very low vibration frequencies, and a limit of 12.7 mms^{-1} is therefore recommended for such relatively unusual vibration. For the type of vibration associated with open pit blasting in this country, the safe vibration levels are seen to be from 19 - 50 mms^{-1}.

5.2.2 A further USBM publication (Bureau of Mines Technology Transfer Seminar, 1987) states that these safe vibration levels are "….for the worst case of structure conditions….", and that they are "….independent of the number of blasting events and their durations", and that no damage has occurred in any of the published data at vibration levels less than 12.7 mms^{-1}.

5.2.3 Any doubt that such low levels of vibration are perfectly safe should be dispelled by considering the strain induced within a residential type property from daily environmental changes and domestic activities. This is confirmed within the 1987 USBM publication which quotes that daily changes in humidity and temperature can readily induce strain of the order that is equivalent to blast induced vibration of from 30 - 75 mms^{-1}. Typical domestic activities will produce strain levels corresponding to vibration of up to 20 mms^{-1} and greater.

5.2.4 It is for this reason that many domestic properties will exhibit cracks that may be wrongly attributed to blasting activities. There are many additional reasons why properties will develop cracks, for example:-

a) Fatigue and ageing of wall coverings;
b) Drying out of plaster finishes;
c) Shrinkage and swelling of wood;
d) Chemical changes in mortar, bricks, plaster and stucco;
e) Structural overloading;
f) Differential foundation settlement - particularly after times of prolonged dry spells.

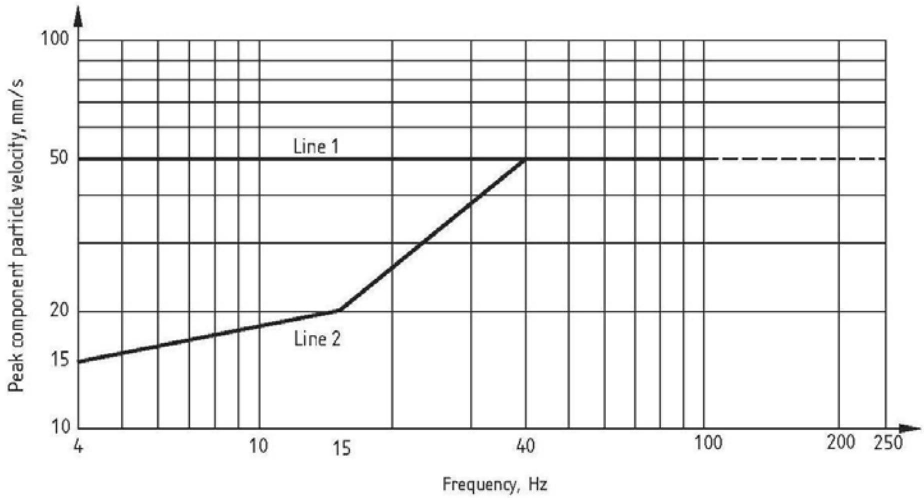
5.3 British Standard 7385-2: 1993 - Evaluation and Measurement for Vibration in Buildings: Guide to Damage Levels from Groundborne Vibration

5.3.1 The British Standards Institution's structural damage committee have investigated impulsive vibration with respect to its damage potential. They contacted some 224 organisations, mainly British, and found no evidence of any damage at levels less than those recommended by the USBM. The investigation culminated in British Standard 7385: Part 2: 1993.

5.3.2 British Standard 7385 gives guide values to prevent cosmetic damage to property. Between 4 Hz and 15 Hz, a guide value of 15 - 20 mms^{-1} is recommended, whilst above 40 Hz the guide value is 50 mms^{-1}. These vibration criteria reconfirm those of the USBM:

Line	Type of Building	Peak component particle velocity in frequency range of predominant pulse	
		4 Hz to 15 Hz	**15 Hz and above**
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mms^{-1} at 4 Hz and above	50 mms^{-1} at 4 Hz and above
2	Unreinforced or light framed structures Residential or light commercial buildings	15 mms^{-1} at 4 Hz increasing to 20 mms^{-1} at 15 Hz	20 mms^{-1} at 15 Hz increasing to 50 mms^{-1} at 40 Hz and above

Note 1 – values referred to are at the base of the building
Note 2 – for line 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) is not to be exceeded



Transient vibration guide values for cosmetic damage (BS 7385-2: 1993, pg 6)

5.3.3 All research and previous work undertaken has indicated that any vibration induced damage will occur immediately if the damage threshold has been exceeded and that there is no evidence of long term effects.

5.3.4 Whilst cosmetic damage levels range from 15 to 50 mms^{-1}, according to BS 7385: Part 2, "Minor damage is possible at vibration magnitudes which are greater than twice those given for cosmetic damage, and major damage to a building structure may occur at values greater than four times the tabulated values". Hence vibration levels necessary for structural damage within property are accepted to be around 200 mms^{-1} and above.

5.4 BS 5228-2: 2009 + A1: 2014, Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration

5.4.1 Damage threshold criteria for transient vibration within British Standard 5228-2: 2009 + A1: 2014 is guided by the tabulated levels contained within BS 7385-2: 1993.

5.5 Planning Practice Guidance to the National Planning Policy Framework (2014)

5.5.1 In March 2014 the Planning Practice Guidance was issued by the Government as a framework for assessing the environmental impacts of mineral extraction in England.

5.5.2 The guidance document states that the environmental impact of blasting operations should be assessed but does not provide an assessment framework or guidance on relevant planning conditions. The British Standards and other documents detailed within this report however provide relevant guidance which is in line with the vibration criteria detailed within the former Mineral Planning Guidance notes MPG 9 and 14, archived in March 2014.

5.5.3 The former MPG 9 and 14 stated that planning conditions should provide for limits on the timing of blasts and on ground vibrations received at sensitive properties, for monitoring to ensure that the limits are not exceeded and for methods to be employed minimising air overpressure.

5.5.4 Acceptable ground vibration criteria within the former MPG 9 and 14 suggested a range of between 6 to 10 mms^{-1} at a 95% confidence level measured at sensitive property, with no individual blast to exceed 12 mms^{-1}.

5.6 The Environmental Effects of Production Blasting from Surface Mineral Workings, DETR (Vibrock Limited)

5.6.1 These same criteria are also recommended within the 1998 Department of the Environment Transport and The Regions research publication, The Environmental Effects of Production Blasting from Surface Mineral Workings.

5.6.2 This same DETR publication also notes that "It would appear that over the years conditions have become progressively more stringent. No doubt this is as a result of MPAs seeking to reduce the number of complaints and by operators seeking to resolve issues more quickly. However, a reduction in complaints will not necessarily follow".

5.6.3 Indeed, one of the principal findings of the study which led to this publication is "Once the threshold of perception had been crossed the magnitude of vibration seemed to bear little relation to the level of resulting complaint".

5.6.4 An explanation of the necessity to use explosives and the likely effects as perceived by a site's neighbours can allay the concern of a significant proportion of those inhabitants of neighbouring property. It is invariably the case that an operator will consider the perception threshold level prior to the design of each and every blast at a particular site.

5.7 Air Overpressure

5.7.1 Comprehensive investigations into the nature and effects of air overpressure with particular reference to its damage potential have been undertaken by the United States Bureau of Mines (R.I. 8485, 1980).

5.7.2 The weakest parts of most structures that are exposed to air overpressure are windows. Poorly mounted, and hence pre-stressed windows might crack at around 150 dB (0.1 p.s.i.) with most cracking at 170 dB (1.0 p.s.i.). Structural damage can be expected at 180 dB (3.0 p.s.i.).

5.7.3 The recommendations by the United States Bureau of Mines are as follows:-

Instrument Response	Maximum Recommended Level (dB)
0.1 Hz high pass	134
2.0 Hz high pass	133
5.0 or 6.0 Hz high pass	129
C- Slow	105 dB (C)

5.7.4 This set of criteria is based on minimal probability of the most superficial type of damage in residential-type structures, the single best descriptor being recommended as the 2 Hz high pass system (R.I. 8485, 1980).

5.7.5 Satisfactory air overpressure levels are contained within BS 6472-2: 2008, which states the previously discussed research by USBM. According to BS 6472-2: 2008, "air overpressure levels measured at properties near quarries in the United Kingdom are generally around 120 dB(lin), which is 30 dB(lin) below, or only 3% of, the limit for cracking pre-stressed poorly mounted windows". The British Standard further suggests that due to the variable effects of the weather conditions at the time of any blast, the aim should always be to minimise air overpressure at source by giving careful consideration to blast design and implementation.

5.7.6 Guidance contained within the previously mentioned 1998 DETR publication and the former MPG 9 and 14 does not recommend an air overpressure limit.

5.7.7 With a sensible ground vibration limitation the economics of safe and efficient blasting will automatically ensure that air overpressures are kept to reasonable levels.

5.8 Perception Levels

5.8.1 The fact that the human body is very sensitive to vibration can result in subjective concern being expressed at energy levels well below the threshold of damage.

5.8.2 A person will generally become aware of blast induced vibration at levels of around 1.5 mms^{-1}, although under some circumstances this can be as low as 0.5 mms^{-1}. Even though such vibration is routinely generated within any property and is also entirely safe, when it is induced by blasting activities it is not unusual for such a level to give rise to subjective concern. Such concern is also frequently the result of the recent discovery of cracked plaster or brickwork that in fact has either been present for some time or has occurred due to natural processes.

5.8.3 It is our experience that virtually all complaints regarding blasting arise because of the concern over the possibility of damage to owner-occupied properties. Such complaints are largely independent of the vibration level. In fact, once an individual's perception threshold is attained, complaints can result from 3% to 4% of the total number of blasts, irrespective of their magnitude.

5.9 British Standard 6472–2: 2008 - Guide to evaluation of human exposure to vibration in buildings: Part 2: Blast-induced vibration

5.9.1 This document discusses how and where to measure blast-induced vibration and gives maximum satisfactory magnitudes of vibration with respect to human response. Satisfactory magnitudes are given as 6 to 10 mms^{-1} at a 90% confidence level as measured outside of a building on a well-founded hard surface as close to the building as possible.

5.9.2 Maximum satisfactory magnitudes of vibration with respect to human response for up to three blast vibration events per day are detailed within Table 1 of BS 6472-2: 2008:

Place	Time	Satisfactory magnitude A) (ppv mms^{-1})
Residential	Day D)	6.0 to 10.0 C)
	Night D)	2.0
	Other times D)	4.5
Offices B)	Any time	14.0
Workshops B)	Any time	14.0

A) The satisfactory magnitudes are the same for the working day and the rest day unless otherwise stated;
B) Critical working areas where delicate tasks impose more stringent criteria than human comfort are outside the scope of this standard;
C) With residential properties people exhibit a wide variation of tolerance to vibration. Specific values are dependent upon social and cultural factors, psychological attitudes and the expected degree of intrusion. In practice the lower satisfactory magnitude should be used with the higher magnitude being justified on a case-by-case basis;
D) For the purpose of blasting, daytime is considered to be 08h00 to 18h00 Monday to Friday and 08h00 to 13h00 Saturday. Routine blasting would not normally be considered on Sundays or Public Holidays. Other times cover the period outside of the working day but exclude night-time, which is defined as 23h00 to 07h00.

5.10 Blaise Farm Quarry Planning Criteria Permission Reference TM/88/1002

5.10.1 Ground vibration as a result of blasting operations within the Phase 1 Operations extraction area shall not exceed:

(a) a peak particle velocity of 6 mms^{-1} in 95% of all blasts when measured over any period of one month as measured at any vibration sensitive locations

(b) a peak particle velocity of 12 mms^{-1} as measured at any vibration sensitive location

(c) a peak particle velocity of 15 mms^{-1} at the remains of the Chapel of St Blaise

6.0 PREDICTION AND CONTROL OF VIBRATION LEVELS

6.1 Ground Vibration

6.1.1 The accepted method of predicting peak particle velocity for any given situation is to use a scaling approach utilising separation distances and instantaneous charge weights. This method allows the derivation of the site specific relationship between ground vibration level and separation distance from a blast.

6.1.2 A scaled distance value for any location may be calculated as follows:-

Scaled Distance, SD = $DW^{-½}$ in $mkg^{-½}$

where D = Separation distance (blast to receiver) in metres
W = Maximum Instantaneous Charge (MIC) in kg i.e. maximum weight of explosive per delay interval in kg

6.1.3 For each measurement location the maximum peak particle velocity from either the longitudinal, vertical or transverse axis is plotted against its respective scaled distance value on logarithmic graph paper.

6.1.4 An empirical relationship derived by the USBM relates ground vibration level to scaled distance as follows:-

$$PV = a\,(SD)^{b}$$

where PV = Maximum Peak Particle Velocity in mms^{-1}
SD = Scaled Distance in $mkg^{-½}$
a,b = Dimensionless Site Factors

6.1.5 The site factors a and b allow for the influence of local geology upon vibration attenuation as well as geometrical spreading. The values of a and b are derived for a specific site from least squares regression analysis of the logarithmic plot of peak particle velocity against scaled distance which results in the mathematical best fit straight line where

a is the peak particle velocity intercept at unity scaled distance
and b is the slope of the regression line

6.1.6 In almost all cases, a certain amount of data scatter will be evident, and as such statistical confidence levels are also calculated and plotted.

6.1.7 The statistical method adopted in assessing the vibration data is that used by Lucole and Dowding. The data is presented in the form of a graph showing the attenuation of ground vibration with scaled distance and results from log - normal modelling of the velocity distribution at any given scaled distance. The best fit or mean (50%) line as well as the upper 95% confidence level are plotted.

6.1.8 The process for calculating the best fit line is the least squares analysis method. The upper 95% confidence level is found by multiplying the mean line value by 1.645 times 10 raised to the power of the standard deviation of the data above the mean line. A log - normal distribution of vibration data will mean that the peak particle velocity at any scaled distance tends to group at lower values.

6.1.9 From the logarithmic plot of peak particle velocity against scaled distance, for any required vibration level it is possible to relate the maximum instantaneous charge and separation distance as follows:-

Maximum Instantaneous Charge (MIC) = $(D/SD)^2$

Where	D	=	Separation distance (blast to receiver) in metres
	SD	=	Scaled Distance in $mkg^{-½}$ corresponding to the vibration level required

6.1.10 The scaled distance approach assumes that blast design remains similar between those shots used to determine the scaling relationship between vibration level and separation distance and those for which prediction is required. For prediction purposes, the scaling relationship will be most accurate when calculations are derived from similar charge weight and distance values.

6.1.11 The main factors in blast design that can affect the scaling relationship are the maximum instantaneous charge weight, blast ratio, free face reflection, delay interval, initiation direction and blast geometry associated with burden, spacing, stemming and subdrill.

6.1.12 Although the instantaneous explosive charge weight has perhaps the greatest effect upon vibration level, it cannot be considered alone, and is connected to most aspects of blast design through the parameter blast ratio.

6.1.13 The blast ratio is a measure of the amount of work expected per unit of explosive, measured for example in tonnes of rock per kilogramme of explosive detonated (tonnes/kg), and results from virtually all aspects of a blast design i.e. hole diameter, depth, burden, spacing, loading density and initiation technique.

6.1.14 The scaled distance approach is also strictly valid only for the specific geology in the direction monitored. This is evident when considering the main mechanisms which contribute to ground motion dissipation:-

(i) Damping of ground vibrations, causing lower ground vibration frequencies with increasing distance.
(ii) Discontinuities causing reflection, refraction and diffraction.
(iii) Internal friction causing frequency dependent attenuation, which is greater for coarser grained rocks.
(iv) Geometrical spreading.

6.1.15 In practice similar rates of vibration attenuation may occur in different directions, however, where necessary these factors should be routinely checked by monitoring, especially on sites where geology is known to alter.

6.1.16 Where it is predicted that the received levels of vibration will exceed the relevant criteria, the operator will have to reduce the maximum instantaneous explosive charge weight. One method of achieving such a reduction is to deck the explosives within the borehole. This technique splits the column of explosives in two, separated by inert material. If blasting is required at closer distances than that where double decking would be a successful strategy, other charge reduction methods would have to be employed. These could be more complex decking strategies or changes to the blast geometry and / or the use of smaller diameter boreholes.

6.2 Airborne Vibration

6.2.1 Airborne vibration waves can be considered as sound waves of a higher intensity and will, therefore, be transmitted through the atmosphere in a similar manner. Thus meteorological conditions such as wind speed, wind direction, temperature, humidity and cloud cover and how these vary with altitude, can affect the level of the air overpressure value experienced at a distance from any blast.

6.2.2 If a blast is fired in a motionless atmosphere in which the temperature remains constant with altitude then the air overpressure intensity will decrease purely as a function of distance. In fact, each time the distance doubles the air overpressure level will decrease by 6dB. However, such conditions are very rare and it is more likely that a combination of the factors mentioned above will increase the expected intensity in some areas and decrease it in others.

6.2.3 Given sufficient meteorological data it is possible to predict these increases or decreases. However, to be of use this data must be both site specific and of relevance to the proposed blasting time. In practice this is not possible because the data is obtained from meteorological stations at some distance from the blast site and necessarily at some time before the blast is to be detonated. The ever changing British weather therefore causes such data to be rather limited in value and its use clearly counter productive if it is not relevant to the blast site at the detonation time. In addition, it would not normally be safe practice to leave charged holes standing for an unknown period of time.

6.2.4 It is because of the variability of British weather that it is standard good practice to control air overpressure at source and hence minimise its magnitude at distance, even under relatively unfavourable conditions.

6.2.5 Such control is achieved in a well designed and executed blast in which all explosive material is adequately confined. Thus particular attention must be given to accurate face profiling and the subsequent drilling and correct placement of explosive within any borehole, having due regard to any localised weaknesses in the strata including overbreak from a previous shot, clay joints and fissured ground.

6.2.6 Stemming material should be of sufficient quantity and quality to adequately confine the explosives, and care should be taken in deciding upon the optimum detonation technique for the specific site circumstances.

6.2.7 Although there will always be a significant variation in observed air overpressure levels at a particular site it is possible to predict a range of likely values given sufficient background information and/or experience. In this respect, past recordings may be analysed according to the cube root scaled distance approach to provide a useful indication of future levels.

7.0 BLAST INDUCED VIBRATION MEASUREMENTS

7.1 Survey Dates

7.1.1 Levels of vibration from production blasts were measured from blasts initiated at 13:15 hours on 7 July, 13 July, 24 August and 26 August 2020. The instrumentation utilised is given in Appendix 1.

7.1.2 The regression line shows that each blast was monitored using instruments which were sited at the following separation distances:-

Date	Separation Distance (Blast to Monitor in metres)
07.07.20	85
07.07.20	152
07.07.20	451
07.07.20	455
07.07.20	512
07.07.20	573
07.07.20	812

Date	Separation Distance (Blast to Monitor in metres)
13.07.20	20
13.07.20	30
13.07.20	40
13.07.20	102
13.07.20	120
13.07.20	154
13.07.20	198
13.07.20	233

Date	Separation Distance (Blast to Monitor in metres)
24.08.20	25
24.08.20	33
24.08.20	42
24.08.20	54
24.08.20	122
24.08.20	168
24.08.20	175
24.08.20	181
24.08.20	187
24.08.20	191
24.08.20	298

Date	Separation Distance (Blast to Monitor in metres)
26.08.20	113
26.08.20	126
26.08.20	133
26.08.20	140
26.08.20	150
26.08.20	187
26.08.20	199
26.08.20	231
26.08.20	256

7.2 Survey Method

7.2.1 The following instrumentation was used for all measurements:-

Manufacturer	Instrument	Type
Vibrock	Digital Seismograph	V901
Vibrock	Digital Seismograph	BRIC

7.2.2 The following set-up parameters were used on the seismographs during vibration measurements:-

Trigger Level:	0.3, 0.5 - 2.5 mms^{-1}
Record Length:	2.5 - 5.0 seconds
Measurement Type:	Impulse

7.2.3 For a full description of this instrumentation see Appendix 1.

7.2.4 The instrumentation was located at varying distances from the blast. The data obtained was used to generate a regression curve plot for blasting at Blaise Farm Quarry. The use of the USBM formula to predict vibration levels calls for the maximum peak particle velocity (PPV) to be plotted against scaled distance (SD) in a logarithmic manner. The latter is defined as:-

$$\text{Scaled Distance } (mkg^{-1/2}) = \frac{\text{blast/receiver separation distance (m)}}{(MIC)^{0.5}}$$

where MIC is the maximum instantaneous charge weight in kg.

8.0 RESULTS

8.1 Details of the blasts monitored are shown in Table 1.

8.2 The results obtained are presented in Tables 2.1 to 2.4.

8.3 Tables 3.1 and 3.2 give the allowable instantaneous explosive charge weights in order to comply with the site vibration criteria.

8.4 Table 4.1 and 4.2 detail the predicted vibration levels from blasting operations within the site boundary.

8.5 A regression line was plotted for the maximum peak particle velocity in the three planes of measurement. The plot includes the 95% confidence limit and is shown in Figure 1.

9.0 DISCUSSION

9.1 The blast design employed during the monitoring is typical of the blast designs to be utilised for future production blasting at Blaise Farm Quarry.

9.2 The data has been processed by the least squares analysis method in order to obtain the regression line, which is the mathematical best fit straight line for the data. An indication of the degree of fit of this straight line is obtained by the correlation coefficient, where -1.0 indicates a perfect fit. In this instance the correlation coefficient is -0.94. The upper 95% confidence level is shown plotted for this data.

9.3 Table 3.1 gives the allowable instantaneous explosive charge weights in order to comply with the site vibration criterion for residential property of 6 mms^{-1} at a 95% confidence level with no blast to exceed 12 mms^{-1} at the given separation distances. A maximum instantaneous charge weight of 10 kg utilised during the monitored blasts could be used 182 metres from the property whilst complying with the site vibration criterion.

9.4 Table 3.2 gives the allowable instantaneous explosive charge weights in order to comply with the site vibration criterion of 15 mms^{-1} at the remains of the Chapel of St Blaise at the given separation distances. A maximum instantaneous charge weight of 10 kg could be used 151 metres from the remains whilst complying with the site vibration criterion.

9.5 The closest residential properties to the boundary of the permitted mineral extraction area are approximately 296 metres to the north of the site and 214 metres to the south east at closest approach.

9.6 Table 4.1 details the predicted vibration levels when blasting within the current mineral extraction area at the quarry utilising instantaneous explosive charge weights of 10 kg.

9.7 Table 4.2 details the worst case predicted vibration levels from blasting operations at the closest approach within the permitted mineral extraction area. The predicted maximum vibration levels given will only occur when using an instantaneous charge weight of 10 kg at the nearest possible distance of approach to the respective locations.

9.8 The locations chosen for the purposes of this report are those which are the closest inhabited residential properties surrounding the permitted mineral extraction area.

Blaise Farm House

9.9 The receptor of Blaise Farm House is located to the north west of current mineral extraction operations. The predicted vibration levels at this receptor from the location of current mineral extraction operations utilising an MIC of 10kg is a most likely 0.97 mms^{-1}, 1.95 mms^{-1} at a 95% confidence level and 3.61 at a 99.9% confidence level.

9.10 Predictions utilising an MIC of 10kg at the closest approach of permitted mineral extraction operations to the considered location would result in a most likely vibration level of 1.23 mms^{-1} at a 50% confidence level, 2.48 mms^{-1} at a 95% confidence level and 4.60 mms^{-1} at a 99.9% confidence level. Vibration of such magnitude complies with the site vibration criterion and is within the relevant criteria with respect to the prevention of cosmetic damage at residential structures and the human perception of vibration.

Beaufighter Road

9.11 The closest residential receptors to the south east of the quarry are located in Kings Hill on Beaufighter Road. The predicted vibration levels from the location of current mineral extraction operations utilising an MIC of 10kg is a most likely 0.72 mms^{-1}, 1.45 mms^{-1} at a 95% confidence level and 2.69 at a 99.9% confidence level.

9.12 Predictions utilising an MIC of 10kg at the closest approach of permitted mineral extraction operations would result in a most likely vibration level of 2.29 mms^{-1}, with 4.62 mms^{-1} at a 95% confidence level and 8.55 mms^{-1} at a 99.9% confidence level. Vibration of such magnitude complies with the site vibration criterion and is within the relevant criteria with respect to the prevention of cosmetic damage at residential structures and the human perception of vibration.

Fre Mell Farm

9.13 The residential receptor of Fre Mell Farm is located to the north west of current mineral extraction operations and to the north of the north western corner of the permitted mineral extraction area. The predicted vibration levels at this receptor from blasting within the current mineral extraction area utilising an MIC of 10kg is a most likely 0.35 mms^{-1}, 0.70 mms^{-1} at a 95% confidence level and 1.30 at a 99.9% confidence level.

9.14 Predictions utilising an MIC of 10kg at the closest approach of permitted mineral extraction operations to the considered location would result in a most likely vibration level of 1.36 mms^{-1}, 2.74 mms^{-1} at a 95% confidence level and 5.08 mms^{-1} at a 99.9% confidence level. Vibration of such magnitude complies with the site vibration criterion and is within the relevant criteria with respect to the prevention of cosmetic damage at residential structures and the human perception of vibration.

10.0 CONCLUSIONS

10.1 A site specific regression line has been derived and interpreted to assess the implications of utilising a MIC of 10kg within the current working area and at closest approach to residential receptors within the permitted mineral extraction area.

10.2 Current and future operations will comply with site planning criteria.

10.3 All vibration will be of a low order of magnitude and would be entirely safe with respect to the possibility of the most cosmetic of plaster cracks as detailed within British Standard 7385-2: 1993.

10.4 Vibration will also be within those levels recommended for blast induced vibration and human perception as being satisfactory within the previously discussed British Standard Guide BS 6472-2: 2008.

10.5 With such low ground vibration levels accompanying air overpressure would also be of a very low and hence safe level, although possibly perceptible on occasions at the closest of properties.

10.6 The programme of blast monitoring should be continued. The results of such monitoring will indicate whether or not there is compliance with the vibration criteria and they can also be used to continually update the regression analysis and thus provide valuable input to the design of future blasts.

11.0 REFERENCES

1. BS ISO 4866: 2010. Mechanical vibration and shock – Vibration of fixed structures – Guidelines for the measurement of vibrations and evaluation of their effects on structures. British Standards Institution.

2. BS 6472-2: 2008. Guide to evaluation of human exposure to vibration in buildings, Part 2: Blast-induced vibration. British Standards Institution.

3. BS 7385: 1993 Evaluation and measurement for vibration in buildings: Part 2. Guide to damage levels from groundborne vibration. British Standards Institution.

4. BS 5228-2: 2009 + A1:2014, Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration.

5. Planning Practice Guidance to the National Planning Policy Framework, 2014, Department for Communities and Local Government.

6. Minerals Planning Guidance Note No. 9, 1992 Planning and Compensation Act 1991: Interim Development Order Permissions (IDOS) - Conditions. Department of the Environment, Welsh Office.

7. Minerals Planning Guidance Note No. 14, 1995 Environment Act 1995: Review of Mineral Planning Permissions. Department of the Environment, Welsh Office.

8. The Environmental Effects of Production Blasting from Surface Mineral Workings, Vibrock Report on behalf of the DETR, 1998.

TABLE 1

BLAST DETAILS AT BLAISE FARM QUARRY

Date:	07 July 2020
Time:	13:15 hours
No of Holes:	50
Diameter:	125 mm
Depth:	4 metres
Burden:	2.5 metres
Spacing:	2.5 metres
Explosive Charge Weight per Hole:	10 kg
Maximum Instantaneous Explosive Charge Weight:	10 kg
Total Explosive Charge Weight:	500 kg
Explosive Type:	ANFO
Initiation:	Non electric system

Date:	13 July 2020
Time:	13:15 hours
No of Holes:	34
Diameter:	125 mm
Depth:	12 metres
Burden:	2.7 metres
Spacing:	2.7 metres
Explosive Charge Weight per Hole:	20 kg
Maximum Instantaneous Explosive Charge Weight:	10 kg
Total Explosive Charge Weight:	680 kg
Explosive Type:	ANFO
Initiation:	Non electric system

TABLE 1 - CONTINUED

BLAST DETAILS AT BLAISE FARM QUARRY

Date:	24 August 2020
Time:	13:15 hours
No of Holes:	29
Diameter:	125 mm
Depth:	15 metres
Burden:	2.7 metres
Spacing:	2.7 metres
Explosive Charge Weight per Hole:	30 kg
Maximum Instantaneous Explosive Charge Weight:	10 kg
Total Explosive Charge Weight:	870 kg
Explosive Type:	ANFO
Initiation:	Non electric system

Date:	26 August 2020
Time:	13:15 hours
No of Holes:	25
Diameter:	125 mm
Depth:	15 metres
Burden:	2.7 metres
Spacing:	2.7 metres
Explosive Charge Weight per Hole:	30 kg
Maximum Instantaneous Explosive Charge Weight:	10 kg
Total Explosive Charge Weight:	750 kg
Explosive Type:	ANFO
Initiation:	Non electric system

TABLE 2.1

RESULTS OBTAINED AT BLAISE FARM QUARRY: 7 July 2020

Separation Distance (Blast to Monitor) (metres)	Measurement Axis	Peak Particle Velocity (mms^{-1})	Air Overpressure (dB)
85	Long Vert Trans	4.70 3.60 4.72	114
152	Long Vert Trans	2.27 1.67 2.10	121
451	Long Vert Trans	<0.5 <0.5 <0.5	-
455	Long Vert Trans	<0.5 <0.5 <0.5	-
512	Long Vert Trans	<0.5 <0.5 <0.5	-
573	Long Vert Trans	<0.5 <0.5 <0.5	-
812	Long Vert Trans	<0.5 <0.5 <0.5	-

TABLE 2.2

RESULTS OBTAINED AT BLAISE FARM QUARRY: 13 July 2020

Separation Distance (Blast to Monitor) (metres)	Measurement Axis	Peak Particle Velocity (mms^{-1})	Air Overpressure (dB)
20	Long Vert Trans	64.8 78.4 127.6	107
30	Long Vert Trans	60.0 97.6 96.0	154
40	Long Vert Trans	19.6 42.0 30.0	141
102	Long Vert Trans	4.35 5.97 4.52	127
120	Long Vert Trans	3.57 6.05 3.52	126
154	Long Vert Trans	1.82 2.97 3.87	118
198	Long Vert Trans	3.85 1.80 2.95	116
233	Long Vert Trans	0.925 1.00 1.10	120

TABLE 2.3

RESULTS OBTAINED AT BLAISE FARM QUARRY: 24 August 2020

Separation Distance (Blast to Monitor) (metres)	Measurement Axis	Peak Particle Velocity (mms^{-1})	Air Overpressure (dB)
25	Long Vert Trans	66.4 38.4 48.8	131
33	Long Vert Trans	26.8 35.6 35.2	132
42	Long Vert Trans	14.8 10.8 14.0	135
54	Long Vert Trans	19.2 11.2 17.6	120
122	Long Vert Trans	2.57 3.35 3.50	105
168	Long Vert Trans	2.80 1.85 2.52	109
175	Long Vert Trans	2.15 1.65 2.27	153
181	Long Vert Trans	2.20 1.47 2.25	111
187	Long Vert Trans	1.95 1.27 2.35	107
191	Long Vert Trans	1.77 1.12 2.27	108
298	Long Vert Trans	1.87 0.975 0.950	107

TABLE 2.4

RESULTS OBTAINED AT BLAISE FARM QUARRY: 26 August 2020

Separation Distance (Blast to Monitor) (metres)	Measurement Axis	Peak Particle Velocity (mms^{-1})	Air Overpressure (dB)
113	Long Vert Trans	11.9 5.52 3.75	132
126	Long Vert Trans	14.4 8.80 14.4	132
133	Long Vert Trans	10.8 8.10 3.15	107
140	Long Vert Trans	5.62 3.40 4.50	126
150	Long Vert Trans	5.80 5.87 4.70	116
187	Long Vert Trans	2.90 2.15 2.22	109
199	Long Vert Trans	1.82 1.95 2.70	109
231	Long Vert Trans	1.72 1.22 1.77	109
256	Long Vert Trans	2.27 1.02 1.67	109

TABLE 3.1

ALLOWABLE MAXIMUM INSTANTANEOUS EXPLOSIVE CHARGE WEIGHTS – INHABITED PROPERTY AT BLAISE FARM QUARRY

The corresponding scaled distance value for a vibration criterion of 6 mms^{-1} at a 95% confidence level with no blast to exceed 12 mms^{-1} is 57.49 $mkg^{-½}$.

This gives rise to the following allowable maximum instantaneous charge weights at the given blast/receiver separation distances:-

Blast/Receiver Separation Distance (metres)	Allowable Maximum Instantaneous Charge Weight, kg to comply with 6 mms^{-1} at 95% confidence level with no blast to exceed 12 mms^{-1}
200	12
250	18
300	27
350	37
400	48
450	61
500	75
550	91
600	108

TABLE 3.2

ALLOWABLE MAXIMUM INSTANTANEOUS EXPLOSIVE CHARGE WEIGHTS – REMAINS OF THE CHAPEL OF ST BLAISE AT BLAISE FARM QUARRY

The corresponding scaled distance value for a vibration criterion of 15 mms^{-1} at a 99.9% confidence level is 47.68 $mkg^{-½}$.

This gives rise to the following allowable maximum instantaneous charge weights at the given blast/receiver separation distances:-

Blast/Receiver Separation Distance (metres)	Allowable Maximum Instantaneous Charge Weight, kg to comply with 15 mms^{-1} at 99.9% confidence level
200	17
250	27
300	39
350	53
400	70

TABLE 4.1

PREDICTED VIBRATION LEVELS AT RESIDENTIAL RECEPTORS PERMITTED MINERAL EXTRACTION AREA AT BLAISE FARM QUARRY

Considering typical maximum instantaneous charge weights utilised within the current working area, the predicted vibration levels are as follows:-

Current Mineral Extraction Working Area

Location	Vibration Level Peak Particle Velocity (mms^{-1}) Maximum Instantaneous Explosive Charge Weight 10 kg		
	50% Confidence Level (mean)	95% Confidence Level	99.9% Confidence Level
1	0.97	1.95	3.61
2	0.72	1.45	2.69
3	0.35	0.70	1.30

<u>Locations</u> (see Figure 2)

1. Blaise Farm House
2. Beaufighter Road
3. Fre Mell Farm

* Maximum instantaneous explosive charge weights reduced in order to comply to vibration criteria.

TABLE 4.2

PREDICTED VIBRATION LEVELS AT RESIDENTIAL RECEPTORS
PERMITTED MINERAL EXTRACTION AREA AT BLAISE FARM QUARRY

Considering a maximum instantaneous charge weight of 10 kg utilised at the nearest distance of approach to the location considered, the predicted vibration levels are as follows:-

Closest Approach Permitted Mineral Extraction Area

	50% Confidence Level (mean)	95% Confidence Level	99.9% Confidence Level
1	1.23	2.48	4.60
2	2.29	4.62	8.55
3	1.36	2.74	5.08

<u>Locations</u> (see Figure 2)

1. Blaise Farm House
2. Beaufighter Road
3. Fre Mell Farm

* Maximum instantaneous explosive charge weights reduced in order to comply to vibration criteria.

FIGURE 1

REGRESSION ANALYSIS

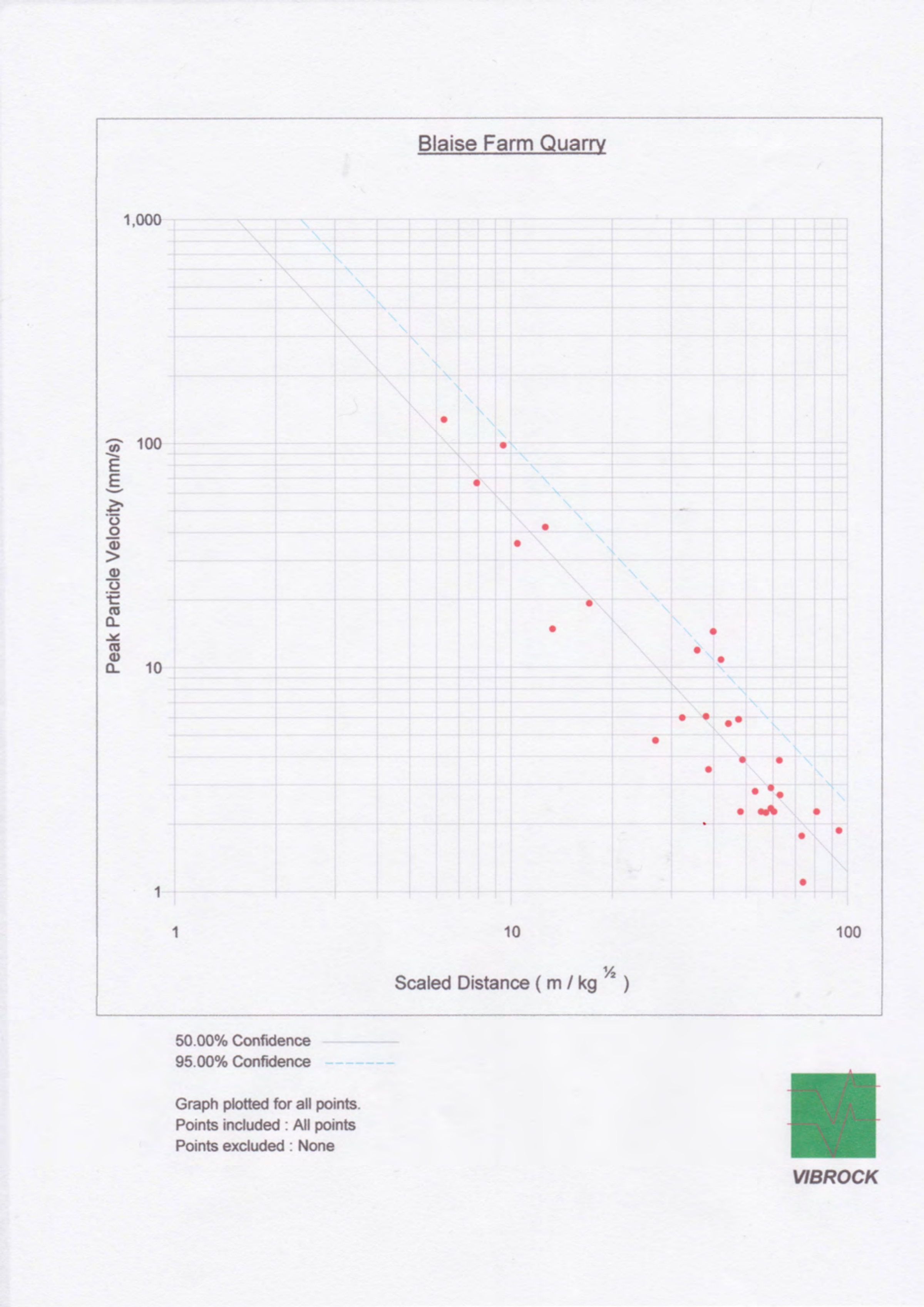

Blaise Farm Quarry
Peak Particle Velocity (mm/s)
1,000
100
10
1
1
10
100
Scaled Distance (m / kg ½)
50.00% Confidence
95.00% Confidence
Graph plotted for all points.
Points included : All points
Points excluded : None
VIBROCK

FIGURE 2

PREDICTION LOCATIONS

1. Blaise Farm House
2. Beaufighter Road
3. Fre Mell Farm

——— Permitted Mineral Extraction Area

APPENDIX 1

The instrumentation used was:-

V901 Digital Seismograph

The V901 Digital Seismograph is a self triggering computerised portable seismograph for use in the monitoring and recording of ground vibration and air overpressure associated with blasting and other operations in which vibration can be of concern, for example piling and demolition.

It can be used for on-the-spot measurements or for unattended operation by means of its internal batteries at up to two locations at any one time.

The V901 records the peak values of seismic vibration in terms of particle velocity, acceleration and displacement in the longitudinal, vertical and transverse axes together with the resultant velocity value, frequency and air overpressure. In addition, each recording includes the date and time at which the vibration event occurred.

A keypad is attached to allow the operator to preset recording parameters in the computer memory for subsequent printout with the seismic data.

The LCD screen can be used to give instant results which, during attended monitoring, allows the cessation of operations prior to vibration criterion exceedance.

The V901 also has facilities that enable triggering and recording in terms of acceleration and displacement values with subsequent storage for around 300 events and provision for downloading to a PC.

BRIC Digital Seismograph

The BRIC Digital Seismograph is a self-triggering computerised portable seismograph for use in the monitoring and recording of ground vibration and air overpressure associated with blasting or any other operations in which vibration is of concern for example piling or demolition. The BRIC is a sealed weatherproof unit designed for operation in hostile conditions. It can be used for on-the-spot measurements or for unattended operation by means of its internal batteries and internal 3 component transducers.

The BRIC records the peak values of seismic vibration in terms of particle velocity in the longitudinal, vertical and transverse axes together with their resultant value and air overpressure. In addition, each recording includes date and time. The BRIC stores up to 300 impulsive events of 2.5 seconds duration in its solid state memory.

Downloading the information from the BRIC to a PC enables comprehensive waveform analysis to be undertaken using menu controlled software.

A keypad is attached to allow the operator to preset values in the computer memory for subsequent printout with the recorded seismic data. The LCD screen gives instant results which, during attended monitoring, allows the cessation of operations prior to vibration criterion exceedance. The operator can preset measurement parameters on site via the keypad on the BRIC, which also allows instant readout on the LCD of previously recorded events.