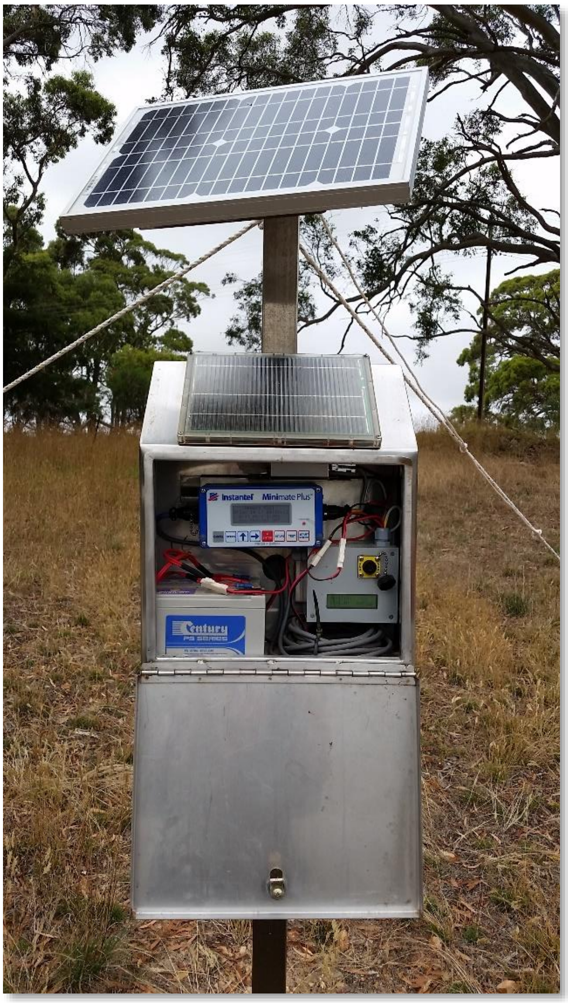
CHAPTER 17
AIR-OVERPRESSURE AND VIBRATION



BIRD IN HAND GOLD PROJECT
MINING LEASE PROPOSAL

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All maps presented in this chapter are in GDA94 / MGA zone 54 (EPSG: 28354) unless otherwise stated.

17 AIR-OVERPRESSURE AND VIBRATION

Ground vibration and air-overpressure occur as a result of using explosives to develop underground tunnels (drives) or stopes in mining. Vibration and air-overpressure is an issue of concern for local residents, and the objective of the blasting impact assessments has been to minimise the impact that blasting could have on the most immediate neighbours.

Air overpressure differs from noise, or sound, in that air-overpressure is a pressure wave transmitted through the air which is felt, rather than heard, while ground vibration is the movement of mechanical energy within the rock mass or soil. Studies and experience show that well-designed and controlled blasts are unlikely to create air-overpressure or ground vibrations of a magnitude that cause damage to buildings or structures. This chapter describes how the introduction of blasting operations could impact sensitive receptor locations, and how it will be managed. It provides a comparison of the predicted air-overpressure and vibration levels against blasting and vibration criteria proposed.

Saros International Pty Ltd (Saros) was engaged by Terramin to investigate the effects of surface and underground blasting operations that may be required during both the construction / development and production phases of the mine. The focus of this study was on environmental impacts induced by the blasting including ground vibration and air overpressure effects, along with mitigation and safety measures.

Baseline air overpressure and ground vibration data has been recorded since May 2016 to gain an understanding of conditions prior to mining operations commencing.

The Assessment of Proposed Blasting Impacts for the Project undertaken by Saros is provided in Appendix P1.

17.1 APPLICABLE LEGISLATION AND STANDARDS

The following standards and guidelines provide criteria to be met regarding blasting and vibration:

- Australian Standard AS 2187.2-2006: *Explosives – Storage and use Part 2: Use of explosives.*
- Assessing Vibration: a technical guideline (DEC 2006).

17.1.1 PROPOSED BLASTING CRITERIA

In underground mining, ground vibration and air-overpressure occur as a result of using explosives to develop underground drives and stopes. Ground vibration from blasting is due to the movement of mechanical energy within the rock mass or soil. Air-overpressure is the pressure wave produced by the blast and transmitted through the air. Studies and experience show that well-designed and controlled blasts are unlikely to create ground vibrations of a magnitude that cause damage to buildings or structures.

The requirements detailed in Australian Standard AS2187.2 cover the use of explosives, and address blasting activities and environmental effects. The provisions pertaining to ground vibration and air-overpressure have commonly formed the basis for compliance limits imposed on blasting activities within Australia. The recommended vibration and air-overpressure limits to minimise human discomfort at a sensitive site for long term blasting operations, is summarised in Table 17-1. Although there are higher limits which apply for receptors which are commercial premises (25mm/s), Terramin have opted for a better community outcome for all receptors which align with sensitive sites.

TABLE 17-1 | SUMMARY OF GROUND VIBRATION AND AIR-OVERPRESSURE LIMITS TO MINIMISE HUMAN DISCOMFORT FROM LONG TERM BLASTING ACTIVITIES AT A SENSITIVE SITE

Category	Criteria	Type	Details
Sensitive site*	Operations lasting longer than 12 months or more than 20 blasts.	Ground vibration	Peak component particle velocity of 5 mm/s at sensitive receiver locations for 95% of blasts per year. Maximum of 10 mm/s unless agreement is reached with the occupier that a higher limit may apply.
Sensitive site*	Operations lasting longer than 12 months or more than 20 blasts.	Air-overpressure	Peak sound pressure level of 115 dBL at sensitive receiver locations for 95% of blasts per year. Maximum of 120 dBL unless agreement is reached with the occupier that a higher limit may apply.

*A sensitive site includes houses and low residential buildings, hospitals, theatres, schools etc., occupied by people

The effects of ground vibration are separated into two categories:

- Human response - Vibration that inconveniences or possibly disturbs the occupants or users of a building.
- Structural damage - Vibration that impacts on the structural integrity of a building, such as causes cracks in plaster walls and masonry.

The vibration criteria for human response are more stringent than the vibration criteria for structural damage for buildings. Cosmetic or structural damage to buildings would only occur due to extreme vibration levels relative to what humans would find tolerable. For this reason the vibration criteria for human comfort has been adopted for this assessment.

The SA Environment Protection Authority (EPA) does not have a policy or guideline for human comfort or structural damage effects due to vibration, however, often defers to the appropriate Australian Standards.

With respect to potential for damage of commercial structures, the recommended limits relate to the *British Standard 7385-2 1993* guidelines which are based on the type of structure and the frequency of the peak particle velocity and has been adopted by AS2187.2. The chart presented in Figure 17-1 details guide values for the prevention of minor or cosmetic damage to structures.

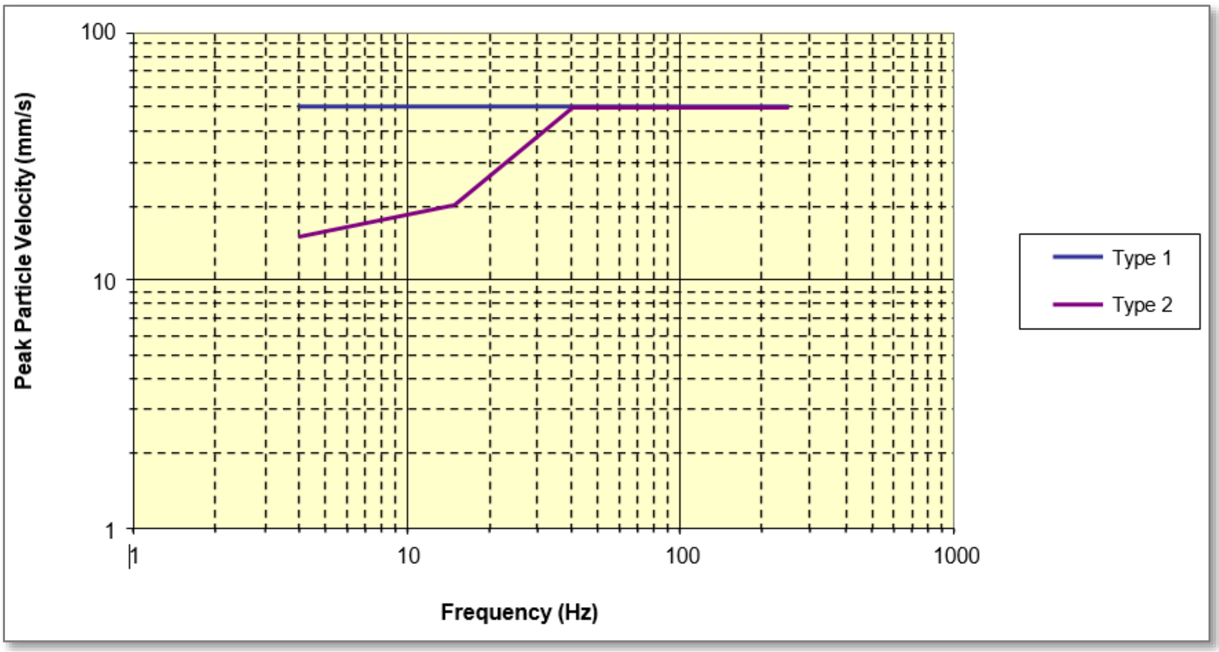

FIGURE 17-1 | TRANSIENT VIBRATION GUIDE VALUES FOR COSMETIC DAMAGE (BRITISH STANDARD 7385-2 1993 GUIDELINES)

The Type 1 structures relate to reinforced or commercial structures, whilst Type 2 is representative of unreinforced or residential buildings. For frequencies between 4Hz and 40Hz, guide values are reduced for Type 2 structures taking into account the higher strains induced by lower frequency vibration of the same magnitude.

Transport infrastructure including roads and railway lines are capable of sustaining much higher vibration levels. Vibration limits in the order of 100mm/s are commonly adopted to ensure a high factor of safety is maintained.

17.2 HUMAN CONTEXT

There has been extensive international research into the effects of blast vibration and overpressure on both personal amenity and the potential for structural damage. Similarly, the community, fauna and structures are subject to both vibration and air-overpressure resulting from non-blast related sources on a regular basis.

The following sections have been provided for readers to gain an understanding as to existing sources of vibration and air overpressure, as well as how they are measured in order to have a better understanding of the existing environment around the proposed project, as well as the effects blasting will have through the construction, development and operation of the project, and how these effects will be managed.

17.2.1 SOURCES OF VIBRATION

The limits as recommended in AS2187.2 are based on minimising human discomfort and are well below the levels likely to produce structural damage. To highlight the conservative nature of these vibration limits, Figure 17-2 details a range of common vibration sources around the typical residential household.

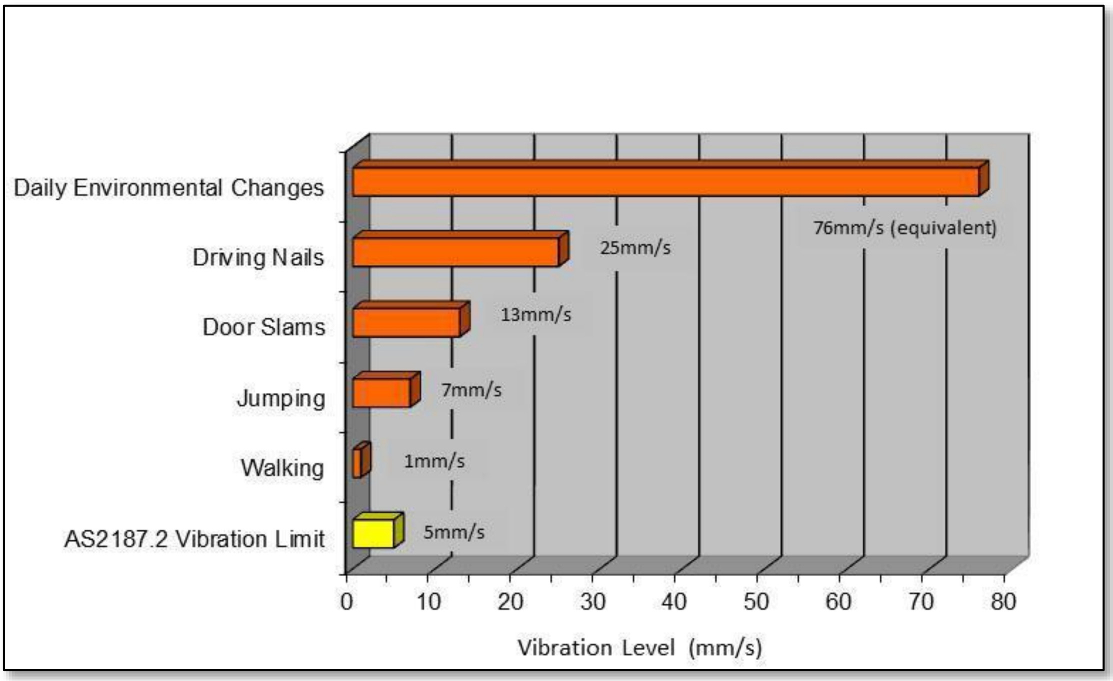

FIGURE 17-2 | EVERYDAY SOURCES OF VIBRATION INDUCED IN RESIDENTIAL DWELLINGS

Activities such as jumping, slamming doors or hammering in a nail can produce vibration levels in excess of compliance criteria. Similarly, daily temperature fluctuations causing expansion and contraction within residential structures can produce strains equivalent to vibration levels which are more than 7 times the 10mm/s interim limits.

17.2.2 SOURCES OF AIR-OVERPRESSURE

Air-overpressure is simply the pressure difference, relative to “normal” or “ambient” air pressure. This means that it is not limited to blasting but is influenced by anything that causes fluctuations in pressure which can include:

- Wind;
- Lightning;
- Trucks;
- Trains;
- Aircraft;
- Fireworks.

In order to demonstrate the influence of environmental factors on overpressure levels, Saros undertook a study correlating wind speed measurements with peak overpressure levels recorded adjacent to a large scale open pit mine. Over the monitoring duration, in excess of 370,000 overpressure measurements were obtained as illustrated in Figure 17-3. More than 4,500 non-blast related events exceeding the 115dBL level, with a maximum level in excess of 135dBL.

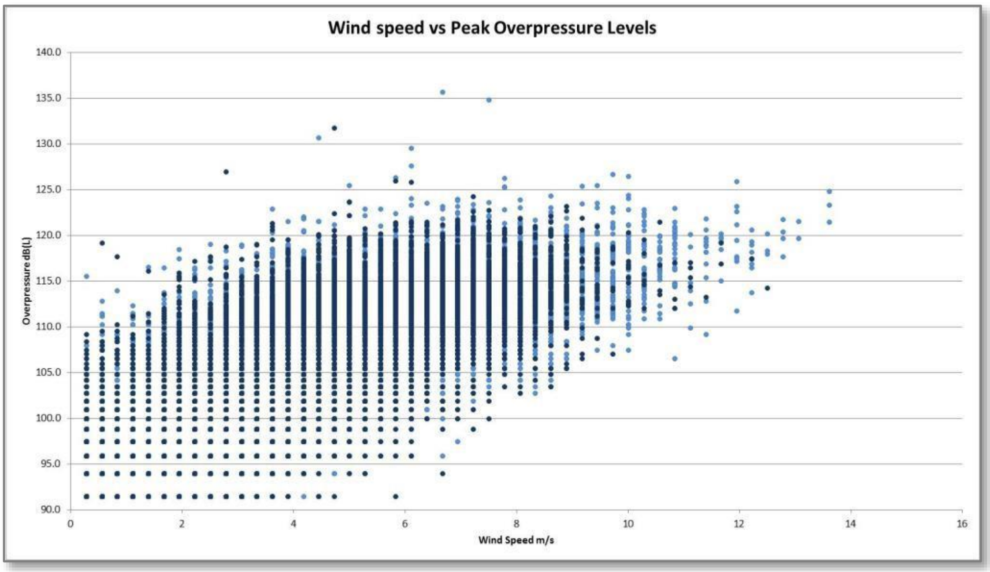

FIGURE 17-3 | WIND SPEED VS OVERPRESSURE MEASUREMENTS OVER A 1 MONTH PERIOD

Like ground vibration, overpressure decays rapidly with distance from the blast area, however this decay depends greatly on the weather conditions at the time of blasting. As with audible noise, wind tends to concentrate overpressure meaning the downwind receivers will experience higher levels than receivers at the same distance up wind. Overpressure travels through the air at a slower speed than ground vibration travels through the ground and will therefore arrive at a location sometime after the ground vibration (approximately 3 seconds for every kilometre from the source). Overpressure interacts with structures as it passes and may cause rattling of windows, doors etc. The level of overpressure required to cause damage to building has been well researched and extremely high levels are required to cause minor damage (i.e. broken windows >150dBL).

17.3 ASSESSMENT METHOD

17.3.1 GROUND VIBRATION

Ground vibration is measured in terms of velocity (mm/s), that is, distance travelled over a certain time period. The most common method for the prediction of vibration levels from blasting is the scaled distance equation which relates the level of vibration to the maximum instantaneous charge weight and distance between the blast and the sensitive receiver. The ground conditions will control the rate the vibration attenuates which can be determined for a given site.

Figure 17-4 presents a plot of measured vibration levels versus scaled distance (relationship between the distance from the source and the instantaneous charge weight) using data points from blasting activities conducted in Adelaidean sediments.

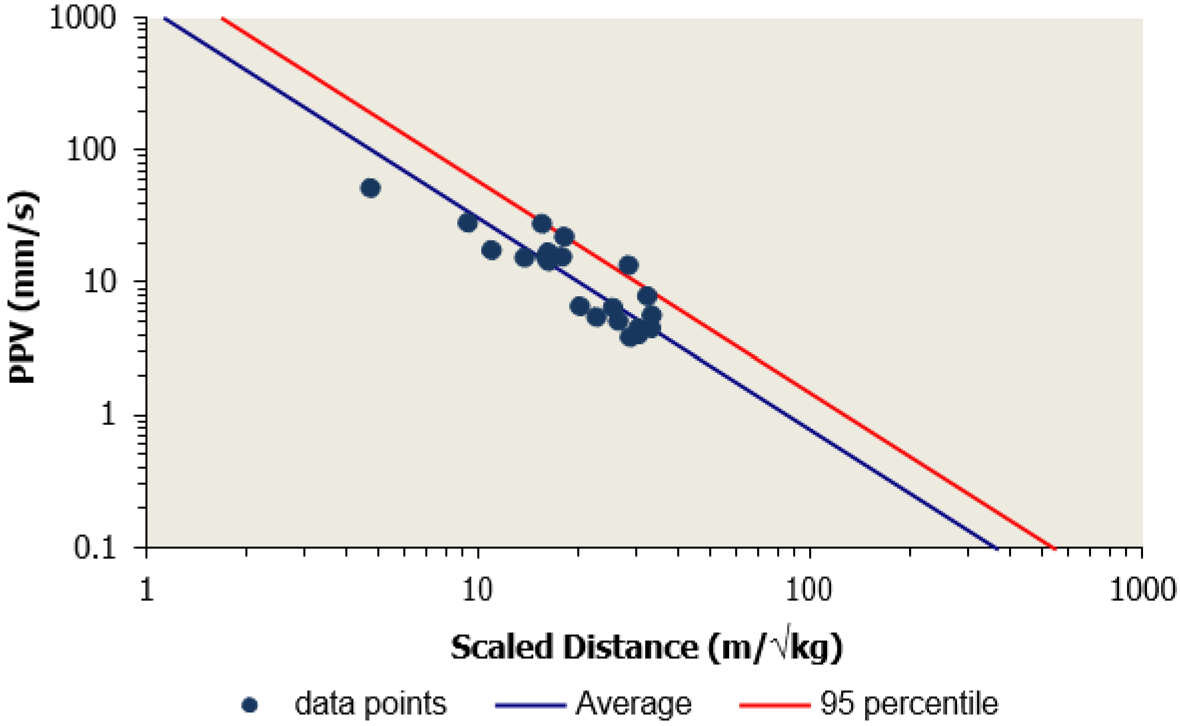

FIGURE 17-4 | VIBRATION REGRESSION ANALYSIS

Equation 1 is based on a 95% confidence level and has the following form:

$$PPV_{95\%} = 2325\left(\frac{R}{\sqrt{Q}}\right)^{-1.60}$$

Where P P V peak particle velocity in millimetres/second;

R distance between source and point of measurement in metres;

Q effective charge weight per delay in kg.

It should be noted that the predictions based on the 95 percentile are considered the upper limit, with the average levels likely to be around 50 percent lower.

17.3.2 Air-Overpressure

Similar to vibration prediction, a scaled distance equation is the most common method for prediction of air-overpressure impacts. Given the variability in blast orientation and atmospheric conditions, modelling and prediction of air-overpressure impacts is more difficult than ground vibration.

In relation to surface blasting activities, measured data has been used to establish Equation 2 for the prediction of peak air-overpressure levels:

$$dBL = 166 - 24\log\left(\frac{R}{\sqrt[3]{Q}}\right)$$

Where dBL Peak overpressure in dB(Linear);
R distance between source and point of measurement in metres;
Q effective charge weight per delay in kg.

With respect to the underground blasting activities, impacts relating to air-overpressure are only anticipated in the initial stages of the decline (tunnel) development close to the surface. Monitoring data measured both in the near and far field from development blasting close to the portal (tunnel entrance) has been used to Equation 3 which has the following form:

$$dBL = 165 - 19.9\log(R)$$

Where dBL Peak overpressure in dB(Linear);
R distance between source and point of measurement in metres;

The above attenuation equation is based on "favourable" blasting conditions with added control measures as detailed in section 17.7.

Overpressure levels will decrease as the decline progresses underground. Previous investigations have indicated that levels can reduce by ~5dB(L) when 300 (lateral) metres along the tunnel. Once the underground operation is established and blasting is occurring further underground, air-overpressure from blasting is not expected to reach the surface.

17.4 EXISTING ENVIRONMENT

As part of the baseline monitoring program, Terramin undertook a series of background vibration measurements over a 12 month period from May 2016, through to October 2017, using SAROS calibrated geophones at two locations adjacent to the eastern boundary of the Mining Lease (ML). This included *Location 1 – South* and *Location 2 – North*, as indicated in Figure 17-6. More recently, air-overpressure monitoring has also been conducted at *Location 1 – South*. Results of the baseline monitoring are summarised in Table 17-2.

The vibration and air-overpressure levels detailed in Table 17-2 relate to the upper limit of the respective percentile band. The analysis indicates that ground vibration levels at *Location 2 - North* did not exceed 0.11mm per second on 99.9% of the monitoring period. Ground vibration levels of this magnitude are considered to be within noise floor of the monitoring instrumentation. A time series plot of the peak vibration levels recorded at *Location 2 - North* is presented in Figure 17-5. Whilst the data indicates very low background levels, random localised vibration peaks are evident in the data with a maximum level of 0.69mm/s.

More recent monitoring at *Location 1 – South* has seen evidence of occasional elevated levels, with a 99.9% level of 0.33mm/s. This may be a result of the closer proximity to Bird in Hand Road.

Air-overpressure levels recorded at *Location 1 – South* during the month of April 2017 highlighted the potential for extraneous sources to influence peak levels. The data indicates that 0.1% of the measured peaks were above 116dB(L) which exceeds the recommended compliance limit relating to blast induced overpressure. This has occurred for 18 of the 20 months - 0.1 % were above 115 dB(L); for 12 of the 20 months 1% were higher than 115dB(L) and for 10 months 5% were higher than 115dB(L). It is likely these peak levels have been driven by environmental factors such as wind, trucks on Bird in Hand Road or aircraft from the nearby airfield. For example fast low flying helicopters are often observed undertaking rapid direction changes in the area, resulting in sudden loud changes in sound and overpressure.

TABLE 17-2 | SUMMARY OF BASELINE GROUND VIBRATION AND AIR-OVERPRESSURE RESULTS MEASURED AT BIH BETWEEN MAY 2016 TO OCTOBER 2017

Location	Vibration Unit	Start	End	Vibration (mm/s)			Overpressure dB(L)		
				Maximum (PVS)	99.9%	99.0%	99.9%	99.0%	95.0%
Location 1 - South	BE12247	1/05/2016	4/05/2016		0.10	0.08	not recorded		
Location 2 - North	BE13865	1/05/2016	23/05/2016	0.0387	0.11	0.11	not recorded		

Location	Vibration Unit	Start	End	Vibration (mm/s)			Overpressure dB(L)		
				Maximum (PVS)	99.9%	99.0%	99.9%	99.0%	95.0%
Location 2 - North	BE13865	16/06/2016	9/07/2016	0.506	0.11	0.11	not recorded		
Location 2 - North	BE13865	15/07/2016	22/08/2016	0.61	0.11	0.11	not recorded		
Location 2 - North	BE13865	2/09/2016	26/09/2016	0.694	0.11	0.11	not recorded		
Location 2 - North	BE13865	21/12/2016	14/01/2017	0.679	0.11	0.11	not recorded		
Location 1 - South	BE12247	4/04/2017	27/04/2017	16.5	0.32	0.22	116.10	109.50	101.90
Location 1 - South	BE12247	1/05/2017	31/05/2017	1.030	0.11	0.11	118.2	112.8	106.5
Location 1 - South	BE12247	1/06/2017	30/06/2017	0.139	0.11	0.11	108.4	101.9	95.9
Location 1 - South	BE12247	1/07/2017	31/07/2017	1.55	0.11	0.11	125.8	121.6	115.8
Location 1 - South	BE12247	1/08/2017	31/08/2017	4.61	0.13	0.11	125.8	121.5	116.8
Location 1 - South	BE12247	1/09/2017	30/09/2017	0.433	0.11	0.11	124.6	119.6	114.0
Location 1 - South	BE12247	1/10/2017	31/10/2017	1.08	0.11	0.10	124.5	116.8	107.0
Location 1 - South	BE12247	1/11/2017	30/11/2017	0.30	0.13	0.12	113.3	108.0	101.9
Location 1 - South	BE12247	1/12/2017	31/12/2017	0.43	0.13	0.12	117.4	112.0	105.5
Location 1 - South	BE12247	1/01/2018	31/01/2018	0.21	0.12	0.12	119.6	114.2	107.5
Location 1 - South	BE12247	1/02/2018	28/02/2018	0.13	0.12	0.12	116.1	110.2	104.9
Location 1 - South	BE12247	1/03/2018	31/03/2018	0.13	0.12	0.12	117.7	113.1	108.0
Location 1 - South	BE12247	1/04/2018	30/04/2018	-	-	-	-	-	-
Location 1 - South	BE12247	1/05/2018	31/05/2018	31.7*	0.13	0.12	132.3	127.0	119.6
Location 1 - South	BE12247	1/06/2018	30/06/2018	0.47	0.14	0.13	137.3	132.1	124.0
Location 1 - South	BE12247	1/07/2018	31/07/2018	0.97	0.14	0.13	139.0	134.8	129.8
Location 1 - South	BE12247	1/08/2018	31/08/2018	2.45	0.14	0.13	139.2	135.3	129.8
Location 1 - South	BE12247	1/09/2018	30/09/2018	0.40	0.14	0.13	135.7	130.8	124.6
Location 1 - South	BE12247	1/10/2018	31/10/2018	0.35	0.13	0.13	132.0	125.9	119.2
Location 1 - South	BE12247	1/11/2018	30/11/2018	0.37	0.13	0.12	134.8	128.1	119.3
Location 1 - South	BE12247	1/12/2018	31/12/2018	0.89	0.33	0.15	138.1	131.7	122.3

Percentages refers to the level that the recorded peaks were equal to or lower than

* Peak levels resulting from re-installation of the monitoring instrumentation on the 9th May 2018

Downtime
19/03/2018 - 31/03/2018 | 1/04/2018 - 30/04/2018 | 1/05/2018 - 9/05/2018

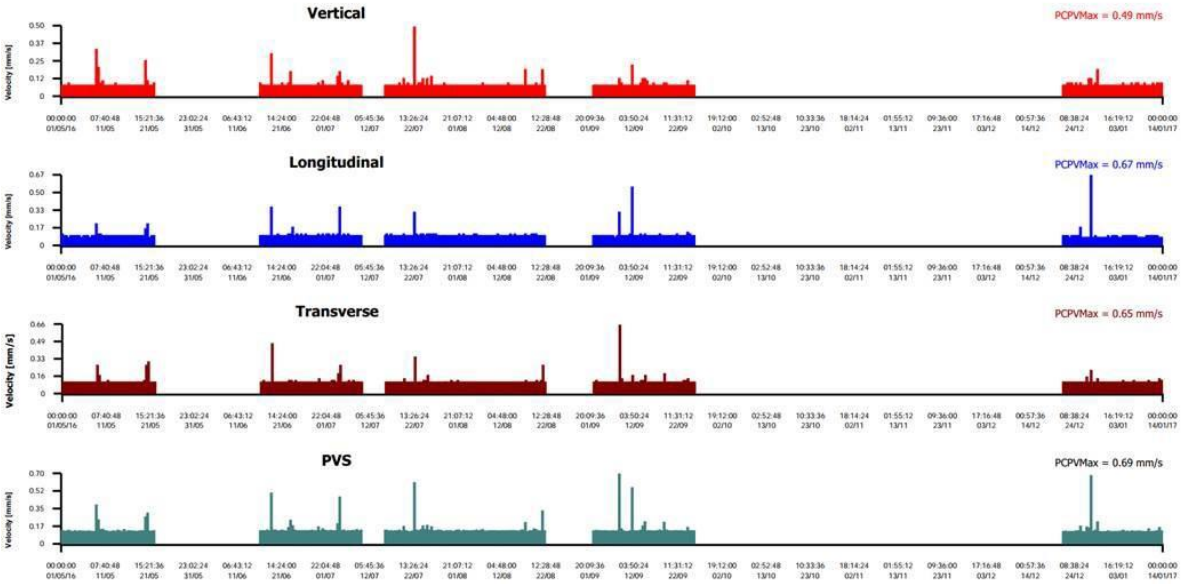

FIGURE 17-5 | HISTOGRAM PLOT OF PEAK BACKGROUND VIBRATION LEVELS RECORDED AT LOCATION 2 - NORTH

17.5 SENSITIVE RECEPTORS

The Bird In Hand Gold Project (BIHGP or the Project) is located amongst rural properties, in an area identified as rural industry zoning by the Adelaide Hills council and the EPA, with a number of residential dwellings in close proximity to the mine. Commercial premises are situated to the east and west of the proposed ML. These include Bird in Hand winery (BIHW) and Petaluma winery and cellar doors and a cellar door called Artwine. Petaluma is located within the ML. To the south, east and north of the operational site, there are various neighbouring residential properties, a sporting club (Polo) and a number of rural industries.

Heritage features including existing mining chimneys (Lone Hand and Ridge) have also been included and are shown in Figure 17-7 and Figure 17-8.

The locations of the neighbouring sensitive receptors in relation to the proposed mining activities are presented in Table 17-3 and Figure 17-6.

TABLE 17-3 | IDENTIFIED SENSITIVE RECEPTORS

Sensitive Receptor	Summary	Impact ID
Hisee	Residence	PIE_17_01 PIE_17_05
Day	Residence	PIE_17_01 PIE_17_05
Reni	Residence	PIE_17_01 PIE_17_05
Petaluma	Winery and cellar door	PIE_17_01 PIE_17_05
Polo Club	Residence	PIE_17_01 PIE_17_05

Sensitive Receptor	Summary	Impact ID
Airstrip	Residence and commercial airstrip	PIE_17_01 PIE_17_05
BIHW House	Residence	PIE_17_01 PIE_17_05
BIHW Winery	Winery and cellar door	PIE_17_01 PIE_17_05
Artwine	Residence and cellar door	PIE_17_01 PIE_17_05
Davis	Residence	PIE_17_01 PIE_17_05
Listed Species - Fauna	Located within the remnant vegetation and native vegetation heritage agreement area	PIE_17_03 PIE_17_07
Listed species - Flora	Located within the native vegetation heritage agreement area	PIE_17_06 PIE_17_08
Local community	Local community broader than those specifically listed	PIE_17_02
Third party infrastructure	Infrastructure outside Goldwyn belonging to third party interests.	PIE_17_04
Lone Hand Chimney	Only listed State heritage place recognised onsite under the *Heritage Places Act 1993* (SA). Figure 17-7.	PIE_17_09 PIE_17_10
Ridge Mine Chimney	Existing stone chimney from Ridge Mine during 1880s. Figure 17-8.	PIE_17_09 PIE_17_10

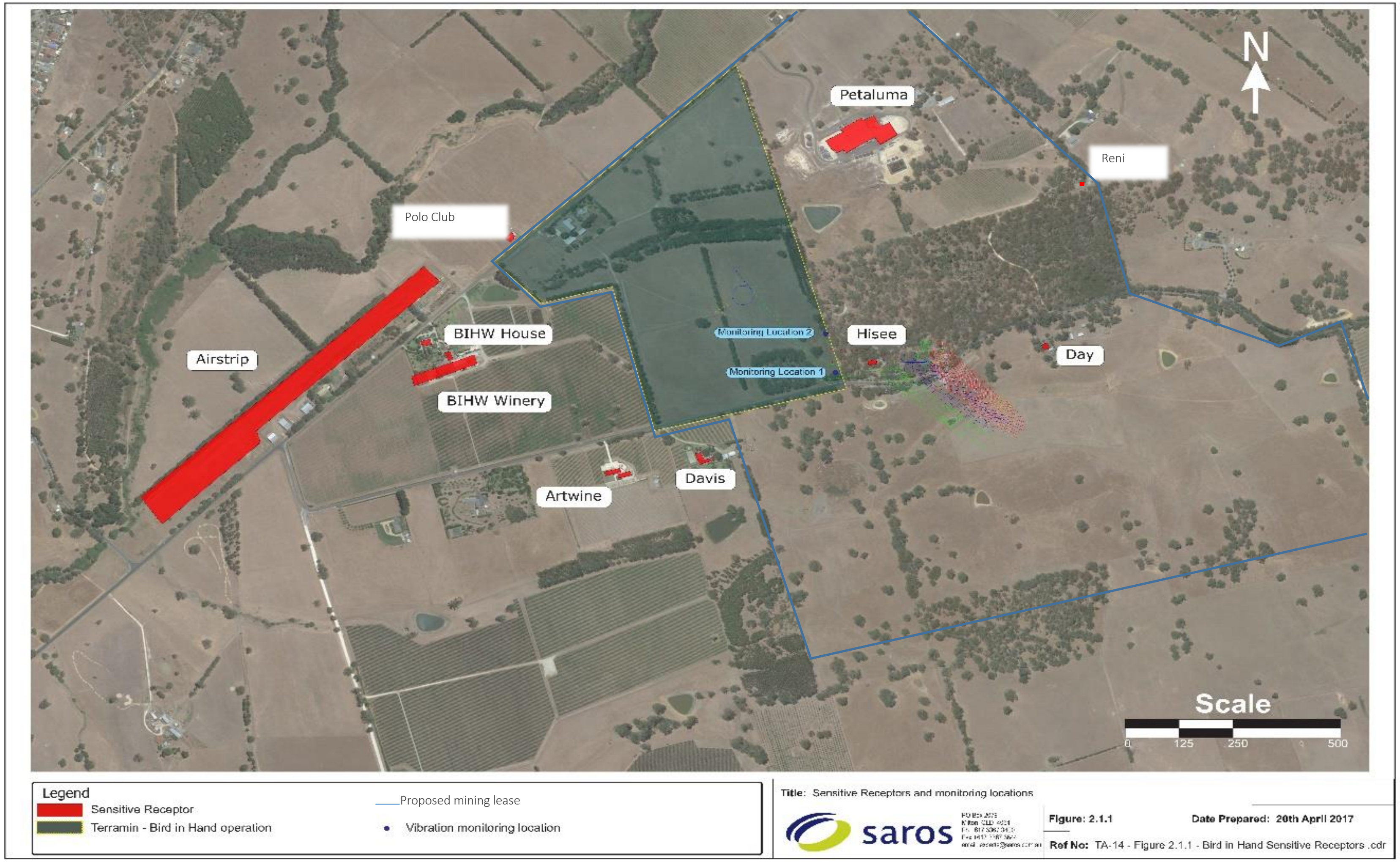

FIGURE 17-6 | BIRD IN HAND – SENSITIVE RECEPTORS AND MONITORING LOCATIONS

FIGURE 17-7 | LONE HAND CHIMNEY AND FLUE. FACING EAST.

FIGURE 17-8 | RIDGE MINE'S TAILINGS DAM AND CHIMNEY. FACING SOUTH.

17.6 POTENTIALLY IMPACTING EVENTS

Potentially impacting events include nuisance to neighbouring properties from both ground vibration and air-overpressure. The blast related 'fly rock' risk is considered in Chapter 7: Public safety.

TABLE 17-4 | SOURCE – PATHWAY – RECEPTOR

Potentially Impacting Events	Mine Life Phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	Impact ID
Vibrations from blasting operations impact on local residents	Operation	Blasting operations	Ground	Neighbouring residents	Yes	PIE_17_01
Air Overpressure impact to local residents as a result of blasting operations	Operation	Blasting operations	Air	Local community	Yes	PIE_17_02
Vibration from blasting has the potential to alter the behaviour patterns of fauna	Operation	Blasting operations	Ground	Listed Fauna within the ML	Uncertain	PIE_17_03
Vibration from blasting operations impacts on off-lease structures	Operation	Blasting operations	Ground	Third party infrastructure	No	PIE_17_04
Vibration from construction and mining operations (excluding blasting) impacts on local residents	Construction, Operation, Closure	Vibration from construction and mining operations	Ground	Neighbouring residents	No	PIE_17_05
Vibration from blasting impacts on listed flora	Operation	Blasting operations	Ground	Listed flora in Native Vegetation Heritage Area	No	PIE_17_06
Air-Overpressure impact to listed fauna	Operation	Blasting operations	Air	Listed Fauna within the ML	No	PIE_17_07
Air-Overpressure impact to listed flora	Operation	Blasting operations	Air	Listed flora in Native Vegetation Heritage Area	No	PIE_17_08

Potentially Impacting Events	Mine Life Phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	Impact ID
Ground vibration from construction blasting has the potential to damage or disturb the State Heritage Chimney on Goldwyn (Lone Hand) and Ridge Mine Chimney	Construction	Blasting operations	Ground	State Heritage Chimney on Goldwyn (Lone Hand) and Ridge Mine Chimney	Yes	PIE_17_09
Air overpressure from construction blasting has the potential to damage or disturb the State Heritage Chimney on Goldwyn (Lone Hand) and Ridge Mine Chimney	Construction	Blasting operations	Air	State Heritage Chimney on Goldwyn (Lone Hand) and Ridge Mine Chimney	No	PIE_17_10

17.7 CONTROL MEASURES TO PROTECT ENVIRONMENT

The following section discusses the controlling factors and details safety and mitigation measures for future blasting activities.

The predictive modelling of ground vibration and air-overpressure impacts has been based on monitoring data obtained from mining and blasting operations which possess comparable geological and/or topographic conditions and utilise similar scale blasting practices.

17.7.1 Design Measures and Management Strategies

To manage the social impacts of blasting on the local community, Terramin will implement an opt in/out SMS blast notification system for local residents, and communicate set blasting times.

Management of the physical impacts of blasting are described below.

17.7.1.1 GROUND VIBRATION

The critical factors with respect to the control of ground vibration are the amount of explosive detonated per delay and the distance from the blast to the sensitive receptor. Therefore, as blasting activities approach the neighbouring residences, a reduction in effective charge weights may be required. This can be achieved by various modifications to the blast design which can include:

- A reduced cut length;

- A reduced blast hole diameter;
- Lower density explosive products;
- Downloading blast holes (decoupled charges); and
- The use of electronic detonators to provide greater flexibility and accuracy in initiation timing, minimising the likelihood of vibration enhancement from multiple blast holes.

Once explosive quantities have been determined for a specified blast, it is important that accurate quantities be loaded into each blast hole and checked against the design plan. It is also important that the initiation sequence be designed to ensure there is adequate delay between blastholes, minimising the effect of vibration enhancement and reducing peak levels. In recent years, the use of electronic detonators has become more prevalent. This initiation method allows for greater flexibility and accuracy over initiation timing providing greater control.

Construction blasting is proposed for times between 10am and 6pm only.

TABLE 17-5 | DESIGN MEASURES AND MANAGEMENT STRATEGIES FOR GROUND VIBRATION

Design Measures and Management Strategies	Impact ID
A reduced cut length	PIE_17_01 PIE_17_03 PIE_17_04 PIE_17_05 PIE_17_06
A reduced blast hole diameter	
Lower density explosive products	
Downloading blast holes (decoupled charges)	
The use of electronic detonators to provide greater flexibility and accuracy in initiation timing, minimising the likelihood of vibration enhancement from multiple blast holes	
Construction blasting between 10am and 6pm only	
Blast Management Plan	
SMS blast notification system for local residents	
Communicate set blasting times to local community	

17.7.1.2 AIR-OVERPRESSURE

Air-overpressure is less affected by the charge weight and geological conditions, but is significantly influenced by the following factors:

- The degree of explosive confinement;
- Topographic relief;
- Orientation of the blast;
- Initiation timing; and
- Atmospheric conditions.

The sources of air-overpressure include the vibration of the rock mass, the movement of the rock at the bench face and the venting of gases through the collar or free face. Peak levels resulting from venting of gases can be minimised with the implementation of tight controls over blast loading practices. The impact of the vibration of the rock mass or movement of the face require modifications to the blast design. In order to address this it will include the continual review and design incorporating one or more of the following measures:

- Increased confinement through increased burdens and/or stemming;
- Reduction in the surface area of the free face;
- Reduction in blasthole diameter;
- Reduction in charge weights;
- Reduction in cut length; and

- Modifications to initiation sequencing.

Peak overpressure levels are likely to result from the initial development phase of the decline when blasting is close to the surface. This will involve the use of added suppression methods which may include one or a combination of the following:

- Shields at the portal;
- Blast curtains;
- Physical barriers in the decline; and
- Insulation.

TABLE 17-6 | DESIGN MEASURES AND MANAGEMENT STRATEGIES FOR AIR-OVERPRESSURE

Design Measures and Management Strategies	Impact ID
Increased confinement through increased burdens and/or stemming	PIE_17_02 PIE_17_07 PIE_17_08
Reduction in the surface area of the free face	
Reduction in blasthole diameter	
Reduction in charge weights	
Reduction in cut length	
Modifications to initiation sequencing	
Shields at the portal	
Blast curtains	
Physical barriers in the decline	
Insulation	
Blast Management Plan	
SMS blast notification system for local residents	
Communicate set blasting times to local community	

17.8 SAFETY MEASURES

Blasting practices require some movement of rock to facilitate the excavation process. The extent of movement is dependent on the scale and type of operation. The surface blasting proposed would be in line with a construction or small scale quarrying operation and is only very short term during the initial construction phase. Key design and implementation factors include the following:

- Adequate confinement of explosives with respect to both stemming heights and burdens to be maintained at all times;
- Downloading of blastholes if minimum burden requirements are not met;
- Accurate loading of charge weights ensuring holes are not overloaded;
- Appropriate distribution of the energy within the blast;
- Depth to the top of the explosive column to be checked with explosive product to be removed from overloaded holes prior to adding stemming material;
- Use of appropriate stemming material; and
- Additional control measures to be applied when assessed as necessary.

The processes which control air-overpressure levels and flyrock are the same and therefore, the restrictions imposed to blasting activities based on regulatory compliance requirements act in turn act as a safety control, restricting the extent of rock displacement.

All blasts will have blast clearance zones on final blast design, none of which will extend to the location of identified receptors. All surface blasts for construction and development will have a clear plan indicating the blast location, proposed time and extent of blast clearance area onsite for staff. Consistency in the firing times where possible can also minimise inconvenience and disruption.

17.9 IMPACT AND RISK ASSESSMENT

The modelling conducted by Saros of blast induced impacts including ground vibration and air-overpressure have been based on the attenuation equation as discussed in Section 4. Predictive models have been developed for each phase of the mining process based on the blasting practices to be implemented and the location of the activities for that period. This section details the modelling results which have been graphically represented as surface contour plots.

Vibration and air-overpressure is a primary concern for local residents, and the objective of the blasting design and impact assessments has been to minimise the impact that blasting could have on the most immediate neighbours.

17.9.1 Surface Blasting – Construction Phase

Terramin have the option of utilising surface blasting to prepare the site, rather than using conventional rock breakers and excavators. The preference during community consultation has been largely to use short, limited surface blasts, rather than months of rock breakers and excavators to prepare the boxcut. The two construction surface blasts have been designed at one 5 m bench using 12 kg of explosives, and the second at a 10 m bench using 40 kg of explosives.

Modelling associated with the initial construction phase has assumed a worst case scenario with blasting in both the boxcut and access road cutting. Designs have assumed blasting the full depth of excavation including both 5 m and 10 m benches.

Figure 17-9 presents the extent of the predicted peak vibration levels generated from the construction blasting. Predicted vibration levels are not anticipated to exceed 5 mm/s at any of the residences and 2mm/s at cellardoor facilities.

Figure 17-10 details the extent of peak air-overpressure levels generated from blasting activities during the initial construction phase. Given the extent of the 115 dB(L) contour, this would indicate air-overpressure levels would also be compliant at residences and cellardoor facilities.

Overall, the impact assessment considered using two blasts to prepare the boxcut, as compared to an excavator and rock breaker preparing the site over months, and consider the expected impact to from two surface blasts through construction to local residents and businesses to be **negligible**, as the vibration and air overpressure are experienced over seconds, during the day time, and within regulatory limits.

17.9.1.1 HERITAGE FEATURES

The Lone Hand Chimney is located approximately 200 m north of the proposed construction blasts. The Lone Hand Chimney is currently experiencing background levels of air overpressure (described in section 17.4) which are well in excess of the 125 db(L) which the two surface construction blasts would produce. For this reason, there is no credible source, pathway and receptor (S-P-R) relationship between the chimney and air-overpressure. In regards to vibration, Terramin have investigated other heritage structures near mining projects in Australia. The most similar is the 1860s Cadia Engine House and Chimney, at Newcrest's Cadia Valley Mine in NSW (listing number 00779). Terramin would propose to limit ground vibration to 15 mm/s at the Chimney, as Newcrest have, which reflects the most conservative peak particle velocity for unreinforced or light framed structures, as outlined in British Standard BS7385-2. Authoritative investigations outlined in Australian Standard 2178.2 *Explosives – Storage and Use*, Appendix J suggest that the guide values and assessment methods given in BS 7385-2 are applicable to Australian conditions (AS2187.2 - 2006, Appendix J). For this reason, Terramin consider impacts to the Lone Hand Chimney to be **negligble**. Impacts to the Ridge Chimney are not plausible based on these standards, as the Ridge Chimney is located where approximately 2 mm/s is predicted through the construction blasts.

Ultimately, impacts could be reduced further by a series of smaller blasts, rather than the two blasts described above, however, the Blasting Impact Assessment (Appendix P1) indicates that the proposed criteria would be met at all receptors and blasting vibration at the Lone Hand Chimney would be below the proposed criteria to prevent structural damage.

Vibration impacts to listed flora and fauna are not considered credible as the limits are within human comfort levels outside of the Goldwyn construction or operational area. Similarly the overpressure is within compliance and the base line data collected. Table 17-2, shows there are regular naturally occurring instances of overpressure being higher than 115dB(L), caused by wind or possibly human induced activities such as gas guns.

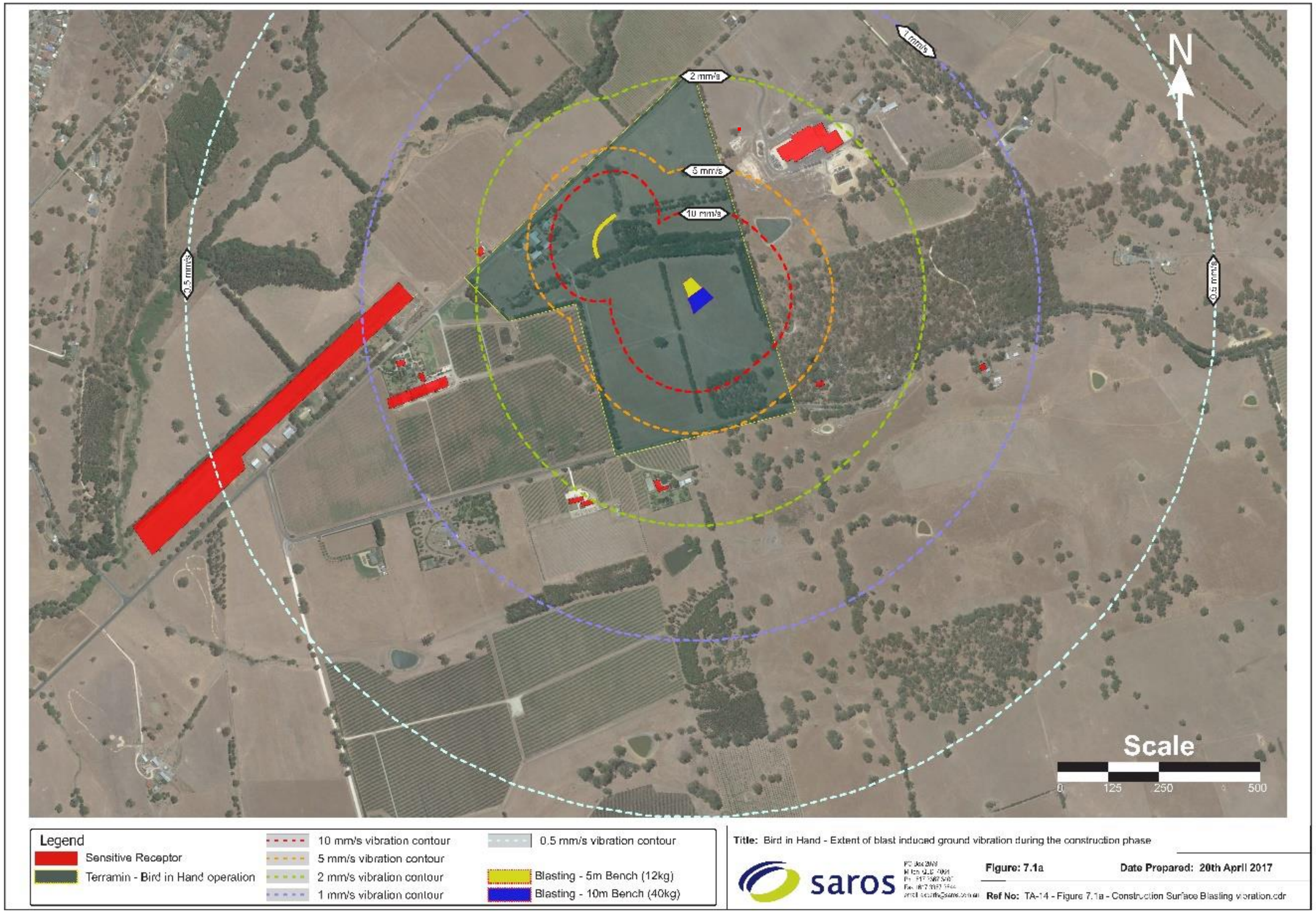

FIGURE 17-9 | GROUND VIBRATION - SURFACE CONSTRUCTION

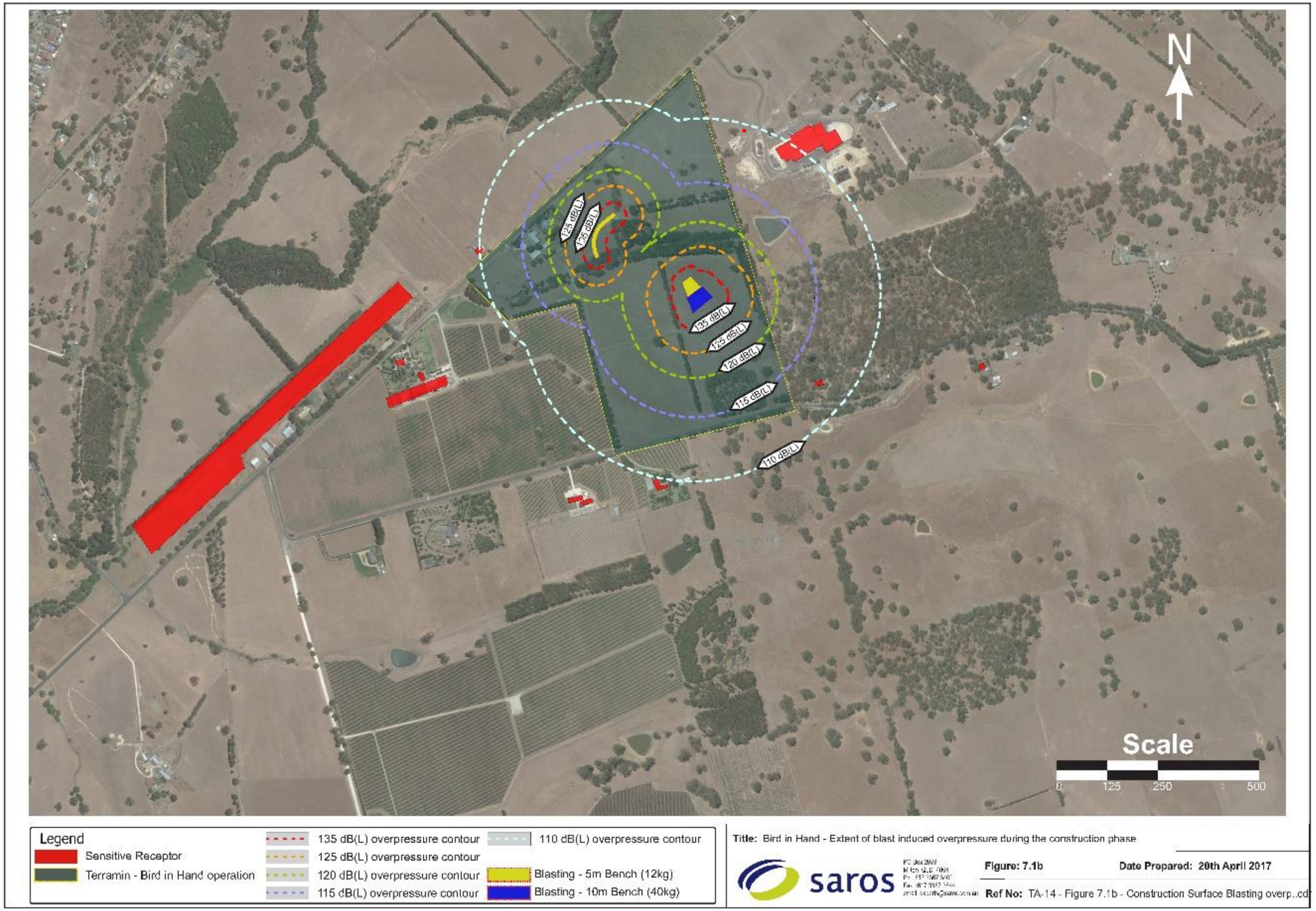

FIGURE 17-10 | AIR -OVERPRESSURE - SURFACE CONSTRUCTION

17.9.2 Decline Development

The modelling of ground vibration impacts from the development of the decline have been based on a typical development heading with a maximum charge per blasthole of 5 kg and assuming an attenuation rate as defined by Equation 1. The modelling also takes into consideration the increased depth of the decline as it progresses underground. As presented in Figure 17-11, the 5 mm/s vibration contour is contained within the ML. As the decline progresses to the southeast, the increased depth of the underground workings provides sufficient separation with the surface.

With respect to the development of the decline, prediction of overpressure impacts have been based on Equation 3, assuming favourable blasting conditions with added control measures. No allowance has been made for directionality based on the orientation of the portal which should provide added conservatism in the modelling.

Illustrated in Figure 17-12 is the extent of the predicted overpressure levels from the decline development. It is important to note this is based on the initial blasting close to the portal, with levels attenuating as the decline progresses underground.

Terramin expect the impact from decline development to be the most intrusive of vibration impacts for the life of the project, however, note that the closest receptor will still only experience vibration between 2 and 5 mm/s. The majority of receptors will experience vibration which is close to imperceptible, ranging from 0 to 1 mm/s. Significantly, hospitality businesses located in the region are expected to experience ground vibration which is less than 1 mm/s. In context, this is similar to the vibration from a person walking alongside another person, as discussed earlier in Section 17.2. For this reason, Terramin expect this impact to be conservatively low.

Vibration impacts to listed flora and fauna are not considered credible as the limits are within human comfort levels outside of the Goldwyn construction or operational area. Similarly the overpressure is within proposed compliance limits.

There are no credible pathways for impact from development or production blasting identified in the Blasting Impact Assessment (Appendix P1) to the heritage Chimneys, as the vibration and air overpressure generated is considered to be too low (that is, less than 2 mm/s vibration and 120 dB(L) air overpressure through decline development).

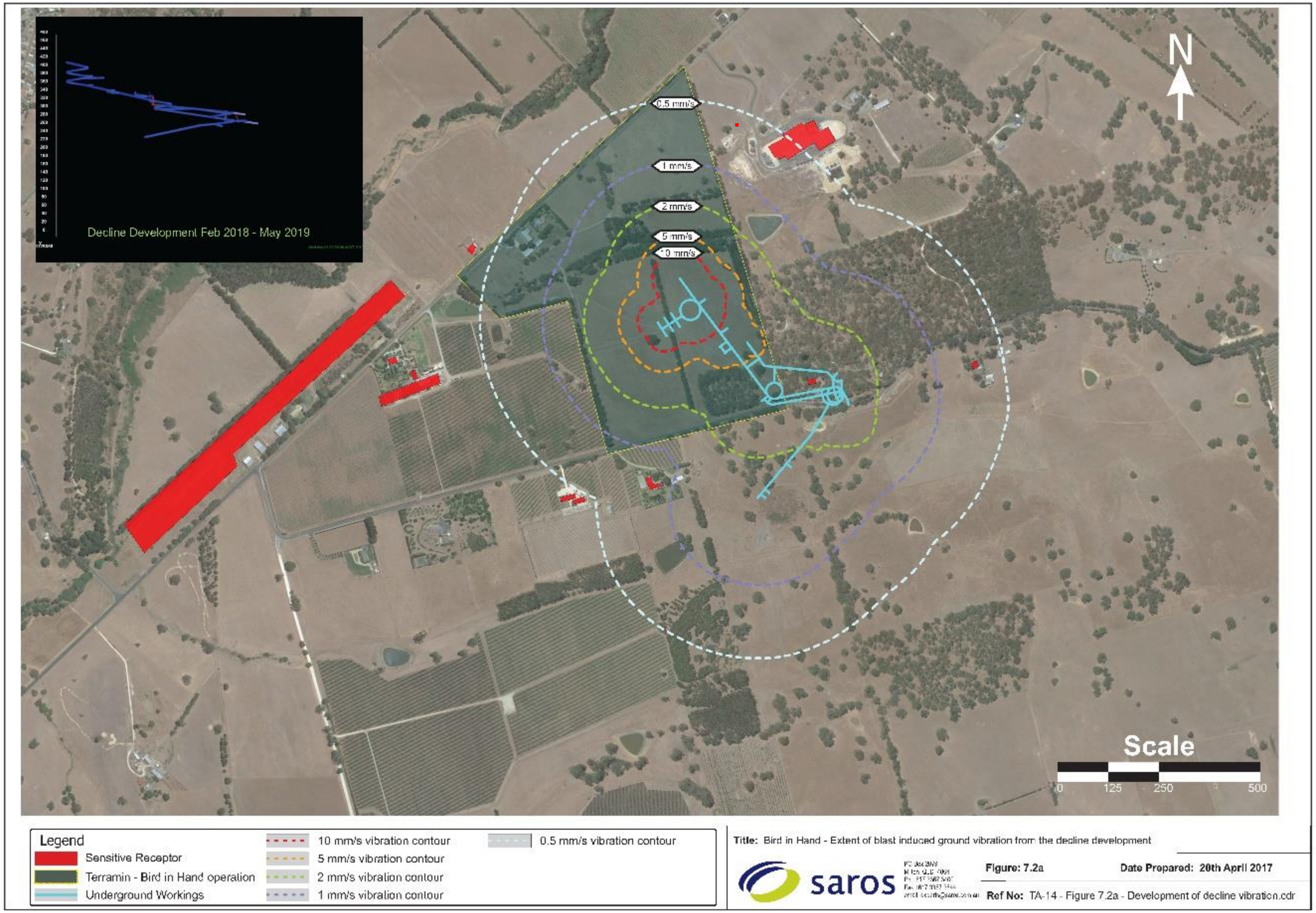

FIGURE 17-11 | GROUND VIBRATION - DECLINE DEVELOPMENT

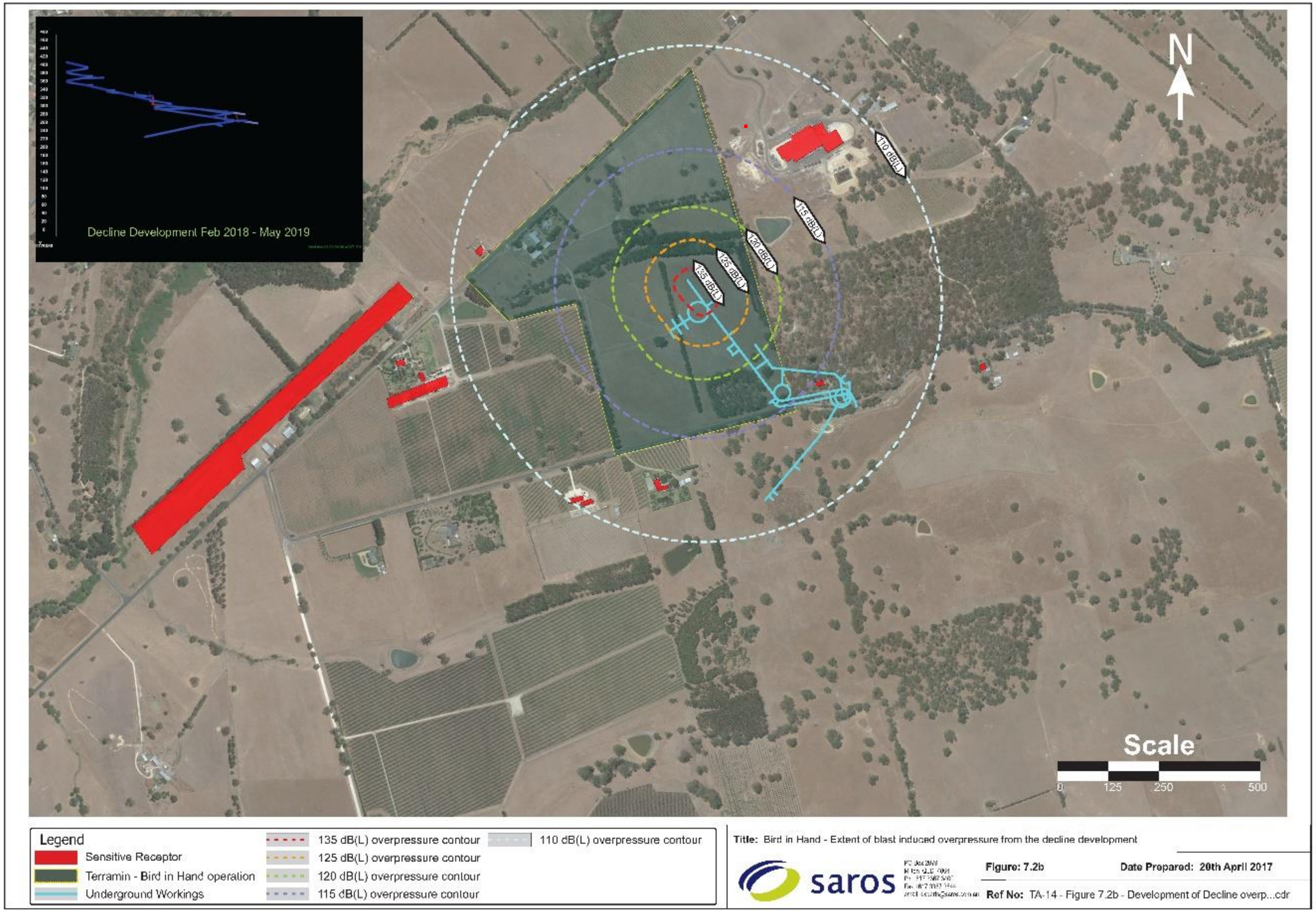

FIGURE 17-12 | AIR-OVERPRESSURE – DECLINE DEVELOPMENT

17.9.3 Production Blasting

Based on the cut-and-fill mining method for ore recovery, the blasting practices for the production phase are consistent with the development blasting. The modelling of the production blasting has been based on a 4 m advance, with a maximum charge per blasthole of 5 kgs. Figure 17-13 to Figure 17-17 detail the extent of the vibration contours based on each year of production. Over the course of the five year production phase, vibration levels of 5 mm/s are not expected to reach the surface. The contour plans illustrate the reduction in the impacts at the surface as the mine progresses underground.

Given the depth and network of the underground workings during the production phase of the mine, air-overpressure levels from the production blasting are not anticipated to impact on the surface.

During ore production, the majority of receptors will experience vibration which is close to imperceptible, ranging from 0 to 1 mm/s, with the exception of one receptor located above the mine workings, which will experience approximately 2 mm/s. Significantly, hospitality businesses located in the region are expected to experience ground vibration which is less than 0.5 mm/s. In context, this is less than the vibration from a person walking alongside another person, as discussed earlier in Section 17.2. For this reason, Terramin expect this impact to be **negligible** to residents and businesses.

Vibration impacts to listed flora and fauna are not considered credible as the limits are within human comfort levels outside of the Goldwyn construction or operational area. Similarly the overpressure is within proposed compliance limits.

There are no credible pathways for impact from development or production blasting identified in the Blasting Impact Assessment (Appendix P1) to the Chimneys, as the vibration and air overpressure generated is considered to be too low (that is, less than 0.5mm/s vibration and no air overpressure anticipated through production).

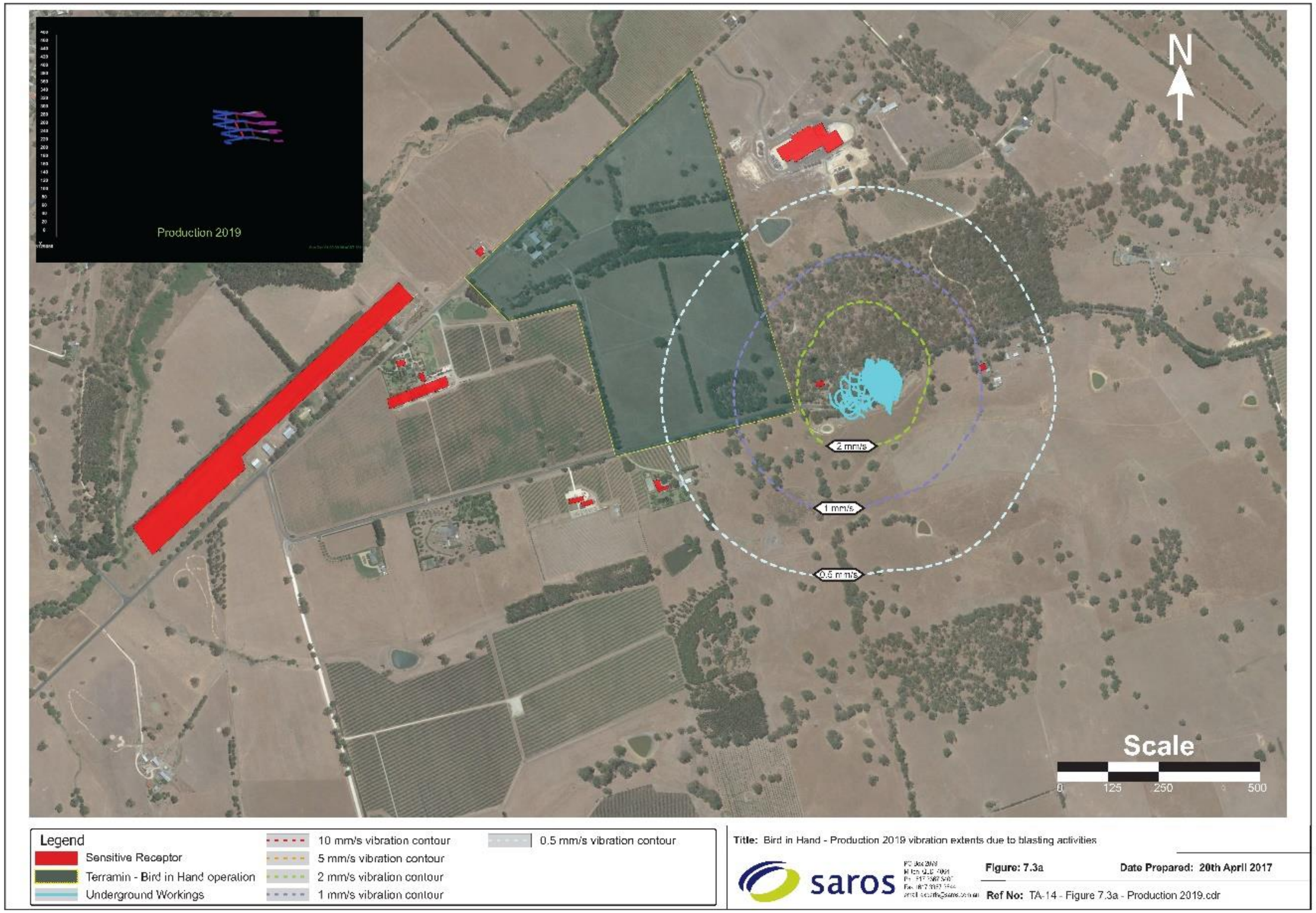

FIGURE 17-13 | GROUND VIBRATION - ORE PRODUCTION YEAR 1

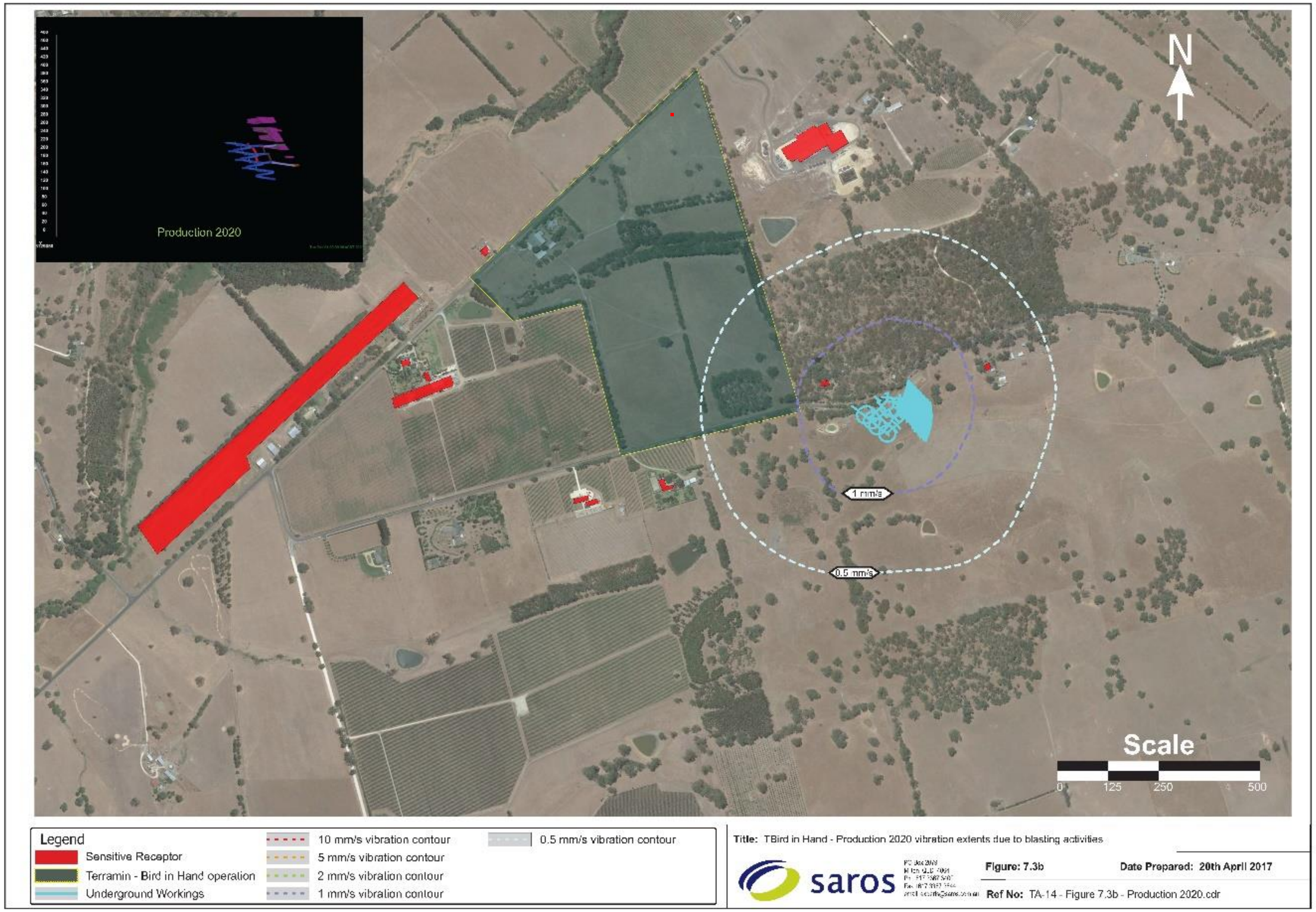

FIGURE 17-14 | GROUND VIBRATION - ORE PRODUCTION YEAR 2

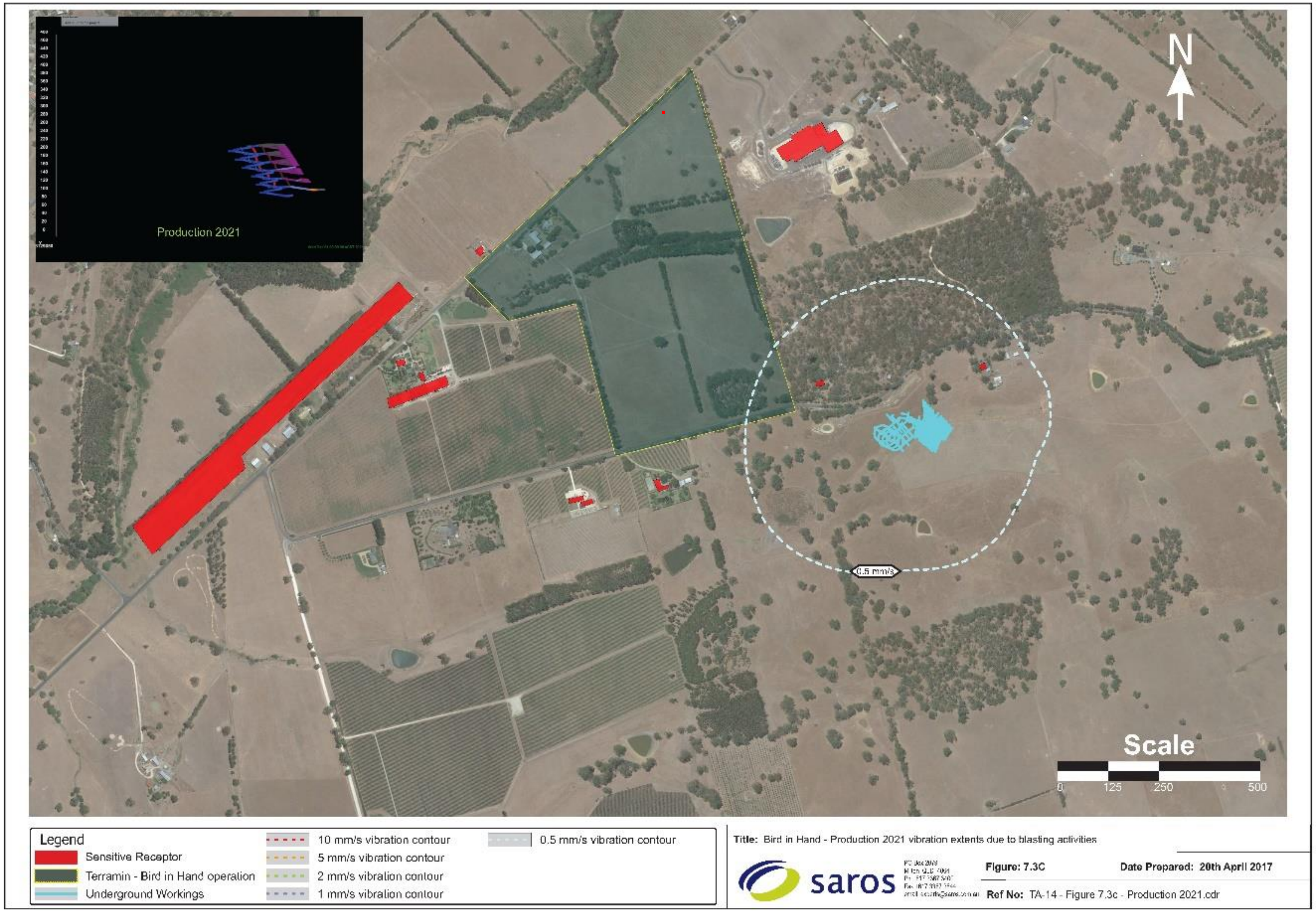

FIGURE 17-15 | GROUND VIBRATION - ORE PRODUCTION YEAR 3

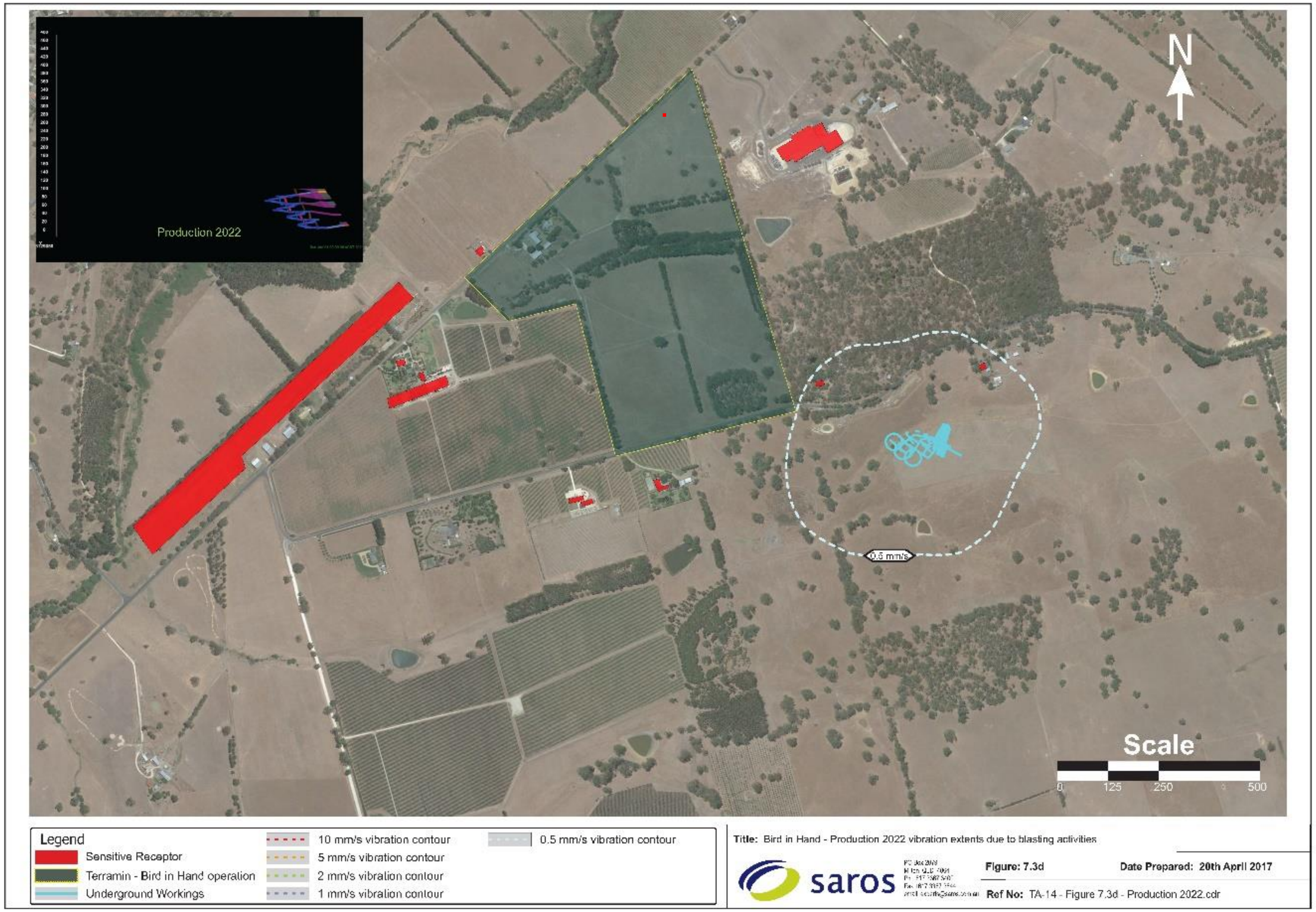

FIGURE 17-16 | GROUND VIBRATION - ORE PRODUCTION YEAR 4

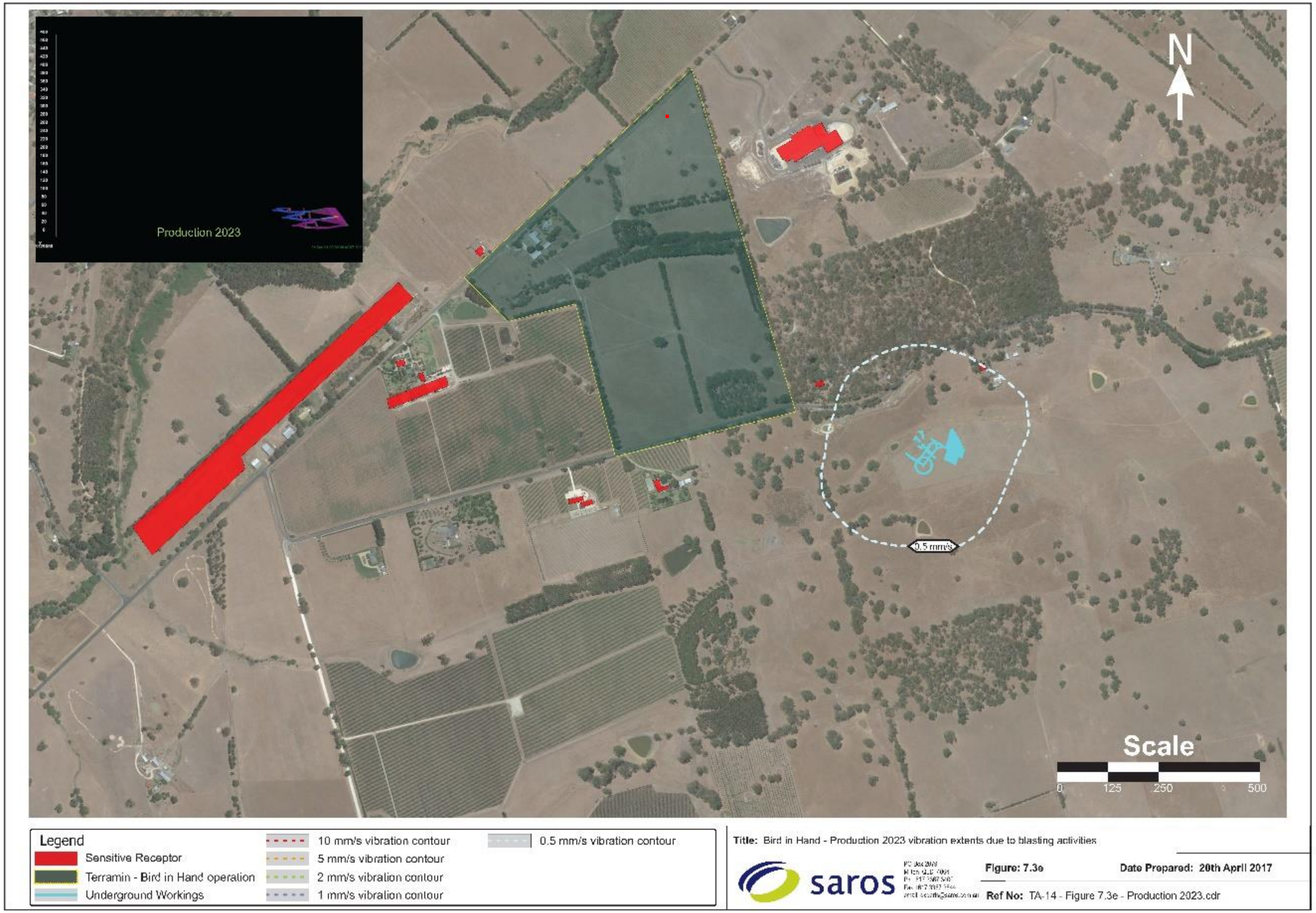

FIGURE 17-17 | GROUND VIBRATION - ORE PRODUCTION YEAR 5

17.9.4 Underground Infrastructure

In addition to the neighbouring sensitive receptors, modelling of blasting impacts was also performed for critical underground infrastructure. This included the underground magazine and primary ventilation fans. A reverse modelling exercise was conducted to establish the extent of peak vibration levels at the critical infrastructure for various sections of the decline development. Figure 17-18 details the predicted peak vibration level generated at the magazine for various sections of the decline. The modelling indicates that limited separation is required for the vibration levels to attenuate significantly.

Similarly, Figure 17-19 details the predicted vibration impacts on the primary ventilation fans from subsequent development blasting. Once again, the impacts are considered minimal with vibration levels quickly dropping below 10mm/s and are not expected to pose any concerns to the infrastructure.

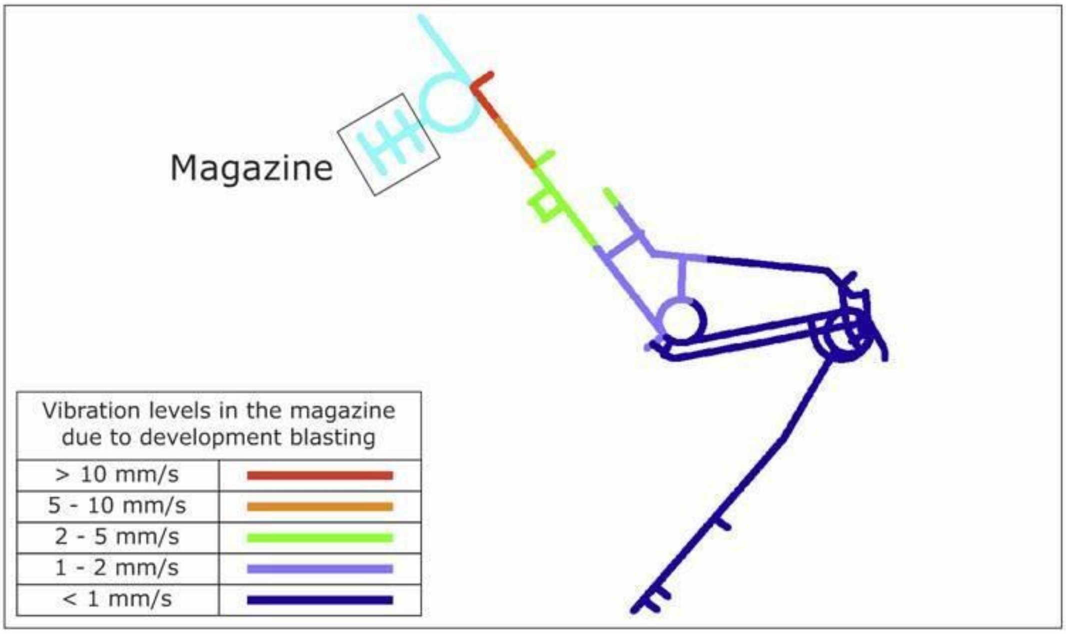

FIGURE 17-18 | VIBRATION LEVELS GENERATED FROM DEVELOPMENT BLASTING ON THE UNDERGROUND MAGAZINE

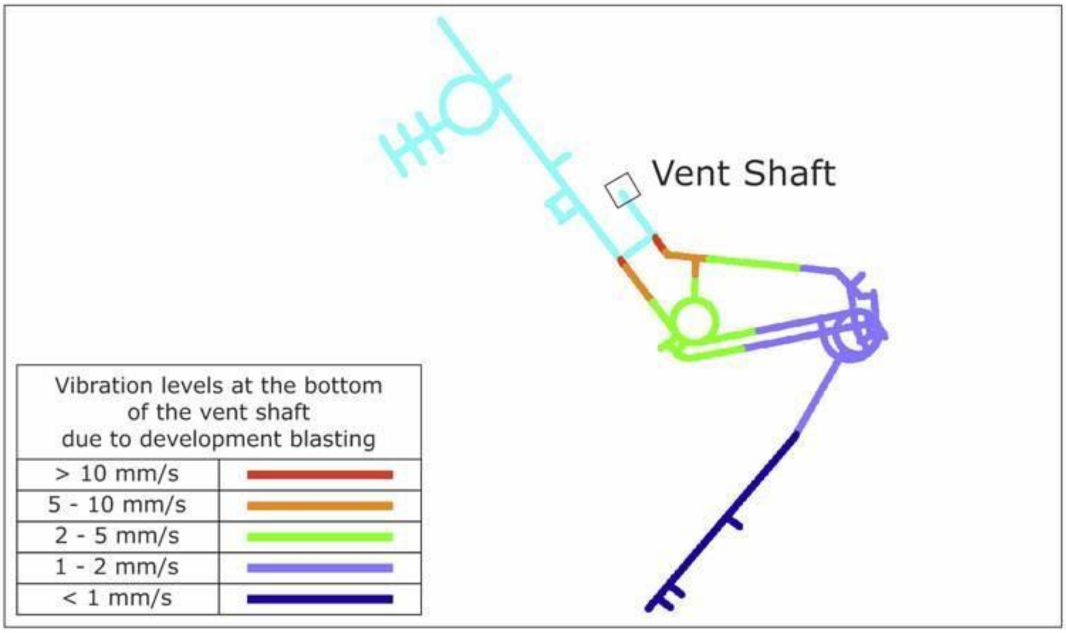

FIGURE 17-19 | VIBRATION LEVELS GENERATED FROM DEVELOPMENT BLASTING ON THE PRIMARY VENT FAN

17.9.5 FAUNA AND LIVESTOCK

BHP's BMA coal operation in the Bowen Basin analysed data from 42 livestock herds. Animal installations were selected for observations on animal behaviour under sonic boom conditions. Sonic booms create sharp releases of pressure, which create air-overpressure conditions reflective of mining. Numbers of animals observed in this study were about 10,000 commercial feedlot beef cattle, 100 horses, 150 sheep and 320 lactating dairy cattle. Sonic booms were scheduled at varying intervals during the morning hours Monday to Friday of each week. Results of the study showed that the reactions of the sheep and horses to sonic booms were slight. Dairy cattle were little affected (125 dB to 136 dB). Only 19 of 104 events produced even a mild reaction, as evidenced by a temporary cessation of eating, rising of heads, or slight startle effects in a few of those being milked. Milk production was not affected during the test period, as evidenced by total and individual milk yield. This analysis was included and approved by the Queensland Government as part of the project's Environmental Impact Statement (BHP BMA, 2009).

Terramin expect there to be no or **negligible** impact on livestock located within and surrounding the mining lease area. An outcome for 'no fauna injuries or deaths (excluding pests) caused by mining activities that could reasonably have been prevented, due to construction, operation and closure activities' is contained in Chapter 18.

Potential impacts associated with blasting and groundwater are located in Chapter 10: Groundwater.

17.10 DRAFT OUTCOME(S) AND MEASUREMENT CRITERIA

In accordance with the methodology presented in Chapter 6, an outcome has been developed for air over pressure and vibration impact events with a confirmed S-P-R link , see Table 17-7.

All outcomes are supported by draft measurement criteria which will be used to assess compliance against the draft outcomes during the relevant phases (construction, operation and closure), and where relevant draft leading indicator criteria. These measurement criteria and leading indicators are indicative only and will be developed further through the PEPR.

All Outcomes for the entire project are presented in Appendix D1.

TABLE 17-7 | DRAFT OUTCOMES AND MEASUREMENT CRITERIA

Draft Outcome	Draft Measurement Criteria	draft Leading Indicator Criteria
No adverse impact on public health or amenity from air overpressure, flyrock and vibration caused by blasting.	All blasting in accordance with Australian Standard AS2187.2.2006 Use of explosive, and demonstrates vibration levels caused by blasting are less than 5mm/s peak particle velocity at the nearest sensitive receptor for 95% of blasts per year, with a maximum of 10 mm/s peak particle velocity for any one blast, or higher limit as agreed with individual sensitive receptors.	All complaints acknowledged in 48 hours and closed out within 14 days to the satisfaction of the complainant or as agreed with the Chief Inspector of Mines.
	All blasting in accordance with Australian Standard AS2187.2.2006 'Use of explosive' and demonstrates peak air-overpressure level caused by blasting are less than 115 dBL at the nearest sensitive receptor for 95% of blasts per year, with a maximum of 120 dBL or higher limit as agreed with individual sensitive receptors.	All complaints acknowledged in 48 hours and closed out within 14 days to the satisfaction of the complainant or as agreed with the Chief Inspector of Mines.
	All blast times and charge weights will be recorded in a register to demonstrate all construction blasting exceeding XXXkg* charge weight will only be conducted between 10am and 6pm. * Maximum allowable weight to be proposed and approved through the PEPR development once final surface blast designs finalised.	None proposed
No adverse impact to heritage buildings from air overpressure, flyrock and vibration caused by blasting.	All blasting demonstrates vibration levels caused by blasting are less than 15mm/s peak particle velocity at the Lone Hand Chimney.	None proposed

17.11 FINDINGS AND CONCLUSIONS

The blasting impact assessment has been undertaken for each phase of the mine development including the surface construction, decline development and production phases. Analysis and modelling of vibration and air-overpressure impacts has been based on site data measured from representative blasting practices and geological conditions. The key findings from the study are as follows:

- Surface blasting associated with the construction phase if proposed for the boxcut and road cuttings for the access road can comply with the proposed outcomes and associated measurement criteria.
- Given the cut-and-fill method of mining proposed for the BIHGP, underground blasting practices are consistent for both the development and production phases and are considered to be small scale (that is, compared to other mining methods).
- The modelling indicates blast practices during all three phases of the mine (construction, development and production) can be conducted safely and maintain compliance with the proposed limits.
- The extent of the 5 mm/s vibration limit is expected to be contained within the ML boundary during development blasting.
- Vibration impacts at the surface will significantly reduce over the life of the mine with the increased in depth of the mining operations.
- Air-overpressure impacts are only anticipated during the early stages of the project, including construction blasting and the initial decline development.
- Once the mine has progressed to the production phase, air-overpressure impacts from blasting are not anticipated to impact on the surface.
- Vibration levels induced by subsequent underground blasting including the continuation of the decline development and production activities are not anticipated to pose any concerns to key underground infrastructure.
- Consistent blast firing times and timely notification to neighbouring sensitive receptors will assist in community management and stakeholder communication.
- Regulatory limits are based on human comfort levels rather than damage thresholds, and therefore, compliance with the licence conditions will minimise human discomfort and prevent the likelihood of damage to neighbouring structures.