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APPENDIX G, PART 1

Vibration Assessment
(Heilig Partners)

Report to

OceanaGold

Vibration Assessment
Project Martha

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EXECUTIVE SUMMARY

At the current mining and processing rates, the known mineral resource for the OceanaGold New Zealand Limited (OGNZL) Waihi operation will be exhausted at the end of 2019. Ongoing exploration and mine optimisation has identified further mineral resources (Au and Ag) that can be economically recovered.

This project description outlines a proposal, named Project Martha, for extending the mine life by developing these additional resources. Project Martha encompasses the mining of three orebodies:

- The Martha Phase 4 pit (MP4);
- The Martha Underground, including the Rex orebody[1].

MP4 and the underground mine can provide a total ore tonnage of 4.5Mt. The surface works associated with Project Martha will be undertaken in the Martha Mineral, Residential and Low Density Residential Zones of the Hauraki District Plan. The underground mining will be undertaken below the Martha Mineral, Active Reserve, Residential and Town Centre Zones.

The assessment for Project Martha is the sixth such detailed modelling exercise undertaken since 2002 (Favona, Trio, Correnso, SUPA (Slevin Underground Permit Application) and MDDP (Martha Drill Drive Project) all preceded Project Martha) by Heilig & Partners. The Martha and Extended Martha projects were also completed prior to 2002. The modelling results for each of the previous projects were subjected to a detailed review and were found to appropriately predict the vibration effects with sufficient detail and accuracy to allow grant of consents for those projects. The Project Martha vibration modelling process and the reliability of the results it produces remain unchanged from those of the previous projects.

The recommendations and conclusions for Project Martha are based upon around 30 years of operational experience of the effects and responses to blast vibration since the start of modern mining in the Martha open pit on which to base that reassessment.

The proposed conditions for Project Martha are generally based around the permitted standards in the Operative Hauraki District Plan, together with the Martha, Favona, Trio, Correnso, SUPA and MDDP consent conditions. In this respect, the proposed vibration conditions will be well aligned with the Hauraki District Council plan objectives of maintaining amenity. Some revisions are, however, recommended to best reflect the dual requirements of permitting a mining operation that implements best engineering practices and protects the amenity of persons within the environment, as well as a set of criteria that can be appropriately administered by the Hauraki District Council.

The proposed consent conditions include:

- Compliance with a 5mm/s vibration criterion during specified blast windows, to be achieved at all monitoring locations;
- At other times, compliance with a 1mm/s vibration criterion for underground mining;
- Combined compliance at the 95th percentile, irrespective of the source of the blasting or vibration limit.

Previous consent conditions for Correnso that relate to the maximum duration of the underground blast events, number of underground blast events, and web-based display of data are unchanged.

The proposed consent conditions are intended to ensure that the effects of blasting activities associated with mining remain appropriate. The intention is that the level of amenity protection

[1] Vibration from mining the Rex orebody is assessed in this report separately from the remainder of the Martha Underground because of its location under residential and other privately owned properties

afforded to residents is not reduced while at the same time providing for better operational management of blasting and for greater ease of blasting management from a compliance and enforcement perspective. The controls on vibration from blasting at the Waihi mines remain amongst the most rigorous applied to blasting activities internationally. Their basis of protecting amenity necessarily ensures that they are also protective of building integrity which is known to occur at values in excess of those assigned to personal amenity protection.

The Correnso consent conditions require the complex tasks of calculating, maintaining and reporting both average and the 95th percentile levels for each monitoring location for both development and production blasting activities. This is considered unworkable for Project Martha. The percentile calculation is based upon all recorded vibration data that exceed the pre-set threshold level set in the Vibration Management Plan. It is proposed that the revised condition considers that the level of vibration for all blasts (i.e. from both MP4 and the Martha Underground) is monitored and the peak level of vibration at each location comply at the 95th percentile with 5mm/s. There will be no difference in terms of the extent to which the blasting will be perceived by residents.

It is proposed that there is no requirement to differentiate between development blasting and production blasting in the underground mine, or to maintain separate statistics for the mining of the different orebodies.

It is proposed that a limit on the number of development/production blast events per day from underground mining within Project Martha is maintained, but be sufficiently flexible to recognise the safety requirements of blasting).

The blasting windows for the underground operations will likely be constrained by shift changes and breaks and a similar condition to that applying at Correnso is proposed for the underground projects within Project Martha, requiring the timing of the blast windows to be detailed in the Vibration Management Plan.

Blasting windows for the open pit activities cannot be synchronised with the underground blast windows. The morning underground blast window will not allow sufficient time to prepare for the open pit blasts. The evening underground blast window would necessitate blasting on the surface within the open pit in non-daylight hours. The midday underground blast window is unlikely to be amenable to synchronised blasting.

It is proposed that the open pit operations limit blasting to an extended window during each day and the details specified in the Vibration Management Plan.

Blasting during times other than within the specified windows is proposed for the underground operations on the basis that compliance with 1mm/s is achieved. This will permit the relatively infrequent small underground blasts to clear blockages, remove oversize and other similar matters that affect production.

Flexibility in the timing of the blast windows for both the underground and open pit operations should be maintained. It is recommended that the Vibration Management Plan is the appropriate document to detail specifics on the blast windows, which complies with current practices.

The duration of the open pit blast activities is not currently restricted by conditions. It has been shown that the geology of the Waihi area affects the number of blastholes that can be initiated within a pattern, necessitating that a delay is introduced between successive blasts to control vibration levels. It is proposed that the duration of the open pit blasting is not restricted by conditions to allow these practices to continue.

The duration of the underground blasts has been previously limited. The Correnso underground blast event duration is limited to 18 seconds to enable successive firing of development and production blasts within the one blast event. No change is proposed to the duration of underground blast events for Project Martha.

Compliance with an overpressure level of 128 dBL has previously been a condition of blasting for the open pit. Given the low levels of overpressure that have been recorded and the demonstrated compliance with the limit, regular monitoring for compliance has not been routinely undertaken but rather assessed in the uncommon instance of overpressure related complaints, or where infrequent blasts that could generate elevated overpressure levels are planned, such as pre-split blasting.

Rather than routine monitoring of overpressure, it is proposed that the overpressure levels from blasting are representatively assessed a minimum of once per quarter, or more frequently when complaints that could be linked with elevated overpressure levels are reported. When no open pit blasting is undertaken in the quarter, there should be no requirement for overpressure monitoring.

The vibration monitoring locations for Project Martha will utilise, where possible, the existing vibration monitoring system although with the relocation of some monitors from the existing Correnso network to alternative locations to provide a more representative network across the Waihi area. A monitoring network has been suggested in this report.

The vibration results from each of the monitoring locations would be displayed shortly after each blast on OGNZL's web page. Updated daily statistics confirming the 95th percentile vibration level at each monitoring location should also be displayed on the same web page. The same approach has been successfully implemented as part of Correnso and SUPA.

The expected scale of blasting, and the associated effects, for each of the Project Martha sites have been based upon an analysis of the recorded vibration levels monitored over the previous 15 year period. These data have been analysed to establish relationships between vibration level, distance and explosive quantity for each of the projects.

The outcomes of the assessment have been presented as a series of vibration contours between 2mm/s and 5mm/s in 1mm/s increments for each of the projects. These contours represent the maximum expected level of vibration at some time throughout the reported period and not necessarily the level that would be recorded day to day from each and every blast. In addition, annualised vibration envelopes that encompass each of the projects are also presented in the analyses and show the range of vibration levels that persons around the Waihi area and closest to the projects would receive over the 11-year mining period for Project Martha.

The analyses and expected levels at or near the surface also show that any impact of the blasting activities on the old workings would not cause them to unravel to the point of collapse. The expected levels of vibration are below those acceptable vibration values given in the HDC commissioned 2001 Geological Nuclear Science (GNS) study into the collapse at Barry Road.

The analyses have shown that compliance with the proposed 5mm/s vibration criterion at each of the adjacent sensitive receivers will require strict control over explosive weights and result in explosive weights varying from less than 2 kilograms through to potentially 30 kilograms for those areas further away from the residents or in the deeper areas of the MP4 pit or the underground mine. OGNZL has previously demonstrated through the mining of Martha, Favona, Trio, Correnso and SUPA, its capability to incorporate similar explosive weights into its mine schedule. It is fully expected that blasting for the Project Martha can be similarly accommodated.

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1. BACKGROUND

At current mining and processing rates the known mineral resource for the Waihi operation will be exhausted at the end of 2019. Ongoing exploration and mine optimisation has identified further mineral resources (Au and Ag) that can be economically recovered.

This project description outlines a proposal, named Project Martha, for extending the mine life by developing these additional resources. The Project comprises two key components:

- The Martha Phase 4 pit (MP4);
- The Martha Underground, including the Rex orebody[2]

The Phase 4 pit and the underground mine can provide a total ore tonnage of 4.5Mt which exceeds the remaining tailings capacity at the end of the current "life-of-mine". The Company will decide based on the prevailing economics at that time, whether to process the open pit feed in preference to the underground feed or alternatively to complete the underground mine in preference to completing the open pit.

Project Martha has the potential to add 0.7Moz of profitable production over an 11-year period.

The surface works associated with Project Martha are being undertaken in the Martha Mineral, Residential and Low Density Residential Zones of the Hauraki District Plan. The underground mining will be undertaken below the Martha Mineral, Active Reserve, Residential and Town Centre Zones.

Project Martha will be authorised by resource consents from the Hauraki District Council and the Waikato Regional Council. The resource consent applications from the Hauraki District Council will be classified as non-complying activities – in part due to 'mining operations' being a non-complying activity in all zones other than the Martha Mineral Zone.

The key outcomes sought by the Hauraki District Plan relevant to the vibration assessment are:

- Provide for the utilisation of the mineral resource in the Martha Mineral Zone in a sustainable manner;
- Provide for the social, economic and cultural well-being of the people of the District, and for their health and safety;
- Ensure that the amenity values of Waihi and the wider community are protected;
- Ensure that vibration levels generated by land use activities do not adversely affect the amenity values enjoyed by other land users.

This vibration assessment has been prepared to ensure that Project Martha can be undertaken in a manner that is consistent with these key outcomes in the first instance, or at worst, demonstrating that the project is clearly not contrary to them.

2. PROJECT DESCRIPTION

The resource consent application will seek to provide for multiple mining areas using both open pit and underground mining methods. There is sufficient confidence around the geological resources to define the works required for this new mining opportunity. The Project will use:

- The existing processing plant in its current configuration for the processing of ore;
- The existing tailings storage facilities (TSF1A and TSF2) for the disposal of tailings.

[2] Vibration from mining the Rex orebody is assessed in this report separately from the remainder of the Martha Underground because of its location under residential and other privately owned properties

- The existing tailings storage embankments and permanent stockpiles for the disposal of some rock, with the remainder used as underground backfill;
- The existing water treatment plant and reverse osmosis plant in their current configurations for the treatment of mine water discharges;
- The existing mine accesses.

The following sections of the report detail the components that make up the Project, the components are:

- Martha Underground;
- Rex orebody;
- Martha Phase 4.

This technical report addresses only the blasting related effects associated with these planned mining areas.

2.1. Martha Underground

This application seeks resource consents for the Martha Underground Mine which covers underground mining from development and mining through to rehabilitation of the land, including but not limited to:

- Use of existing surface and underground facilities and infrastructure;
- Portals, access drives, declines and inclines;
- Ventilation drives and ventilation shafts including any surface expression associated with a ventilation network;
- Sill drive development (development in the ore body);
- Underground mining, including drilling, blasting, earthworks and the removal of rock and ore;
- Dewatering;
- Discharges to air;
- Underground support facilities including maintenance and servicing workshop areas;
- Ongoing exploration;
- Rehabilitation activities including backfilling of stopes with rock and cemented aggregate fill, and re-flooding of the workings.

The assessment for Project Martha re-evaluated and updated the underground mining aspects for the Martha Mine. Ore sources comprise previously unmined blocks – AVOCA stopes, remnant mining blocks either backfilled or skins on unfilled stopes and ore development. *Figure **1*** shows a long section looking north with AVOCA stopes shown in green, remnant backfilled stopes shown in yellow and remnant unfilled stopes shown in red.

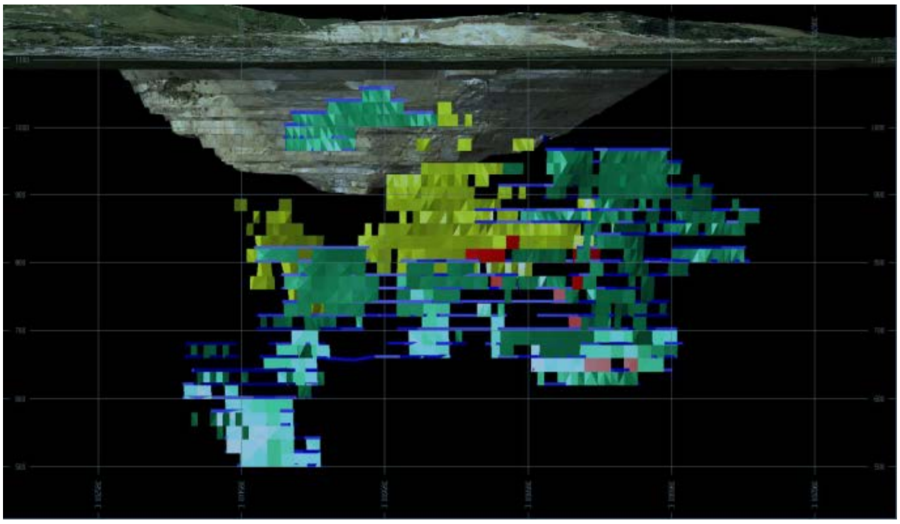


Figure 1 - Conceptual long section of the Martha Underground ore sources

The following assessment of blast-related vibration applies to wherever mining occurs and whatever method of mining is used.

In terms of scheduling, the Martha Underground is accessed from Correnso in Year 1 with decline development, stockpiling areas and return air accesses developed. A total of 4 kilometres of development is undertaken in Year 1 ramping up to 8 kilometres of sustainable development over years 2 to 4 and declining through to Year 9 when all development is completed. Stoping (and related blasting) occurs in the Rex orebody during Years 2 and 3, and in the remainder of the Martha Underground it ramps up from a very small scale in Year 1 to a relatively consistent rate for Years 4 to 9, peaking in Year 5, before declining through Years 10 and 11.

2.1. Rex Orebody

The application seeks resource consents for the Rex orebody as part of the Martha Underground, which covers underground mining from development and mining through to closure. The Rex orebody is accessed off the Martha Drill Drive Project and is located beneath residential and commercial areas as shown in *Figure **2***. As already stated, blasting in the Rex orebody has been considered separately in recognition that it is overlain by privately-owned properties and hence likely to attract consent conditions similar to Correnso that might differ slightly from those applicable to the remainder of the Martha Underground.

Figure 2 - Plan of the Rex orebody

Recent drilling has highlighted high grade intercepts on the Rex lode approximately 100 to 250 metres below the surface. Details include:

- The Project is planned to extract 225,000 tonnes of ore;
- The Project requires minimal development as access is provided by the Martha Drill Drive Project which is currently being permitted;
- The Project will be serviced by a single spiral decline and dedicated escape raise / return air raise;
- It is proposed the mining method will be conventional AVOCA mining as per Correnso;
- Sublevel intervals, blasting and backfilling practices will be the same as Correnso;
- No surface expressions of the Project are required.

The Rex orebody is developed off the Martha Drill Drive accessed via Correnso. The Project comprises around 2.95 kilometres of waste development including the spiral decline and this will be completed in Year 1. Ventilation and escape raises are also established. Rock will be taken to the surface and stockpiled or backfilled directly into Correnso or SUPA stopes where these are available. Ore development is completed in Year 2 and stoping undertaken in Years 2 and 3. Backfill will be sourced from the development of the Martha Underground Project.

Mining of the Rex orebody is expected to be undertaken with practices typical of small blasthole development blasting. The approach is consistent with blasting undertaken for Favona, Trio and Correnso development and mining activities.

The location of the Rex orebody in relation to populated areas makes blast vibration control an important engineering consideration. This is addressed via the following control measures:

- Reduction in level spacing to 15 metres to reduce blast hole lengths and hence assist in reducing blast vibration by limiting the maximum charge length as much as possible;
- Anticipated to be smaller diameter drill holes, deck charging of holes and use of a lower bulk density explosive;
- Use of overhand cut and fill in the upper levels, as required.

2.2. Martha Phase 4 Pit

The application seeks a land use consent for the MP4 Pit which covers open pit mining and mining operations from development and mining through to rehabilitation of the land.

The Phase 4 cut back will be mined in a single top down sequence. The pit is shown in *Figure* ***3***. Points of note are:

- Requires partial relocation / realignment of Cambridge Road / Bulltown Road;
- Provides waste rock to backfill the underground mine;
- Requires noise bunds to be constructed on the north wall.

Figure 3 - Conceptual plan of the MP4 pit

As a consequence of the general proximity to residences, the blasting activities for MP4 will necessarily require the same high level of control as has been used throughout the 30 years of surface mining and mining operations in Martha. It is likely blasting will be undertaken using emulsion and electronic detonators.

The Phase 4 pit will employ drill and blast techniques typical of those near to residential areas. Benches with a height of up to 5 metres will be drilled with small diameter blastholes and loaded with bulk explosives. Maximum explosive quantities per blasthole are expected to vary up to around 10 kilograms. Best practices will continue to be followed with respect to controlling potential environmental effects of vibration, overpressure and fly rock, including implementing practices presented in a detailed Vibration Management Plan.

3. POTENTIAL ENVIRONMENTAL EFFECTS FROM BLASTING

The environmental impacts of blasting occur as one or more of three main effects – vibration, overpressure (air borne vibration), and flyrock. The potential impacts depend upon the nature of the operation (open pit or underground) as well as the scale of blasting and the proximity of the activities to sensitive receivers.

Both vibration and air overpressure will occur to varying extents from all open pit blasting. Through appropriate blasting practices and a blast design philosophy that varies the scale of blasting according to the distance to the nearest sensitive receiver, the levels of ground vibration and overpressure can be controlled to acceptable values. Overpressure from underground blasting is typically not an issue.

Flyrock can be considered to refer to the movement of rock beyond a small working area around the blast pattern, commonly of the order of 20 to 50 metres. Like ground vibration and air overpressure, flyrock can also be controlled, as demonstrated by the few isolated instances of flyrock that have occurred from the many thousands of blasts that have occurred at the Waihi sites. Flyrock does not occur from underground blasting.

Levels of both vibration and overpressure can be assessed and the levels compared against international standards, guidelines or other peer reviewed values to confirm their acceptability with respect to personal amenity or structural damage. There are however no quantitative standards for flyrock and an acceptance of the potential consequences generally compares to the proximity of sensitive infrastructure and personnel with the scale of blasting.

3.1. Ground Vibrations

High levels of ground vibrations have the potential to impact on both human comfort and structural integrity. Most international standards and legislation, including the Operative Hauraki District Plan criteria and the Australian Standard AS2187.2[3], present levels of vibration that best aim to ensure that blast-induced vibration levels are maintained at or below levels of human tolerance. These documents limit the permissible levels of vibration to well below those capable of causing structural, or even cosmetic, damage to residential or commercial structures. Whilst compliance with such limits does not necessarily ensure residents surrounding the operation will not perceive the vibration from blasting, it ensures that a high percentage of the population will be tolerant of the blasting. Compliance with the same levels effectively guarantees that property damage is eliminated.

3.2. Human Perception of Ground Vibration

Early research on human sensitivity to vibration concentrated on the response to continuous vibration, such as that produced by traffic, rail movements or mechanically induced vibration like that generated by tunnel boring machines, hydraulic hammers, vibratory rollers and so on. These studies gave rise to many of the commonly referenced degrees of perception, including the often quoted table in the German Standard DIN4150, 1975[4]. The table is given below:

Approximate Vibration Level	*Degree of Perception*
0.10 mm/s	Not felt
0.15 mm/s	Threshold of perception
0.35 mm/s	Barely noticeable
1.0 mm/s	Noticeable
2.2 mm/s	Easily noticeable
6 mm/s	Strongly noticeable
14 mm/s	Very strongly noticeable

Table 1 - Summary of vibration perception based upon German Standard DIN4150

*Table **1*** suggests that human perception of vibration (i.e. when one can sense vibration), as distinct from human comfort or amenity considerations, occurs around 0.2mm/s with vibration amplitudes around 1mm/s being described as noticeable. Because of their continuous nature, the degrees of perception and their corresponding equivalent vibration levels are often thought to be lower than the comparable impulsive vibration level like that generated by blasting.

A later study by Wiss[5] addressed the response of people to transient vibration of similar characteristics to that produced by blasting activities. The study concluded that vibration levels between 1 and 5mm/s were considered "*barely perceptible*", levels between 5 and 20mm/s were considered "*distinctly perceptible*", and beyond 20mm/s, the levels were "*strongly perceptible*" to "*severe*". Wiss's chart is reproduced as *Figure **4***.

[3] AS2187.2-2006 Australian Standard, "Explosives Storage and Use- Use of explosives", Australian Standards, SAI Global
[4] DIN4150-2 (1975) Structural vibration Part 2 – Human exposure to vibration in buildings
[5] Wiss.J.F.,(1981), "Construction Vibrations: State of the art", Proceedings of the American Society of Civil Engineers, Journal of the Geotechnical Division, Volume 107.

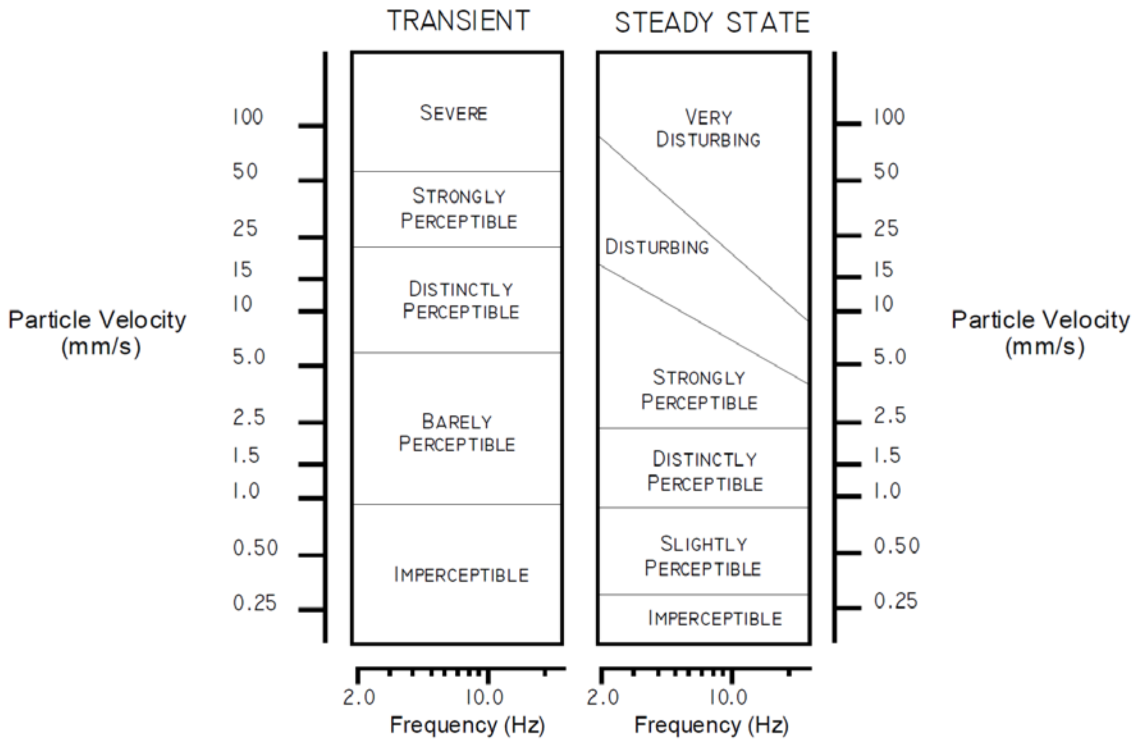


Figure 4 - Human response to vibration from transient and steady state vibration events (Wiss, 1981)

When compared to other more commonly observed responses from residents living adjacent to quarrying and mining activities, these "*transient*" based responses appear to lie at the higher end of associated effects. That is, a vibration level of 5mm/s would more likely be classed as "*distinctly perceptible*" rather than "*barely perceptible*". Based upon information collected by Heilig & Partners at many sites over a thirty year period, the response of most individuals to blasting tends to better align with Wiss's finding for "*steady state*" events, that is:

- Less than 0.3mm/s is imperceptible;
- Between 0.3mm/s and 1mm/s is slightly perceptible;
- Between 1mm/s and 2.5mm/s is distinctly perceptible;
- Between 2.5mm/s and 5mm/s is strongly perceptible.

For a compliance vibration level of 5mm/s, the vibration would therefore be classed as perceptible, but to varying degrees, rather than as disturbing.

Although Wiss's description of the degrees of perception may differ from that presented in the German Standard DIN4150 values for continuous vibration given in Table 1, there appears consistency between assessment of continuous vibration given in the DIN4150 document, the steady state vibration referred to by Wiss, and the observed effects by Heilig & Partners of people living near to quarries and mines.

It is possible that given the duration of a blast generally extends more than a few seconds, it allows persons to subconsciously consider the event more as a continuous source of vibration, suggesting that once the vibration extends more than a few seconds, it has similar impacts to a continuous vibration source.

Heilig & Partners maintains the view that defining a vibration level based on perception and amenity remains the most appropriate basis for a performance standard. People are sensitive to vibration, although may be unable to distinguish between different levels or intensity of vibration. The protection of amenity values as the basis for determining an appropriate vibration limit is also recognised in many of the commonly referred to international standards (Australian, British, German and so on), as well as the limits given in the Operative Hauraki District Plan.

Vibration levels based on human comfort are also significantly more stringent than those aligned with the protection of the built environment from structural or cosmetic damage. Therefore, setting vibration limits for human comfort will in turn ensure no structural or cosmetic damage to buildings.

It is noted that the degree of acceptance or otherwise of vibration is dependent upon numerous factors in addition to the vibration amplitude, such as the length of time of the vibration event, the frequency spectrum of vibration, the number of occurrences per day, the time they occur and the magnitude. Other aspects such as the project duration and extent of community awareness are equally important in assessing its "*degree of acceptance*".

3.1. Damage to Buildings from Ground Vibration

Most International standards, legislation, and guidelines, including the conditions currently applicable at Waihi, were developed to ensure that induced vibration levels are maintained at or below levels of human tolerance. These documents limit the permissible levels of vibration well below those capable of causing structural, or even cosmetic, damage to residential structures.

It is well accepted that residential and commercial dwellings as well as other infrastructure can withstand vibration levels far greater than those applied for personal amenity. Not surprisingly, vibration criteria representing the on-set of damage are therefore higher than commonly quoted environmental conditions applied for residential areas for quarry and mine blasting. It is also accepted that both frequency and amplitude of vibration affect the possibility of damage. For the same reasons that low frequency vibration, like earthquakes, are damaging and accompanied by low limits, high frequency vibrations, as occur at much closer distances, result in lower displacements and correspondingly reduced chances of damage.

The relationship between vibration and building damage has been intensively studied and reported in the literature. The International Society of Explosives Engineers reference database alone has more than 1700 articles discussing vibration and the on-set of damage. Some of these papers have been used to guide the permissible criteria that have been presented in the International Standards commonly applied to blasting studies, such as the Australian Standard AS2187.2[6]. This commonly applied standard further references the widely recognised British Standard BS6472[7], Part 2 which lists levels for the prevention of minor or cosmetic damage occurring to structures from ground vibration generated by vibration. The table is reproduced below:

Type of Building	*Peak component particle velocity in frequency range of predominant pulse*	
	4Hz to 15Hz	*15 Hz and above*
Reinforced or framed structures. Industrial and heavy commercial buildings	50mm/s at 4 Hz and above	
Un-reinforced or light framed structure. Residential or light commercial type buildings	15mm/s at 4 Hz increasing to 20mm/s at 15Hz	20mm/s at 15 Hz increasing to 50mm/s at 40 Hz and above

Table 2 - Transient vibration guide values for cosmetic damage (BS7385-2)

The standard further defines cosmetic damage as the formation of hairline cracks on drywall surfaces, the growth of existing cracks in plaster or drywall surfaces or the formation of hairline cracks in the mortar joints of brick/concrete constructions. Minor damage is defined as the formation of cracks or

[6] AS2187.2-2006, "Explosives Storage and Use – Use of explosives", SAI Global
[7] BS7385, Part 2 Evaluation and measurement for vibration in buildings – Part 2 – Guide to damage levels from ground borne vibration

loosening and falling of plaster or drywall surfaces, or cracks through brick/concrete blocks. The same standard proposes limits for ground vibration for control of damage to structures as shown in the following table.

Category	*Peak component particle velocity (mm/s)*
Other structures or architectural elements that include masonry, plaster and plasterboard in their construction	Frequency dependent damage limit criteria as in Table J4.4.2.1
Unoccupied structures of reinforced concrete or steel construction	100mm/s maximum unless agreement is reached with the owner that a higher limit may apply
Service elements, such as pipelines, powerlines and cables	Limit to be determined by structural design methodology

Table 3 - Recommended ground vibration limits for control of damage to structures (taken from AS2187.2 Section J)

Given the frequency of vibration from blasting in the Correnso orebody is generally above 40Hz for those occurrences of elevated levels of vibration, *Table* ***2*** indicates that damage to residential and commercial type buildings is very unlikely.

A perceived association between blasting vibrations and those from earthquakes is common for those people around mines and quarries, and commonly centres on whether there is any correlation between the "*Richter Magnitude*" and the compliance limit expressed in mm/s. People are aware of the effects of the Christchurch earthquake and how it was felt by residents, as well as the damage that it caused. The Christchurch earthquake registered a magnitude of 7.1.

It is generally considered that people seeking the relationship between earthquake and blast generated vibrations do so to obtain some concept of the likelihood of damage to their property. Aside from having very different characteristics in terms of frequency, amplitude, duration and wavelength, most importantly, the Richter scale defines earthquakes by the magnitude of the energy at the source of the earthquake and provides no indication of the vibration at the point of concern. A high magnitude, deep sourced earthquake could have minor impact on the surface when compared to a smaller magnitude, shallow sourced earthquake. Of greater importance, is the intensity which indicates how strong the shaking was at the point of concern. however the Richter scale continues to be the most widely used description for earthquakes

Ground vibration from earthquakes usually fall in the frequency range of 0.1Hz to 10Hz. Ground vibrations from blasting at Waihi falls in the window of 10Hz to 50Hz and above.

It is generally accepted that a low frequency earthquake with an acceleration of around 0.1g would have potential for damage whilst a low frequency earthquake with an acceleration of around 1.0g would be highly destructive. In contrast, an acceleration of 1.09g from blasting at Waihi would be of little concern.

Perhaps the best comparison between vibration from earthquakes and blasting considers the very different frequencies of both and the different displacements that each may cause. In the following table, the displacement (i.e. the distance that the ground moves) is given for different frequencies and amplitudes.

Description	Frequency of Vibration	Amplitude of Vibration	Displacement	Comment
Waihi conditions of 5mm/s	20Hz	5mm/s	40 microns	Movement around ½ the thickness of a sheet of paper
Maximum level of vibration recorded at Waihi on the 12th September 2005	21Hz	8.89mm/s	67 microns	Movement around 2/3 the thickness of a sheet of paper. Acceleration of 0.12g
Low frequency, minor earthquake	0.2Hz	780mm/s	0.6 metres	Minor earthquake measuring 0.1g generating displacements of 0.6 metres
Low frequency, major earthquake	1Hz	3100mm/s	1 metre	Significant earthquake generating widespread damage

Table 4 - Comparison of earthquake and blast induced vibration

In addition to the significantly lower frequencies, earthquakes also possess very long wavelengths which tend to move a structure in its entirety rather than blast vibrations which are higher frequency and pulse through the property.

Several efforts have also been made to compare the energy of blasting activities with that of earthquakes. A relationship referenced by Anderson[8] suggests that an earthquake equivalent to the Christchurch 7.1 Richter magnitude on the 4th September, 2010 had the equivalent explosive energy of approximately 150 billion kilograms of explosive. Typical explosive quantities for the Waihi blasting are generally not more than 1000 kilograms per blast.

The analyses demonstrate that an assessment of the vibration from earthquakes, both in terms of how it is perceived by residents as well as how it may damage a property, is of little relevance. The very different frequencies of vibration, duration of vibration, wavelengths and energy at the source do not permit a valid comparison.

3.1. Vibration Effects on Old Mine Working

A collapse of old mine workings in 1999 and again in December 2001 led to surface subsidence in the area south and east of the Martha pit. A review of the potential effects and any contributing source from the Martha blasting was undertaken and a report prepared in January 2002. The report was reviewed by the Institute of Geological and Nuclear Sciences who concluded the findings of the document were accurate and agreed that the impact of blasting on the underground workings was not a contributing factor in the collapse events. Some of the key findings from the 2002 assessment are reproduced below.

The report noted many studies that considered whether there is a link between vibration generated by mine, quarry or construction blasting with the loss of stability in underground rock masses or openings. Typically, these studies have measured the level of vibration, via geophones or accelerometers, and correlated such data with observations of damage. Damage may be detected visually, such as spalling of loose material, or by using detailed methods such as borehole cameras, seismic scanning, ground probing radar etc.

Where the measured level of vibration has been high, relative to the strength of the rock, damage to the rock mass occurs via fall of rocks from unsupported openings. Through the continued impact of these high levels of vibration, damage of this type could be expected to ultimately contribute to the collapse of a large area. Failure in this instance occurs where the strength of the rock mass (either tensile or shear) has been exceeded by the energy contained in the vibration pulse and the rock is

[8] Anderson, D.A (1994), "Tell Me Professor Richter – How much did they shoot", Proceedings of Society of Explosives Engineers Annual Conference

fractured and falls from the edges of the opening. At a lower level of vibration, where the energy is insufficient to fracture the rock mass, it may however be adequate to cause weakly held rock particles to become dislodged from around the perimeter of the underground opening. At even lower levels of vibration, the energy is insufficient to cause the detachment of even these weakly held rock fragments.

The 2002 report concluded that the level of vibration generated by mine blasting was incapable of causing rock failure or promoting stope void migration for the Waihi area. Whilst the level of vibration at the exposed void face may be capable of dislodging loosely or precariously positioned rocks, the energy within the vibration pulse will be incapable of creating new and intersecting fractures that could result in larger scale failure and significant increase in the void size. Any dislodged rocks will however have played no part in the overall stability of any existing and/or open voids.

It is concluded that based upon the scale of blasting that will occur in the MP4, the Martha Underground or the Rex orebody, the vibration from blasting would not induce or accelerate any instability of the old underground workings. Any fretting of the stope walls will be controlled by adopting minimum standoff distances or through the low level support afforded by the backfill material.

3.2. Airblast Overpressure

Overpressure from blasting refers to the momentary levels of pressure above atmospheric pressure. It is measured irrespective of frequency with no weighting, and on this basis, is distinguished from noise criteria. Blasting is not assessed against a value with respect to its audibility.

Unlike vibration which can be perceived at very low levels, any direct perception of overpressure is unlikely unless the level of overpressure exceeds 145 to 150dBL. The perceived effect on people at these elevated levels is commonly felt as a pulse impacting on the chest or face. These levels rarely occur from blasting unless the receiver is very close to a blast, typically within tens of metres.

In terms of personal injury, in a United States Bureau of Mines (USBM) document[9], reference is made to the likelihood of injury and hearing damage from impulsive noise. The document refers to a threshold of ear drum rupture and inner ear damage of 178 to 185dBL. Although these levels are high, the same reference further states that no ear protection is required for peak levels below 140dBL, regardless of the number of events per day or the duration of these events.

Perhaps more appropriate is the reference to work completed by the Committee on Hearing, Bioacoustics and Biomechanics in Washington discussing tolerance for humans. Their work, also referenced in the same USBM document, identified an allowable level with respect to personal impact of 139dBL for blasting type activities.

Little research has been completed on the issue of the subjective response of people to blast overpressure. The challenge arises as a consequence that a significant portion of the energy contained in the overpressure response is outside of the usual hearing frequency range, is of short duration and affects relatively few people for anything other than short periods of time.

The most commonly observed effect of elevated overpressure levels is the associated rattling that it may cause to some parts of a dwelling, such as ill-fitting windows, loose timber panelling and so on. In this manner, the effect is often confused with that of elevated vibration.

At low levels of overpressure like those generated by well controlled blasting, the effect is not detrimental to persons, is incapable of damaging any property, and furthermore, unlikely to cause rattling and other side effects mistaken for increased vibration levels.

4. TYPE AND SCALE OF BLASTING

The type of blasting differs according to whether it occurs for the open pit or underground operations. Blast patterns for the open pit operation tend to be simpler, involving drilling of blastholes on a regular

[9] Siskind, D.E., Stachura, V.J., and Stagg, M.S., 1980. "Structure Response and Damage Produced by Airblast from Surface Mining", United States Bureau of Mines, Report of Investigations No 8485.

pattern to a consistent depth, loading a known quantity of explosive into the base of the blasthole, adding stemming material to the blasthole above the explosive column and initiating the blast with a series with small intervals between successively detonated blastholes.

Blasting in underground operations is more complex and broadly either classed as development or production. Development blasting is small scale, in terms of the blasthole diameter, blasthole length, explosive weight and overall yield of broken rock. Production blasting is larger scale, although less than the amount of rock broken by an open pit blast. The blasting is significantly more detailed in design than open pit blasting.

Blasting is always engineered to minimise the potential risks and consequences of vibration, as well as overpressure and flyrock (in the case of open pit blasting).

4.1. Open Pit Blasting

Drilling and blasting is expected to be required for the removal of the ore and other rock from all open pit areas, possibly excluding some of the upper areas which may be free dig or those areas of debris within the MP4 pit associated with the north wall failure.

The scale of blasting will be one that promotes environmental compliance, and in particular, compliance with the vibration restrictions. Over the previous 30 years, the Martha operation has undertaken blasting practices aligned with conventional small scale drilling and blasting operations and achieved a very high degree of compliance (>99%).

Drill and blast design is a stepped process and involves the following stages:

- Design of drill and blast patterns, including burden and spacing, hole depths, air decks, explosive weights and number of blastholes, are detailed in a pre-blast plan. Probe drilling is completed in advance of the blasthole drilling to identify any old workings or open voids. These techniques are part of best practices and assist in controlling both vibration and flyrock;
- The drilling pattern is marked out in accordance with the prepared plan.
- The blast pattern is loaded according to instructions in the Vibration Management Plan,
- The firing of the drill and blast pattern is sequenced using inter-hole delays that best promotes minimum vibration levels and achieves the required fragmentation and diggability.

The open pit resource will be designed around 5 metre benches, although some of the upper sections of the MP4 pit may use smaller 2.5 metre benches as a vibration control measure. The blasthole diameter is expected to be consistent with current blasting practices at 89mm. The blasting configuration for a 5 metre bench height with ½ metre of sub-drill, an 89 mm diameter blasthole, a 2.6 metre uncharged collar height and loaded with bulk explosive as shown in *Figure* **5** is typical of previous Martha blasting. The uncharged collar length of 2.6 metres is proposed to limit air overpressure levels and control any ejection of material from around the blasthole. *Figure* **5** also shows the blasthole design for the smaller 2.5 metre bench height.

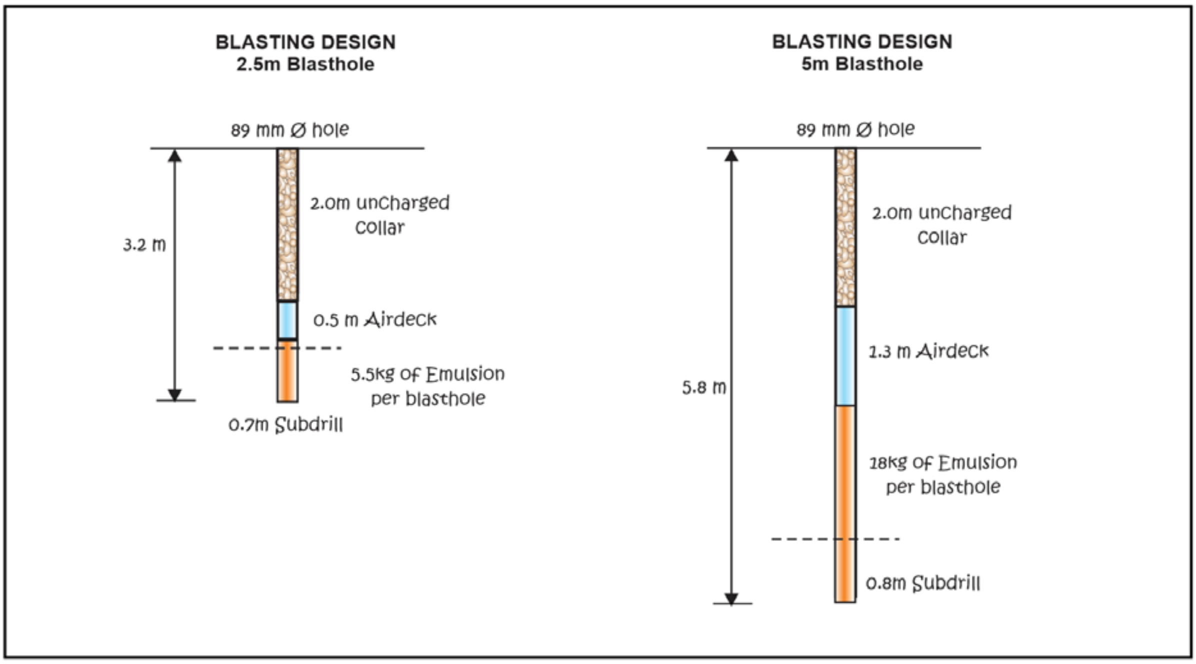


Figure 5- Drilling and blasting design for 2.5 and 5 metre benches

The explosive density typically lies between 1.15 and 1.20g/cm^3.

4.2. Underground Development Blasting

Underground development blasting is small scale horizontal or inclined blasting specifically undertaken in underground operations to provide access for the subsequent larger production blasting activities. Whilst the development blasting process may produce some ore in those locations where the development occurs within the orebody, the blast design and effects with respect to vibration do not differ from those where blasting occurs away from the orebody.

The primary objective of development blasting is to allow access to the orebody (i.e. construct drives or tunnels). This may include developing an access for production or exploration drilling or for haulage of the blasted ore and rock.

Development blasting is significantly different from production blasting. The differences include:

- Blasthole diameter: Development blasting utilises a small blasthole diameter commonly in the range of 45mm to 51mm. Production blasting uses larger blasthole diameters in the range of 64mm to 89mm;
- Blasthole length: The maximum blasthole length for a development blast is around 3 metres compared with up to 18 metres or more for a production blasthole;
- Blast yield: The yield from a development blast is typically around 280 tonnes compared with several thousand tonnes from production blasting;
- Blast duration: Development blasts are initiated over a 10 second window compared with the production blasts which are shorter (complete within several seconds);
- Explosive quantity: Development blasts typically use around 150 kilograms of explosive in total with each blasthole containing up to 4 kilograms of explosive. Production blasts may contain several hundred kilograms of explosive in total with each hole containing up to 30 kilograms.

With respect to the vibration generated by the different types of blasting, development blasting generally produces significantly lower levels of vibration than that produced by production blasting. This is by virtue of the lesser explosive quantity associated with the smaller diameter blasthole and the smaller length of blasthole. The lower level vibration however persists longer than that produced from a production blast due to the different initiation systems.

4.3. Underground Production Blasting

Production blasting of the stopes occurs after the accesses have been developed and is restricted to within the orebody.

The production stopes are planned as the main source of ore from the underground operations. The stope sizes are typically small, around several thousand tonnes, and constrained by the geometry, particularly the width, of the orebody and the geotechnical parameters that define its stability.

In general, it is anticipated that stope sizes will be consistent with the Favona, Trio and Correnso underground operations, with distances between sub-levels varying between 12 and 20 metres (back or roof of one level to the floor of the level above) depending upon the depth below surface. Larger sub-level intervals require greater explosive weights which are only possible within the deeper stopes that are more distant from sensitive receivers. Blasthole diameter will necessarily be small and lie in the 64 to 89mm diameter range. Explosive type will depend upon ground conditions and vibration constraints however a low density bulk emulsion, low density ANFO or ANFO will be typically used. These explosive types are consistent with the current underground operations.

5. LEGISLATION AND POLICY

The purpose of this report is to identify the vibration and associated impacts from blasting activities associated with Project Martha, and to propose methods and monitoring that can be included in consent conditions and management plans to ensure that the effects on people (and structures) are reasonable and are at least as restrictive as those widely accepted internationally, while at the same time not imposing unrealistic restrictions on the ability to mine efficiently.

5.1. New Zealand RMA

The Resource Management Act (1991) requires that local councils ensure the effects on the environment are managed sustainably.

This technical report is prepared to assist the Hauraki District Council in quantifying the effects of the blasting activities associated with Project Martha, including the methods by which some of the effects may be mitigated or controlled to permissible values.

5.2. Hauraki District Plan

Section 8.3.2.1 of the Operative Hauraki District Plan provides commentary on the effects of ground vibration, how it may affect structures or personal amenity, and a series of permissible levels for different activities. Section 8.3.2.1 states:

(1) Introduction –

- *a. Ground vibration from land use activities can range in effect from structural damage to buildings (relatively extreme level of vibration) to disturbance of sleep and reduction of amenity as a result of people being able to perceive vibration. It is considered that ground vibration standards should be set in terms of human perception rather than in relation to the structural implications for buildings, thus ensuring that the amenity values of any area are not unreasonably compromised.*
- *b. Measurement of vibration is taken in the ground rather than in affected buildings, as buildings respond differently and thus the vibration response in the building may amplify ground vibration. It is beyond the scope of this standard to define that response.*

(2) Types of Ground Vibration

- *a. Ground vibration may be continuous or transient, with transient vibration being either impulsive or intermittent vibration.*

b. *Continuous vibration is vibration that remains uninterrupted over a given time period, typically a period of several minutes or more (e.g. vibration generated by construction equipment such as impact and vibratory rollers).*

c. *Impulsive vibration is a short duration event, that involves the rapid build-up of vibration then decay, that may comprise a single pulse or a number of pulses (e.g. vibration generated by blasting)*

d. *Intermittent vibration is a string of vibration incidents, each of short duration and separated by intervals of a much lower vibration magnitude*

e. *Acceptable levels for continuous vibration are considerably less than those for transient vibration.*

(4) Transient Vibration[10]

(a) Isolated vibration events that occur infrequently and/or irregularly (e.g. only a few times a day) present special concerns to residents and accordingly must also be addressed and managed. This will be done by setting an appropriate standard for transient vibration, to ensure that amenity values are maintained at a reasonable level. Any transient vibration in excess of the standards set may be considered through the resource consent process and the standards set out in this rule will be used a guideline in setting conditions.

(b) Vibrations from blasting are impulsive, of short duration and superimposed on background vibration levels

(c) Human response to transient vibration can be wide ranging, with the same event being imperceptible to some persons, while causing nuisance to others

(d)The standards set to control transient vibration are based on international standards and monitoring and experience, developed to protect and preserve amenity values

(e) In considering transient vibration from the perspective of human perception the following levels have been adopted.

Transient Vibration Level	
Less than 0.5mm/s	*Imperceptible (threshold of perception)*
0.5mm/s to 2.0mm/s	*Slightly perceptible (barely noticeable)*
Greater than 2.0mm/s	*Distinctly perceptible (noticeable)*

(f)Transient vibration levels in excess of 5mm/s have the potential to compromise amenity values

(g)As the vibrations are of relatively short duration where V_{Max} is controlled to avoid nuisance the statistical analyses to obtain the 99 percentile vibration levels is of little meaning, as the results depend on the length of vibration record. Accordingly, when monitoring vibrations, the control will be in terms of V_{Max}.

(h) Blasting events should be designed in such a way as to comply with the standards set. However, the Council recognises that the prediction of the maximum ground vibration experienced from any particular blast event is dependent upon distance from the source, ground conditions and design of the blasting pattern. A complex relationship exists between these factors and therefore occasional exceedances of V_{max} may occur.

Section 8.3.2.3 gives standards for vibration and proposes values for continuous and transient vibration. The section on transient vibration is included below:

(a)The maximum limits and parameters for ground vibration exposure resulting from activities other than those using explosives or similar impulsive and energetic materials are:

[10] Section (3) entitled Continuous Vibration has not been included in this report because of its irrelevance

Parameter	*Standard*
Monday to Saturday 0700-1800	*5mm/second peak amplitude (Vmax)*
All other times and on Sundays and public holidays	*1mm/second peak amplitude (Vmax)*

(b)The maximum limits for ground vibration and overpressure exposure resulting from activities using explosives or similar impulsive and energetic materials are:

Parameter	*Standard*
(1) Blast Event[11] Duration as defined by the delay timing (ie the difference in time between the first and last charge detonation)	*1 second*
(2) Number of Blast Events per holding, or for exploration activities, per exploration or mining permit area	*3 per day, separated by an interval of not less than 10 minutes between blast events, and no more than 21 within a calendar year*
(3) Overpressure (P_{Max})	*120dBL*
(4) Peak Amplitude (V_{Max})	*5.0 mm/second*
(5) Time of Day	*0700-1800*
(6) Days	*Monday to Saturday (excluding public holidays)*

Section 8.3.2.4 of the District Plan states the following in relation to the 95-percentile:

(7) For resource consents, transient ground vibration is typically set in terms of a 95 percentile, and may include a maximum limit. The percentile limit will generally be applied to the design for each and every blast so that induced disturbances will not exceed the 95 percentile limit on more than 5 percent of occasions (and will never exceed the maximum limit where set). The 95 percentile limit has little meaning for the activities that are permitted under the transient ground vibration limits set in this standard as the derivation of the relationship between explosive charge, distance and ground response required to undertake such a design can only be achieved through a series of trial blasts. Accordingly it is the V_{Max} level as referred to and defined in this standard that is the performance standard for transient ground vibration.

5.3. Comparison with other International standards and guidelines

Performance guidelines for vibration from blasting activities are typically drawn from standards and guidelines from Australia, Britain, Germany or the International Standards Organisation (ISO) because of the high level of detail and analyses that have been applied in developing these guidelines. The standards are necessarily peer reviewed which further enhances their credibility. *Table* ***5*** gives an overview of the relevant standards reviewed and their relevance to the Martha, Favona, Trio, CEPPA and SUPA conditions.

Standard	*Content*	*Relevance to Project Martha*
NZS4403: 1976[12] *The storage, handling and use of explosives (Explosives Code)*	Outdated and withdrawn standard developed in 1976 with no significant updates since initial version. References methods of blasting which are now rarely undertaken. Standard provides values which are significantly higher than other values specified in local district plans or other internationally accepted standards	Initially applied to blasting at Martha as per the expired Mining Licence conditions prior to the ML variation in 2017,

[11] For the purposes of the above standard a "blast event" means an individual or number of linked individual blasted of not more than the total duration specified in (1) above

[12] NZS4403: 1976, Standards Association of New Zealand, Code of Practice for "The storage, handling and use of explosives (Explosives Code)", UDC 614.83:662.2

Standard	*Content*	*Relevance to Project Martha*
(New Zealand Standard)		although now no longer relevant.
ANZEC: 1990[13]	Australia and New Zealand Environment Council document specifically addressing vibration and air overpressure limits for long term activities that recognise amenity for adjacent residents.	Vibration levels consistent with the Hauraki District Plan and Martha, Favona, Trio, CEPPA and SUPA
AS2187.2:2006[14] *Explosives—Storage and use* *(Australian Standard)*	Specifies personal amenity criteria for blasting based upon project duration (Less than or greater than12 months). References BS7385-2:1993 for protecting buildings from vibration related damage from blasting. Proposes ground vibration limits for blasting that are based upon human comfort which necessarily prevent cosmetic or structural damage to dwellings. Specifies a vibration limit for sensitive sites which are described as houses, theatres, schools and other similar buildings occupied by people at 5mm/s. Also specifies a limit of 25mm/s for occupied non-sensitive sites, such as factories and commercial premises.	Consistent with the Hauraki District Plan, the Mining License following the 2017 variation, Favona, Trio, CEPPA and SUPA
BS6472-2:2008[15] *Guide to evaluation of human exposure to vibration in buildings. Blast induced vibration* *(British Standard)*	Supersedes BS6472-1:1992 which was generally considered one of the most authoritative standards in terms of vibration assessment with respect to amenity and damage. Small changes in 2008 version with respect to weighting factors associated with dosage criterion Provides advice in respect of human exposure to blast induced vibration in buildings. Suggests human comfort criteria for building usage categories, listed below in order of increasing sensitivity: • Workshops • Offices • Residential (daytime) • Residential (evening) • Critical working areas. Maximum satisfactory vibration magnitudes for up to three blast vibration events per day vary between 2mm/s for night time residential through to 14mm/s for offices. A daytime residential criteria is set at between 6 and 10mm/s, based upon 90% compliance. Satisfactory air overpressure limits are not given but indicate that a level of 120dBL is around 3% of the minimum level required to crack pre-stressed, poorly mounted windows	Permissible BS6472 levels are higher amplitude than the vibration levels in Hauraki District Plan, the Mining License following the 2017 variation, Favona, Trio, CEPPA and SUPA Suggested compliance percentile is 90%

[13] Australian and new Zealand Environment Council (1990), "*Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration*".
[14] AS2187.2-2006, "Explosives – Storage and use – Use of explosives, SAI Global
[15] BS6472-2:2008, "*Guide to evaluation of human exposure to vibration in buildings Part 2: Blast induced vibration*", British Standards BSI

Standard	*Content*	*Relevance to Project Martha*
BS7385-2:1993[16] *Evaluation and measurement for vibration in buildings. Guide to damage levels from ground borne vibration* *(British Standard)*	Along with the German Standard DIN4150, considered one of the widely referenced standards relating to the protection of buildings. Proposed limits in the standard adopted by the Australian Standard AS2187.2-2006 indicates limits for prevention of cosmetic damage for different building categories Provides guidance on managing buildings and structures which may require case by case consideration (rather than blanket assumptions). For example: • A building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive. • Structures below ground are known to sustain higher levels of vibration and are very resistant to damage unless in very poor condition. • There is little probability of fatigue damage in residential building structures due to normal construction vibration.	Necessarily complied with as a result of the more stringent Hauraki District Plan, the Mining License following the 2017 variation, Favona, Trio, CEPPA and SUPA
DIN4150-3:1999 [17] *Structural vibration Effects of vibration on structures* *(German Standard)*	Well referenced standard that provides guidance for services and structures. For building types consistent with those around Waihi, the standard proposes acceptable values between 5mm/s and 20mm/s, depending upon the frequency of vibration. Typical blast frequencies at Waihi equate to a minimum permissible value of around 10 to 15mm/s. Higher thresholds: may be applied where structure condition is sound.	Necessarily complied with as a result of the more stringent Hauraki District plan values and Mining Licence conditions Often applied in Auckland for the protection of buildings

Table 5 - Summary of permissible levels presented in other international standards and guidelines

6. EXISTING ENVIRONMENT

Section 6 provides background context by outlining the vibration limits that were imposed on the various mining projects around Waihi. The rationale for the differences between the project specific vibration limits and the Operative Hauraki District Plan is also provided.

6.1. Mining Licence Conditions for Martha

The vibration limits for the mining of the Martha deposit have varied over time. The original 1987 Mining Licence 32 2388 limited vibration levels to those specified in the New Zealand NZS4403[18] standard which permitted vibration levels of 50mm/s for frequencies less than 3Hz, decreasing to 12.2mm/s for frequencies up to 10Hz and continuing to reduce to 5mm/s at 20Hz. For frequencies above 20Hz, the limit remained at 5mm/s. In all instances the permissible limit was considered a maximum value measured in any of the three mutually orthogonal directions, rather than a percentile limit or a vector sum value.

[16] *BS7385-2:1993, "Evaluation and measurement for vibration in buildings – Part 2: Guide to damage levels from groundborne vibration", British Standards, BSi*

[17] DIN4150-3, (1999), "*Structural vibration – Effects of vibration on structures*", SAI Global

[18] NZS4403: 1976, Standards Association of New Zealand, Code of Practice for "*The storage, handling and use of explosives (Explosives Code*", UDC 614.83:662.2

Blasting at the Martha operation was restricted to 10am to 3pm for Monday to Friday with a 10am to 12 noon window on Saturday. No blasting was permissible on Sundays or public holidays. There were no further restrictions on the number of blasts or their duration.

An elevated limit of 10mm/s applied during the construction phase of the project.

In 1999, the Extended Martha Mine Project varied the Mining Licence and sought a Land Use Consent identifying a maximum vibration value across all frequencies of 5mm/s to be consistent with the then Operative Hauraki District Plan. Like the 1987 conditions, the limit was the maximum of the three mutually orthogonal directions and a maximum rather than a vector sum value. The previous restrictions in terms of the restricted blast windows applied.

An additional constraint of 25mm/s was applied to the Cornish Pumphouse. The limit of 25mm/s was maintained for the Cornish Pumphouse for all blasting activities within 250 metres.

Blasting in the open pit continued to be limited to 10am to 3pm Monday to Friday and 10am to 12 noon on Saturday. The 10mm/s for construction blasting continued to apply.

The Mining Licence was again varied in 2017 to delete conditions relating to construction blasting and vibration on the basis that that they were superfluous as construction activities authorised under the Mining Licence had been completed. In addition a number of other minor changes were made to delete reference to MEP on the basis that it did not proceed, and resolve inconsistencies including updating the standards for consistency with the Hauraki District Plan.

An overpressure limit, granted with the original Mining Licence and retained through the subsequent variations set a peak overall sound pressure level due to air blasts (overpressure) should not exceed 128dB linear (unweighted) when measured at any affected residence, excluding those properties owned by the Company or subject to an agreement with the Company.

The Mining Licence expired on 16th July 2017, and any activity conducted in accordance with the relevant terms and conditions of, and within the areas covered by Mining Licence 32 2388 are permitted activities subject to conditions in the Hauraki District Plan (refer Rule 5.17.4.1 P1). The vibration and overpressure limits in the Land Use Consent will also become permitted activity rules when that consent expires on 18 October 2019 (refer Rule 5.17.4.2 P2).

6.2. Conditions for Favona

The blasting of the Favona orebody was permitted in two phases, an initial consent in 2003 covering the Favona portal and decline and a second consent in 2004 addressing the mining areas.

The development consent limited the blasting for the portal and decline to 5mm/s for blasting between the hours of 7am and 9pm.

The Favona Underground Mine conditions permitted a slightly elevated permissible criterion of 6mm/s at 95% compliance between 7am and 9pm (Monday to Saturday) on the basis of introducing additional constraints in terms of the blast events and blast durations. The maximum number of blasts at 6 mm/s was limited to four (4) and blasting outside of these hours and on public holidays was restricted to 1mm/s. The limited number of blast events necessitated that on occasions multiple development and production blasts would be initiated concurrently. Modelling demonstrated that a slightly elevated level of vibration up to 6mm/s could occur, however it was agreed that for receivers it would be indistinguishable from a 5mm/s event, and was to be preferred overall in that fewer blast events would be required. All levels were 95 percentile values with limited durations for production blasts of 6 seconds, development blasts of 12 seconds, and combined production/development blasts of 18 seconds.

The distinction between a development and production blast was agreed on the basis of the maximum explosive weight per blasthole of 7 kilograms respectively.

6.3. Conditions for Trio

The Trio orebody was similarly permitted to the Favona orebody with separate consents for the decline and orebody.

The 2010 Land Use Consent for the decline development required compliance with a 1.5mm/s vibration level between 7am and 9pm for blasting on Monday to Saturday. The limit at other times was 1mm/s. No restrictions on the number of blasts or their duration were included as part of the conditions.

The 2011 Land Use Consent for mining of the Trio orebody reflected the Favona conditions, including the same restrictions on the number of blasts, blast durations, blast windows and permissible vibration levels.

The consent conditions specified the monitoring locations where compliance was required.

6.4. Conditions for Correnso

The Correnso Land Use Consent of 2013 further limited the vibration conditions to those imposed by the Favona and Trio Consents. The maximum permissible vibration limit was reduced to 5mm/s for consistency with the Operative Hauraki District Plan with the percentile limit maintained at 95%. Blasting continued to be permitted on Monday to Saturday, although the permissible timeframe for blasting was further restricted by one hour from 9pm to 8pm. The allowable commencement time for blasting remained at 7am.

The number of blasts events was reduced from four to three. Similar restrictions were imposed on the duration of production, development and combined blasts of 6, 9 and 12 seconds with no blast able to extend beyond 18 seconds.

A project specific condition was introduced that required the separated assessment of development and production blasts. Both production and development blasts were assessed against the same 5mm/s criterion. The distinction between production and development blasts was as previously implemented as per the 7 kilogram division.

An additional condition for Correnso related to a constraint on the "*average*" level of vibration. All previous consents necessitated compliance only with the maximum level of vibration. In addition to the maximum level of vibration, the consent required that production blasts were also required to comply with an average vibration criterion of 3mm/s at all monitoring locations calculated over a rolling six month period. Development blasts also required compliance with a lower 2mm/s average limit calculated over a roiling six month average.

The "*average*" criterion was introduced as a supplementary control measure to ensure that mining activities progressed from area to area and therefore limited the short term exposure of residents near to the mining activities.

6.1. Conditions for SUPA/MDDP

The Slevin Underground Project (SUPA) and the Martha Drill Drive Project (MDDP) were granted in 2016 and 2017 respectively and almost mirrored the relevant Correnso conditions. For the SUPA project, development blasting was limited to a 95 percentile limit of 5mm/s with an "*average*" level across each monitoring site of vibration of 2mm/s. Production blasting was limited to a 95 percentile limit of 5mm/s with an average of 3mm/s. Three blast events per day were allowed between the hours of 7am to 8pm for Monday to Saturday.

MDDP involved development blasting only. The conditions for MDDP required the compliance with the same 5mm/s at the 95 percentile limit and a maximum of 2mm/s on average. .

For both projects, blasting on Sundays and public holidays was not allowed.

7. RECOMMENDED BLASTING CONDITIONS

A set of vibration related conditions is proposed for Project Martha. The proposed conditions are generally based around the Hauraki District Plan standards and the conditions of the existing land use consents held by OGNZL, but include a number of changes to better reflect the dual requirements of permitting a mining operation that adheres to best engineering practices as well as an operation that protects the amenity of persons within the environment.

The proposed conditions include changes to some aspects of the previous conditions but they are relatively minor and maintain at least the same level of protection on amenity as those earlier versions. The proposed conditions do not include changes from the current conditions in regard to:

- Peak vibration amplitude
- Number of underground blast events
- Number of open pit blast events
- Duration of open pit blast events
- Restrictions on blasting during evening periods, Sundays or public holidays
- Overpressure monitoring

Whilst the changes that are proposed are around averaging and blast event durations, these are largely administrative and in practice do not depart from conditions that have been previously imposed. The proposed conditions seek changes to the following:

- Separation of production and development blasts
- Average vibration amplitude
- Duration of underground blast events
- Separation of timing between open pit and underground blast events
- Separate monitoring of individual project elements

7.1. Vibration Amplitude

Adopting a single vibration amplitude across the full project is recommended, rather than a limit that varies according to different areas of project. The latter approach would introduce complications to the design and management of blasting that are likely to be more difficult to administer by OGNZL and the Hauraki District Council. In this regard, the following comments are relevant:

- The proposed daytime limit is 95% compliance with 5mm/s. Notwithstanding the very low charge weights required at times, 30 years of experience at Waihi has demonstrated that this limit provides an adequate level of amenity protection and is generally workable within the mining plan, although in accepting this low magnitude it will be important not to overly constrain other aspects of blasting (e.g. duration, numbers of blast events, timing of blasts and so on).
- Previous reviews that considered the impact of reducing the limit to 4mm/s have demonstrated significant operational impediments with no amenity benefit (the difference between 4mm/s and 5mm/s is barely detectable).
- Previous reviews considered the impact of increasing the limit to 6mm/s on the basis that the difference between 5mm/s and 6mm/s is indistinguishable. A limit of 95% compliance with 6mm/s applied to the Favona and Trio underground mines. 6mm/s is not proposed for Project Martha.
- A proposed “out of hours” (including Sundays and public holidays) blasting limit with 1mm/s is recommended to permit small scale works to remedy issues within the mine that impact upon the mining schedule and safefy, such as blasting of oversize, blasting of blockages within drawpoints and so on.

- It is generally presented in the international standards that the vibration amenity limit for persons within commercial or industrial properties is less stringent than for residential properties. The Australian, British and German Standards all propose limits for commercial premises twice that applied for residential properties.
- The Hauraki District Plan makes no differentiation on where its vibration standards apply, but the vibration amplitude limits in all of the existing and past Waihi mine consents apply to ground measurements adjacent to residential dwellings not owned by OGNZL. The same limits are proposed for Project Martha.
- Project Martha will necessitate some areas of blasting closer to the Waihi CBD than has been undertaken for other projects, but the 5mm/s limit is still proposed at those commercial buildings that could be used for residential purposes, effectively setting the same limit for most of the CBD.

7.2. Separating Development and Production Blasts

The consent conditions for Correnso required separating the recorded vibration values from development and production blasting. The intent of the condition was to prevent dilution of the 95% compliance statistic for the generally higher amplitude production blasts by the lesser magnitude development blasts.

Project Martha comprises both open pit and underground blasts. There will be no development blasting within the open pits making the separation meaningless for those elements and hence of questionable benefit to the project overall.

As a general statement, to a resident who perceives vibration from the mining activities, the origin of the vibration and whether this is production or development related appears irrelevant.

7.3. Average Vibration Limits

In addition to the separate reporting of production and development blasts required under the Correnso consent conditions, OGZNL is also required to comply with an additional “*average”* vibration limit for each blast type (production and development). The intent of imposing an “*average”* limit was to ensure that production blasting did not continue near a given location (and group of residences) for an extended period of time, or to reduce the overall vibration effect if it did.

The conditions for all other Waihi based mining activities calculate the 95 percentile statistic on the basis of the maximum measured vibration level, irrespective of where that level is recorded. While the “average” was imposed to ensure the site of blasting moved with time, the reality is that the nature of mining necessitates that this occurs anyway. The result with or without an average limit is that for a period, some areas could experience elevated levels of vibration whilst other areas lower levels of vibration, but once an area is blasted the activity must move away to the next area.

The following *Figure* ***6*** shows the recorded levels of vibration at the “*Main Central*” location from production blasting within Correnso for the six month period between the 1st January and 30th June, 2017. The two trends lines show the 95 percentile and the average level of vibration for the six month period. The 95 percentile and average levels of vibration are 3.90mm/s and 2.21mm/s respectively.

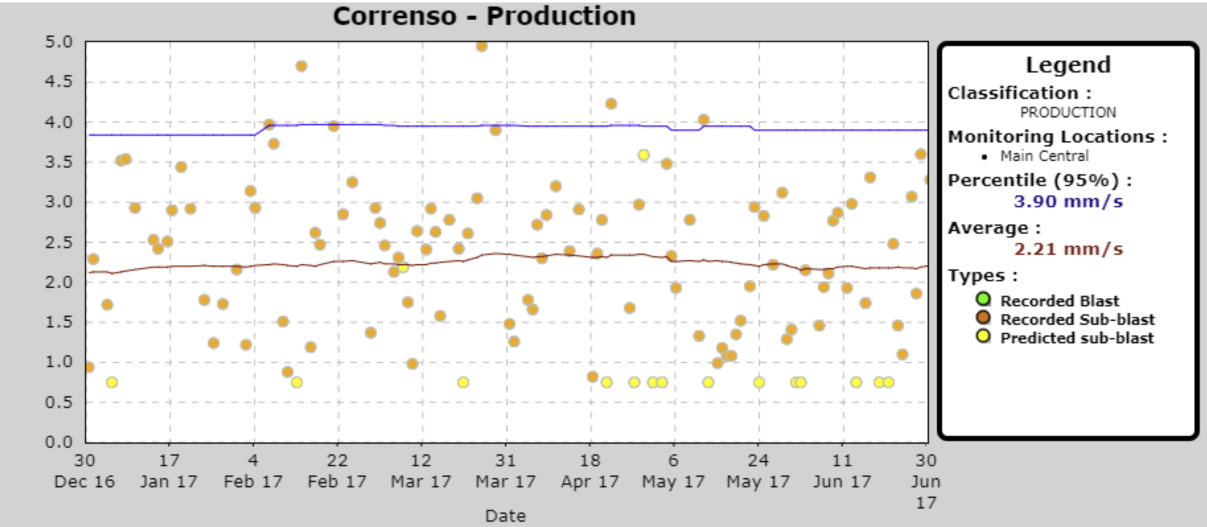


Figure 6 - Summary of measured vibration at Main Central site for 1st January to 30th June, 2017

The nature of underground mining operations is that the location of blasting has to move to accommodate the drilling, loading, firing, bogging and backfilling cycle. Imposing an average limit ignores this operational necessity. Blasting at Favona, Trio and Correnso has demonstrated that the normal underground mining cycle ensures that it does not repeatedly fire within a given area, and that its normal operations comply with the blast event average limits. An assessment of the "*average*" statistics and their consistency over time shows the mining plan and the inherent movement of stoping within the orebody is sufficient in itself to ensure concentrated areas of mining do not occur.

Furthermore, the nature of blasting and the resulting vibration statistics means that designing to achieve 95% compliance with 5mm/s is equivalent to designing to achieve an average level of vibration in the 2-3mm/s range. The average limits in the Correnso condition serve little additional purpose whilst imposing an administrative burden and cost, and it is suggested they should not form part of the Project Martha conditions.

For Project Martha, the majority of underground blasting will not be under residences and, therefore, the justification for the conditions imposed on Correnso is not considered to hold. Whilst blasting in the Rex lode will be under residences, the mining area is small and the duration of the project is short. With this portion of the mine being small, there is no ability to reduce average vibration limits for those living above the lode by moving to and blasting within other areas (beyond the normal breaks in blasting necessitated by the mining cycle).

For the open pit, the blast areas also move with time, providing relief for nearby residents as the activity moves along the edge of the pit (in the same way road works move towards then away from a given property), so a similar argument against imposing average vibration limits applies.

7.4. Number of Daily Underground Blast Events

The Correnso mine consents limit the number of daily blast events to three to coincide to the greatest extent practicable with shift changes and meal breaks.

It needs to be recognised that there will be infrequent occasions where, in spite of best endeavours of the blast crew, a slight delay occurs that means an absolute blast event deadline is just missed. If there is no flexibility to accommodate such occurrences this would result in the shot being slept overnight awaiting the next window. This has safety and operational implications and would typically result in a bigger shot being fired in the following window. For these reasons also it is suggested that consent provides some flexibility that allows for the occasional deviation from the daily norm. The current constraints have proved largely workable and no major change is proposed for the numbers of underground blast events or the management of their timing.

7.5. Number of Daily Open Pit Blast Events

Within the existing conditions, there is an allowable time for blasting in Martha between 10am to 3pm (and 10am to 12pm on Saturdays). There is no restriction on the number of blast events per day that can be initiated within the open pit.

As discussed above in relation to the underground blast events, the practical limitations associated with the open pit mining cycle (drilling, loading, blasting, excavating) mean that there is a limit to the number of blast events that can physically occur during the available blasting times. Also as discussed above in relation to the underground blasting, and for similar reasons, retention of flexibility around open pit blasting windows is considered necessary and delivers potential benefits to the management of the associated vibration effects.

Because of the physical limitations that apply to blast numbers it is considered that the current consent limits on blasting times remain appropriate, although consideration should be given to specifying the number and timing of blast events in the Vibration Management Plan where a best endeavours standard would be appropriate to cater for those occasions when circumstances prevent or delay firing.

7.6. Duration of Underground Blast Events

Peer reviewed literature acknowledges the duration of vibration as a factor that influences human response to a vibration event. If duration does have an effect on the "*degree of acceptance*", it could be that based upon the information presented by Wiss and discussed in Section 3.2 that once the duration of a blast generally extends more than a few seconds, extending the duration further has little effect on how it is perceived. To date, the extent to which duration influences the magnitude of effect has not been quantified, and several investigations of OGNZL's complaints database have failed to derive a meaningful relationship. While the OGNZL complaints database may understate this component of the vibration effect, the numbers of complaints that explicitly mention duration are too few to provide any measure of how people respond to event duration. To the extent that duration is an effect, it is considered secondary to the numbers of blasts and their vibration magnitude.

As discussed above, separate identification of development and production blasts is no longer proposed making the previously-applied duration limits by blast type meaningless. Under the current Correnso conditions, underground blast events are limited to no more than 18 seconds. The underground operation's blasting regime has always complied with the duration limit, and the intention is to adopt the existing maximum limit in a simplified condition.

7.7. Duration of Open Pit Blast Events

There is currently no limit on the duration of the Martha pit blast events. To remain compliant with proposed vibration criterion, some blasting at the lower charge weights around 1.5 kilograms will be required. To maintain efficient production at these very low charge weights necessitates firing large panels containing many holes. Experience has shown that large panels cannot be fired continuously as the magnitude of vibration builds with time, i.e. there is an additive vibration effect that increases as more holes are fired. The cumulative vibration effect is managed by separating the panels into several smaller portions and introducing a 1-2 second delay between each sub-panel to allow vibration from the preceding sub-panel to dissipate prior to blasting starting in the subsequent panel. Compliance with the vibration magnitude limit requires extended blast event durations and therefore no duration limit for the open pit is proposed.

7.8. Separation between Open Pit and Underground Blast Events

The greatest vibration effect with respect to amenity appears to be related to the number of blast events. This was the justification for limiting the number of underground blast event in Correnso. Whilst simultaneous blasting in the open pit and in the underground offers a means of reducing vibration effects, it is however unlikely to be a practical option.

The morning and evening underground blast events at the 7am and 7pm shift changes are not practically feasible for the open pits, and the evening blast window lies outside the existing and proposed open pit blasting times. Similarly, any morning and afternoon blast events in the open pit would occur at times that cannot be matched in the underground.

On this basis, firings in the open pit would therefore occur at different times to those in the underground.

There is a theoretical opportunity for the midday pit and underground blasts to be timed together, but the practical difficulties make this untenable. Aside from being difficult to link the firing electronically, a delay in firing in one mine would delay the firing in another, and in the case of the underground could result in missing a production blast window entirely, delaying that shot to the following day. It should be noted that after firing in the underground, an elapsed period must occur before workers can re-enter the mine to allow blast fumes and dust to lessen to acceptable levels. Delays to the open pit blasting time could therefore significantly affect the underground operations and potentially cause safety issues.

7.9. Separate Monitoring of Individual Project Elements

There are currently no conditions on the existing consents that require the vibration effects from individual mines, e.g. Correnso and SUPA, to be monitored and recorded separately. Vibration source is completely irrelevant in RMA terms. To a resident perceiving a vibration effect, the source of that event is immaterial. There is no vibration management justification in separating vibration by source.

In terms of cost, practicality and usefulness of monitoring and recording vibration events, it is significantly easier and more robust to set up a single monitoring network and to record each vibration event and its related blast design in a single database.

7.10. Blast times

The current conditions prevent blasting in Martha open pit at night and on Saturday afternoons, Sundays and public holidays. The current conditions prevent blasting in Correnso between 8pm and 7am and on Sundays and public holidays

A proposed "*out of hours*" (including Sundays and public holidays) blasting limit of 95% compliance with 1mm/s is recommended for the underground operations to permit small scale works to remedy issues within the mine that impact upon safety and the mining schedule, such as blasting of oversize, blasting of blockages within draw-points and so on.

No change to the existing limits is proposed for the Martha open pit operation.

7.11. Overpressure Monitoring

Compliance with an overpressure level of 128dBL has previously been applied for the Martha operation. Overpressure monitoring has not been regularly undertaken but rather assessed in the event of overpressure related complaints, or when blasting that could lead to higher overpressure levels, such as pre-splitting. The present method of placing monitoring units inside a bunker prohibits regular overpressure monitoring as it would require exposure of the microphone sensor potentially leading to vandalism.

It is proposed that the overpressure levels from blasting are representatively assessed at a minimum of once per quarter, or where complaints can be linked with elevated overpressure levels. Where no open pit blasting is undertaken in the quarter, there is no requirement for overpressure monitoring.

7.12. Unscheduled Small Scale Blasting

Access to and from the Martha Underground Mine will continue to use the existing underground drive network. As with all roading systems, maintenance of these drives will be required but it is still conceivable there could be localised falls of ground that necessitate small scale blasting to either remove the fallen ground, or possibly develop a bypass around the failure zone.

Whilst the likelihood of these failures is expected to be very low, it is appropriate to consider the impacts of any blasting that could be required to mitigate any of these isolated failures. In broad terms the blasting will be consistent with the existing maintenance blasts permitted under the existing Favona and Trio conditions and with the proposed Project Martha maintenance and safety blast conditions.

The level of vibration from these blasts will be dependent upon the blasting horizon. Currently there is an 800mRL drive and a 920mRL associated with the Martha Drill Drive project that, along with new drives at lower levels will become accesses between Correnso and the proposed Martha Underground. Vibration magnitudes from development blasting in the lower access levels of Correnso and SUPA are expected to produce maximum levels of around 1mm/s although blasting within the upper level could induce maximum levels of up to around 2mm/s. The expected or more likely level is around half of these values.

Figure 7 shows the maximum and expected level of vibration from these unscheduled blasts as a function of the mining horizon in Correnso or SUPA. While similar vibration levels would be produced directly above such blasting elsewhere, e.g. in Trio or Favona, there are no directly overlying properties and greater separation distances would mean lower vibration levels at the nearest sensitive receiver.

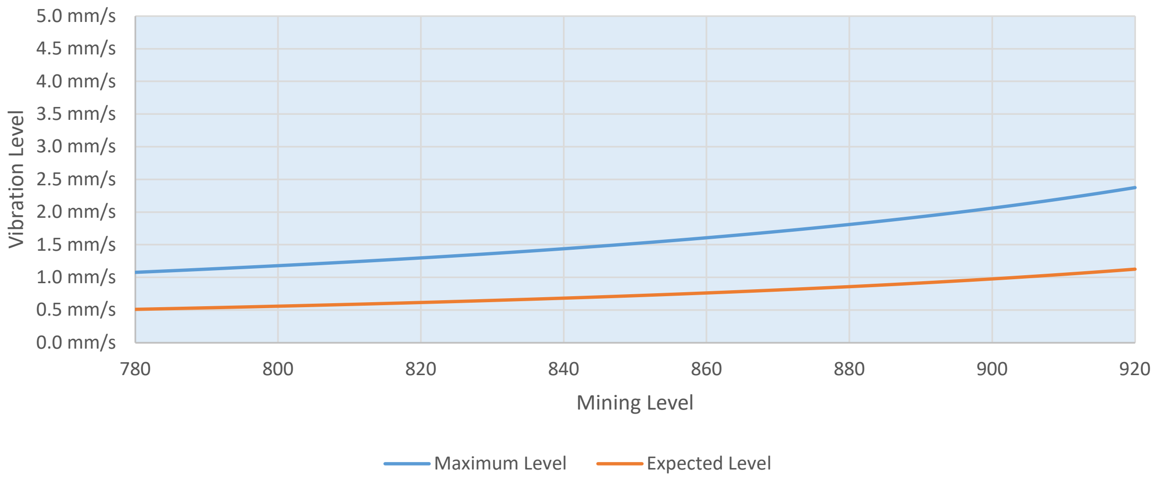


Figure 7 - Maximum and expected level of vibration as a function of the mining horizon for the development scale blasting

7.13. Proposed Conditions for Project Martha

The proposed conditions for Project Martha are generally based around the Hauraki District Plan and those of the existing consents held by OGNZL, with amendments that better reflect the longer term tenure of the operation and improvements in administering the conditions while maintaining the same high level of amenity protection.

The vibration assessment requiring the complex tasks of calculating, maintaining and reporting both the 95th percentile and "*average*" levels of vibration for each monitoring location for both development and production blasting activities is considered complex and perhaps impractical for the Project Martha, while not adding a meaningful level of amenity protection given the natural progression of underground development and production. It is proposed that there is an amended blasting condition for Project Martha. The key aspects are:

- The level of vibration for all blasts must be monitored and the peak level of vibration at each location comply at the 95th percentile with 5mm/s. Similarly the 95-percentile with 1 mm/s will comply for blasts for maintenance/safety purposes for underground mining. The percentile calculation is based upon all recorded vibration data that exceeds the pre-set threshold level set in the Vibration Management Plan.
- There is no requirement to calculate averages. The proposed vibration condition is well aligned with the plan objectives of assessing impact.

It is proposed that the existing limit on the number of underground blast events per day be retained, but be sufficiently flexible to recognise the safety requirements and operational constraints of blasting.

It is proposed to retain the existing open pit blasting times recognising that flexibility in timing these blasts can deliver potential benefits to the management of the associated vibration effects.

Whilst there is an opportunity for the midday pit and underground blasts to be timed together, the practical difficulties make this untenable. Aside from being difficult to link the firing electronically, a delay in firing in one mine would delay the firing in another, and in the case of the underground could result in missing a production blast window entirely and delaying that shot to the following day.

It is proposed that the overpressure levels from blasting are representatively assessed at a minimum of once per quarter. Where no open pit blasting is undertaken in the quarter, there is no requirement for overpressure monitoring.

The duration of the underground blasts has been limited as a measure of maintaining amenity. The Correnso underground blast duration is limited to no more than 18 seconds to enable successive firing of development and production blasts within the one blast event. The same condition is proposed for the underground blast activities.

The duration of a blasting event for the open pit blast activities is not currently limited by conditions. It has been shown that the geology in some sections of the Waihi area affects the number of blastholes that can be initiated within a pattern, commonly necessitating that a delay is introduced between successive blasts to control vibration levels. It is proposed that the duration of the open pit blasting is not conditioned.

The vibration monitoring locations for Project Martha will utilise where possible the existing vibration monitoring network although with the relocation of several monitors from the existing Correnso project to alternative locations to provide a more representative network across the Waihi area.

It is proposed that blasting results from each of the monitoring locations are displayed on the OGNZL's web page. The data will be pre-assessed to nominally display only blast related events.

A summary is given in the following ***Table 6***.

Project	Departures from Existing Conditions	Limits	Times
Martha Phase 4 Pit	None	5mm/s at 95 percentile 128dBL	Monday to Friday blasting between 10am and 3pm Saturday blasting between 10am and 12pm No blasting Sunday and public holidays
Martha Underground Rex orebody	. No differentiation between development and production blasts. No average vibration limits. Single blast duration limit	5mm/s at 95 percentile for a maximum of 3 blast events per day of no more than 18 seconds duration 1mm/s at 95 percentile	Monday to Saturday, 7am to 8pm Monday to Saturday, 8pm to 7am, Sunday and public holidays

Table 6 - Summary of proposed blasting conditions

8. PREDICTION OF VIBRATION

The prediction of vibration levels from blasting activities has been well addressed in the international literature. It is known that several factors exhibit an influence over the measured vibration value and these are generally well understood. The knowledge for the Waihi area is better than many other sites as a consequence of the long history of mining in the area, the intense monitoring program and the frequent analyses of the measured results.

It is accepted in the peer reviewed blasting literature that vibration level is affected by:

- The distance between the monitoring location and the blast area.
- The scale of blasting, and in particular the explosive weight per blasthole.
- The delaying sequence between successively initiating blastholes.
- The rock mass.

In addition to these parameters, and in particular for the Waihi area, it is also known that the following other aspects of blast design influence vibration level to a varying degree:

- The degree of water saturation in the areas around the monitoring location with highly saturated zones leading to elevated levels of vibration.
- The presence of large open discontinuities, such as old workings, which can prevent the uniform geometric spreading of the vibration pulse leading to elevated values in some direction and reduced values in others.
- Variable ground conditions which can lead to isolated and localised zones of elevated or depressed vibration.
- The number of blastholes fired in quick succession with some locations experiencing a gradual build up in vibration with increasing number of blastholes.

The influence of these parameters leads to varying levels of vibration even though the blast design parameters and the separation distance between the blast and monitor are unchanged. The overall variability in vibration level is however consistent with that observed at other sites and therefore reasonably well predicted by those same equations that have been used for the different Waihi areas over the previous 30 years. The form of these equations is consistent with the recommendations given in the Australian Standard AS2187.2 for assessing and predicting blasting effects.

Since 2003, the vibration monitoring system for each of the Waihi projects has been automated and allows for the near instantaneous reporting of vibration results. The vibration results are communicated from the monitoring sites via a modem to a dedicated computer at OGZNL offices where they are automatically processed and the preliminary results forwarded through to the HDC and other key personnel, generally within 5 minutes of a blast. These preliminary results are subsequently independently verified by Heilig & Partners and blast design details added to the system to allow for a complete assessment and review of all blast events and vibration results. The same system that has been used to demonstrate compliance can also be interrogated to determine area specific vibration relationships. OGNZL does not control any aspects relating to the monitoring data or display of the reported results.

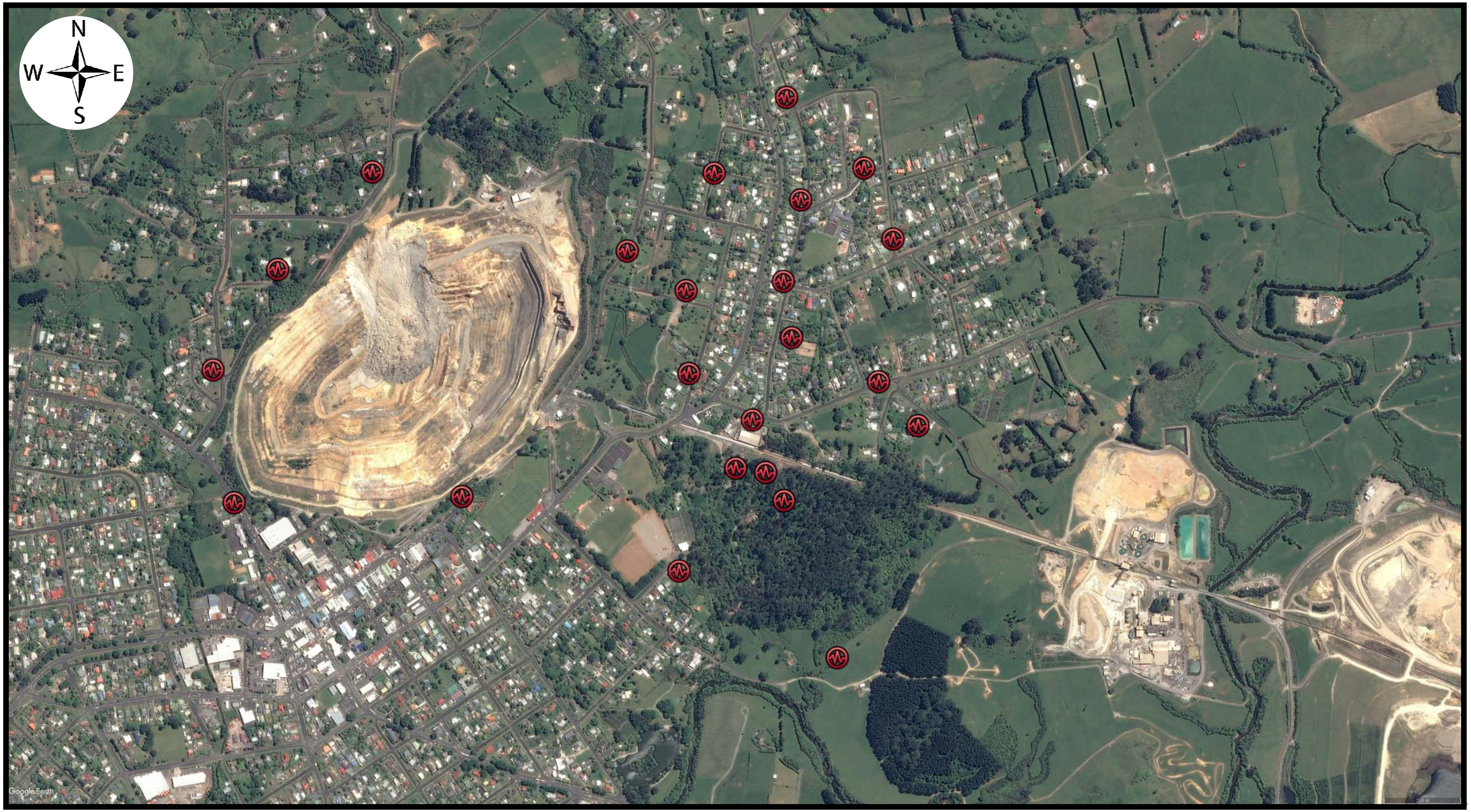
The basis of assessing the expected effects from the blasting for each of the areas within Project Martha is the data collected since 2003. Depending upon the location of the blast area, the nearest historical data from other projects has been regressed to determine an area specific vibration/distance/explosive weight relationship, that is, a specific relationship for MP4, Rex and the remainder of Martha Underground. These data replace that measured from the trial blasting information that had previously been undertaken for each new project.

*Figure **8*** shows the locations of the historical blasting activities that have occurred for the different Waihi projects **and** have produced levels of vibration that have exceeded the threshold level of 0.75mm/s. The data base of results contains approximately 20,000 events where vibration levels in excess of the trigger threshold have been recorded.

Figure 8 - Locations of blast events that have produced levels of vibration that have exceeded the minimum threshold of 0.75mm/s at least one of the monitoring stations

Assessment of the blasting data from Martha, Favona, Trio and Correnso has been considered in the selection of data for subsequent analyses. Plate A shows the locations of the permanent monitoring sites for the recording of vibration from the these blasting activities.

A summary of the recorded vibration data since 2003 is given in *Table **7***



Created using TunnelTRAP Software

SCALE

0 150 300 450 600 750m

Project Description: Locations of the permanent vibration monitoring stations where measurements of vibration have been undertaken for each blast as part of the Martha, Favona, Trio and Correnso projects

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OCEANAGOLD
WAIHI OPERATION

Plate No. A

Revision History

R1: Original

Date Drawn: **21 February 2018**

Ref No: Report drawings 2018

Job No: HP1712-6

In preparing this drawing, HP have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request were complete, accurate and up to date. Where we have obtained information from a Government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware why any of the assumptions are incorrect.

<table>
<tr><th>Project</th><th>Number of permanent monitoring locations</th><th>Number of blast events[19]</th><th>Number of vibration readings at monitors above 0.75mm/s</th></tr>
<tr><td>Martha Open Pit</td><td>6</td><td>1569</td><td>3727</td></tr>
<tr><td>Favona Underground</td><td>3</td><td rowspan="2">6835</td><td rowspan="2">14262</td></tr>
<tr><td>Trio Underground</td><td>5</td></tr>
<tr><td>Correnso Underground</td><td>10</td><td>1495</td><td>3282</td></tr>
</table>

Table 7 - Summary of vibration monitoring results for the Waihi region

All vibration data at Waihi have been analysed using techniques consistent with the recommendations provided in the Australian Standard AS2187.2. The form of the equation typically used to predict the level of vibration for a given explosive quantity and distance is used and has the following form:

$$PPV = K\left(\frac{d}{\sqrt{w}}\right)^{\alpha}$$

where

PPV is the peak particle velocity measured in mm/s,
d is the distance from the blast measured in metres,
w is the maximum quantity of explosive per delay measured in kilograms, and
K and α are site constants.

The term in brackets (d/√w) is referred to as the scaled distance term.

Figure ***9*** shows the recorded vibration data for all of the blasts monitored over the previous 13 year period where values above the threshold of 0.75mm/s have occurred. There are also some occasions where lower thresholds have been utilised for specific purposes of analyses. The values on the Y axis indicate the measured vibration level (vector sum value). The values on the X axis represent the value of the scaled distance term, calculated as the distance between the blast and the monitoring site divided by the square root of the explosive quantity.

It should also be noted that some of the monitors, such as the Ventilation Shaft monitor for the underground mine, are positioned at locations closer than the nearest affected residence and compliance with the vibration criterion is not required. Typically these are represented by vibration levels above 5mm/s. These vibration data are either used to assist with regression analyses or to assist with confirmation of a blast event.

[19] The number of blasts relates to blast patterns that have occurred between 2004 and April, 2017 and for which all vibration and blast design data have been provided and collated within the database.

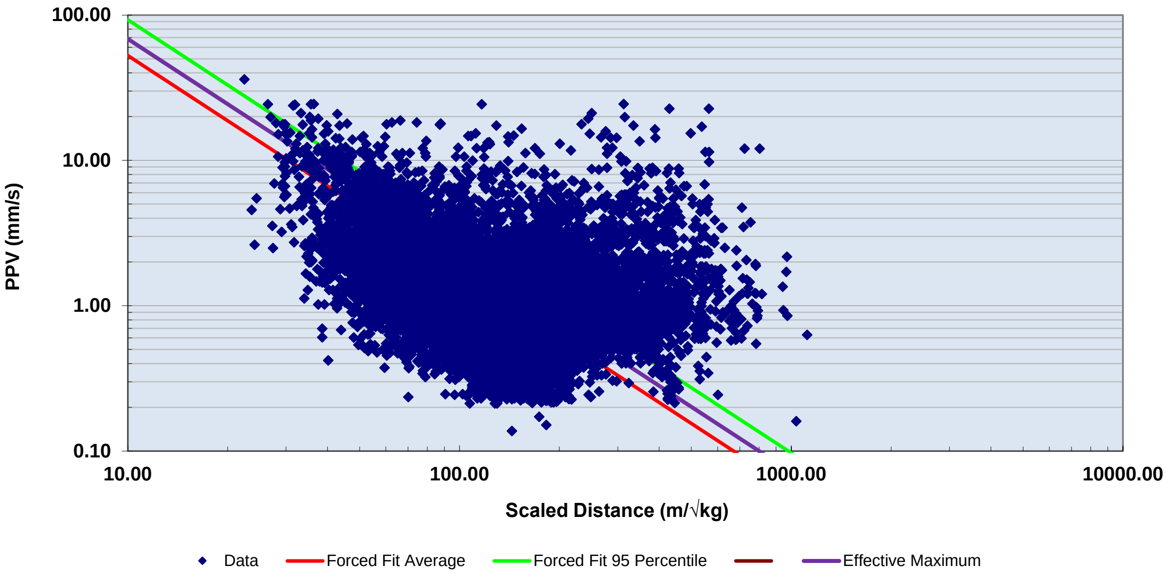


Figure 9 - Regressed data from all sites recorded at Waihi over the previous 13 years

Figure 9 shows considerable variability in vibration levels as a function of the scaled distance term. There are occasions where a similar scaled distance value, that is a combination of distance and explosive weight, yields vibration values less than 0.75mm/s and yet on other occasions more than 10mm/s. The variability is however typical of that produced from a very large data sets that incorporates multiple projects completed over an extended period of time. The variability could be associated with multiple aspects and includes, but are not limited to:

- Varying geology with more competent rock masses leading to higher levels of vibration.
- Varying degrees of confinement with confined blasting expected to produce higher level of vibration that undertaken with a free face.
- Differences in the blasting practices, including variations in the explosive types and performances.
- Varying initiation systems ranging between conventional pyrotechnic delay elements and the accurate electronic elements.
- Initiation patterns, including the direction of initiation and the number of blastholes sharing a common nominal delay time.
- Varying levels of quality control associated with the blast loading process, including improvements in the accuracy of delivery of small explosive quantities.
- The degree of water saturation around the blast region, the monitoring location or the intervening ground between these two locations.
- The presence of old workings which could either shield or elevate the level of vibration.
- Varying localised ground conditions around the monitoring arrangement.

An unbiased statistical regression of all data shown in *Figure **9*** shows almost no relationship between vibration level and scaled distance with a coefficient of regression (R^2) of 0.1. A value of 1 reflects a perfect relationship and 0 indicates no relationship. The calculated α term, as per the Australian Standard equation, is -0.42. It is however known through other work at Waihi, and as reported in the peer reviewed international literature, that the value for α commonly lies between -1.2 and -2, depending upon rock type and other blasting parameters.

Vibration studies that have been completed at Waihi over more than twenty years have linked the level of vibration with the distance from the blast and the quantity of explosive initiated at a given time. These studies have generally found that the whilst the “K” parameter in the vibration equation varies according to the blast area and other aspects of blasting, the α term remains consistent at around -1.49. There appears no justification that any analyses should consider that the α term would vary from the value of -1.49.

An assessment for all vibration/distance/explosive weight relationships for the Waihi region is therefore based upon a fixed α term of -1.49. The project specific relationships shown in *Table **8*** have been developed for each of the existing mining areas.

Mining Area	*Description*	*Average Vibration Relationship*	*Effective maximum Vibration Relationship*
North wall interim layback	Blasting for stabilisation of the north wall of the Martha pit has occurred since 2016. Small scale development blasts have occurred on the upper benches. Approximately 50 blasts and more than 70 vibration events have been recorded.	$PPV_{Average} = 1730\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	$PPV_{Effective\ Maximum} = 2970\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$
Martha Pit	Blasting for the Martha Pit has been monitored using the current reporting system over a 13 year period. All blasts were monitored at a minimum of 5 locations. Approximately 1570 blast events have induced vibration greater than 0.75mm/s. A total of 3730 events producing vibration greater than the 0.75mm/s threshold have been recorded across the Martha monitoring network.	$PPV_{Average} = 2090\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	$PPV_{Effective\ Maximum} = 3130\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$
Favona Underground	Favona blasting occurred between 2005 and 2014 during which time 2300 blast events occurred. Blasts were monitored at a minimum of 3 locations. Approximately 12000 blasts have been monitored with more than 2300 events producing vibration greater than the 0.75mm/s threshold	$PPV_{Average} = 1510\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	$PPV_{Effective\ Maximum} = 4540\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$
Trio Underground	Trio blasting followed on from the Favona blasting, commencing in 2012. An additional 3 monitoring sites were added to the Favona network. Approximately 12000 blasts have been monitored with more than 2300 events producing vibration greater than the 0.75mm/s threshold	$PPV_{Average} = 760\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	$PPV_{Effective\ Maximum} = 2160\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$
Moonlight Underground	Blasting of the Moonlight orebody occurred during the Favona mining period	$PPV_{Average} = 1520\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	$PPV_{Effective\ maximum} = 3520\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$
Correnso Underground	Correnso blasting has been extensively monitored across a network of 10 stations. More than 1200 blast events have produced vibration exceeding the 0.75mm/s threshold value.	$PPV_{Average} = 910\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	$PPV_{Effective\ Maximum} = 1920\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$

Table 8 - Summary of calculated vibration relationships from historic measurements

In addition to the project specific relationships that have been developed for the previous mining areas completed in Waihi, each of the three proposed mining areas (MP4, Rex and the remainder of the

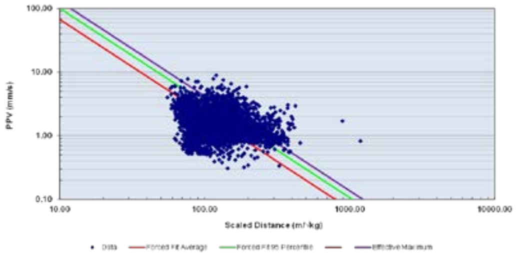
Martha Underground) was assessed using a region specific vibration relationship identified from existing data. The specific equations have been determined by filtering the data to include only those data where blasting has occurred near to the proposed orebody. As an example, for the Rex deposit, only those vibration data relating to blasting on the southern side of the pit together with SUPA blasts and development blast data from the MDDP exploration decline have been considered in determining the vibration relationship.

*Table **9*** indicates the limits of the data which are identified as being applicable to each of the projects.

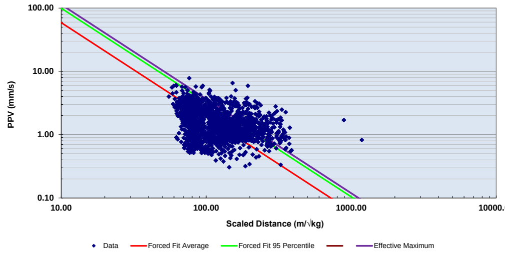
Project	*Applicable Vibration Relationship Data Origin*
Martha Underground	Regress recorded Martha blast data for all blasts
Rex	Regress both Martha blast data for blasts that lie on the southern side of the pit together with available blast data from the SUPA and MDDP
Martha Phase 4 Pit	Regress all vibration data from the Martha open pit

Table 9 - Source data location to establish relevant vibration relationship for each project

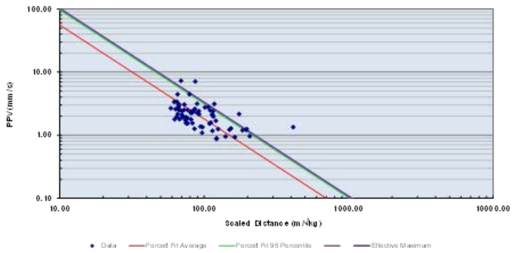
For reference, the vibration versus scaled distance graphs for each of the three mining areas are given in *Figure **10***.



Martha Underground



REX Underground



Martha Phase 4 Pit

Figure 10 - Vibration vs scaled distance for each of the past five projects. These data have been used to develop the project specific relationships

*Figure **10*** shows the vibration/distance/explosive weight relationships for each of the three mining areas forming Project Martha. A comparison of the relationships show that the "*average*" relationship is reasonably consistent across all three sites with the Martha Underground indicating the average vibration is slightly higher than the MP4 and Rex orebody. The MP4 relationship specifically addresses the blasts associated with the north wall interim remediation blasting.

The following *Table **10*** shows the regressed site specific vibration relationships.

Project Martha	*Basis of Relationship*	*Average Vibration Relationship*	*Effective maximum Vibration Relationship*
Martha Underground	Regressed Martha blast data for all blasts that lie within 500 metres of the centre of the pit.	$PPV_{Average} = 2090\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	$PPV_{Effective\ Maximum} = 3130\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$
Rex	Regressed Martha blast data for all blasts that lie on the southern side of the pit together with available blast data from rom SUPA and MDDP	$PPV_{Average} = 1880\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	$PPV_{Effective\ maximum} = 3520\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$
Martha Phase 4 Pit	Regressed the vibration data from the blasts associated with the north wall interim remediation blasting.	$PPV_{Average} = 1730\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	$PPV_{Effective\ Maximum} = 2970\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$

Table 10 - Summary of vibration/distance/explosive weight relationships for each project

8.1. Comparison with Previously Predicted Results

A review of the recorded vibration data from each of the projects undertaken at Waihi over the previous 30 years has shown variability in vibration levels that reflects the effect of the parameters listed in Section 8, the variable geology, water saturation, and structural features. *Table **11*** lists the vibration relationships that were applied for each of the projects during the assessment and hearing phase of the project. The third column in the same table shows the relationship which has been subsequently derived from the measured data and the fourth column shows the difference between the predicted and measured results.

Project	*Predicted 95 percentile equation*	*Calculated 95 percentile equation from recorded data*	*Difference*
Martha	$PPV_{Effective\ Maximum} = 2720\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	$PPV_{Effective\ Maximum} = 3130\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	15% greater
Favona	$PPV_{Effective\ Maximum} = 3500\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	$PPV_{Effective\ Maximum} = 4540\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	29% greater
Trio	$PPV_{Effective\ Maximum} = 2230\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	$PPV_{Effective\ Maximum} = 2160\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	3% less
Correnso	$PPV_{Effective\ Maximum} = 2230\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	$PPV_{Effective\ Maximum} = 1920\left(\frac{d}{\sqrt{w}}\right)^{-1.49}$	13% less

Table 11 - Comparison between predicted and actual vibration results from Waihi projects

A comparison of the predicted and expected relationships show good agreement, typically within 15% and for the Trio project, within 3%. The data contributing to the increased variability is typically associated with unfavourable rock mass conditions. Improved practices, better accuracy in terms of the delivery of explosive quantities and an improved understanding by the underground workers of the critical nature of blasting compliance has contributed to the reduced vibration levels from the Correnso operation when compared to the initial stages of mining the Favona orebody.

It is expected that the accuracy of the predictions for Project Martha will be similar to these recently completed projects, that is, within 5 to 15%.

9. ASSESSMENT APPROACH

The impacts of blasting in each of the different orebodies have been assessed. This includes determining the maximum extents of the vibration by showing a series of vibration contours of varying levels between 2 and 5mm/s in 1mm/s increments. The analyses also include a series of vibration envelopes at representative properties closest to the various projects elements that illustrate the range of vibration levels and how these vary according to the mining blocks over the life of the project. The envelopes have been developed annually for representative properties over the entire life of the Project Martha.

The schedule for blasting within each project is based upon the available mine design schedule as provided by OGNZL. The approach is consistent with the level of analyses undertaken for each of the previously consented projects.

9.1. Vibration Contours

The effects of blasting the Project Martha orebodies have been studied and the results presented as a series of contours ranging between 2mm/s and 5mm/s. These contours consider the maximum permissible scale of the blasting and the rate of vibration attenuation specific to the particular blast area. The contours present the maximum extent of vibration over the entire mine life. Importantly, properties will not receive the same level of vibration designated by the contour level for each and every blast. As an example, when blasting in the eastern section of the MP4 area, persons along Moresby Avenue are not expected to receive perceptible vibration.

The vibration contours also represent the maximum extent of vibration, but not the most frequently experienced or average level of vibration. The expected vibration levels are based upon the maximum explosive weight. There are likely to be situations where OGNZL chooses to use alternative mining designs which result in a lower explosive weight, such as a reduced bench height or smaller sub-level interval.

9.2. Vibration Envelopes

Whilst the vibration contours provide an indication as to the maximum expected vibration within a given period of mining, the contours provide little indication of the average, most likely, or distribution of vibration levels. These levels are best determined by presenting a series of vibration envelopes for a number of representative properties around the orebody. These vibration envelopes show the expected level of vibration from all blasts, taking into account the explosive weight planned for each blast, the distance between the blast and the property, as well as inherent variabilities in the predictions, including effects like water saturation, accuracy of loading, blasthole variation, explosive performance and so on.

"*Life of mine*" vibration envelopes for selected properties around the orebody area have been calculated taking into account the location of each of the planned production blasts and development blasts for Project Martha. The resulting vibration distributions for each property, referred to here as "*envelopes*", address the shortfalls of presenting effects via vibration contours which simply show the maximum extent of vibration, irrespective of the number of occurrences it may occur.

The envelope modelling adopts "*Monte-Carlo*" simulation methods to account for the variability in vibration levels. For each blasting location, the model predicts a level of vibration based upon the designed explosive weight and distance to the property in question. The calculation is repeated 30 times using different attenuation rates expected to reflect the overall variability in vibration that has been observed at the Waihi operations. The results are collated to show the predicted levels of vibration from the "*Life of mine*" for Project Martha recognising that some blasts are further from a property than others, some blasts generate higher or lower levels of vibration than expected, the quantity of explosive per blast varies and so on. The modelling is considered to present the best overall representation of vibration effects from the blasting activities.

A total of 43 representative properties have been selected based upon their proximity to the Project Martha blast areas. The properties are chosen to represent a spread of properties above, near and distant from the blast areas.

The representative properties are shown in Plate B and listed in *Table **12***.

Project	*Property Address*		
Martha Underground and Martha Phase 4	114 Seddon Street	53 Seddon Street	Waihi Central School
	39 Walker Street	46 Moresby Avenue	27 Moresby Avenue
	20a Islington Terrace	9 Islington Terrace	9 Savage Road
	7 Savage Road	1 Cambridge Road	61 William Street
	1 King Street	2 Boundary Road	1 Dobson Street
	4 Dobson Street	29 Grey Street	21 Roycroft Street
	24b Roycroft Street	28b Roycroft Street	176 Kenny Street
	2 Barry Road	20 Barry Road	
Rex	8a Baker Street	19 Clarke Street	36 Clarke Street
	22 George Street	126 Kenny Street	122 Kenny Street
	95 Kenny Street	144 Seddon Street	81c Kenny Street
	5 Mueller Street	5a Mueller Street	6 Gilmour Street
	6b Gilmour Street	1 Gilmour Street	1a Gilmour Street
	1b Gilmour Street	1c Gilmour Street	114 Seddon Street
	22 George Street	36 Clarke Street	19 Clarke Street
	53 Seddon Street		

Table 12 - List of properties where envelope modelling has been completed

The envelopes are presented in Volume 2 of the Blasting Assessment Report. For each year in which blasting is planned for Project Martha, the results of the modelling indicate:

- The percentage of scheduled blasts within each year grouped according to the predicted level of vibration varying between 0.25mm/s and 6.25mm/s in 0.5mm/s increments.
- The number of scheduled blasts within each year grouped according to the predicted level of vibration varying between 0.25mm/s and 6.25mm/s in 0.5mm/s increments.
- The number of scheduled blasts within each year grouped according to the distance between blast and the property.

The modelling presents predicted levels of vibration for each individual blast, rather than blast event which combines multiple blasts. This results in a conservative assessment as there is no allowance for firing more than one blast in the same event as typically occurs in the underground, e.g. for Correnso, there has been an average of three blasts fired in each event. For the open pit, an individual blast represents a single blast event.

The results are presented for each of the 43 properties between 2020 and 2030 in Volume 2 of the technical report. *Figure **11*** shows a typical presentation of the data for "114 Seddon Street" in year 2020.

Created using TunnelTRAP Software

SCALE

0 150 300 450 600 750m

Project Description: PROJECT MARTHA - Representative locations where vibration envelope modelling has been undertaken for the blasting duration of the Project Martha

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OCEANAGOLD
WAIHI OPERATION

Plate No. B

Revision History

R1: Original

Date Drawn: **21 February 2018**

Ref No: Report drawings 2018

Job No: HP1712-6

In preparing this drawing, HP have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request were complete, accurate and up to date. Where we have obtained information from a Government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware why any of the assumptions are incorrect.

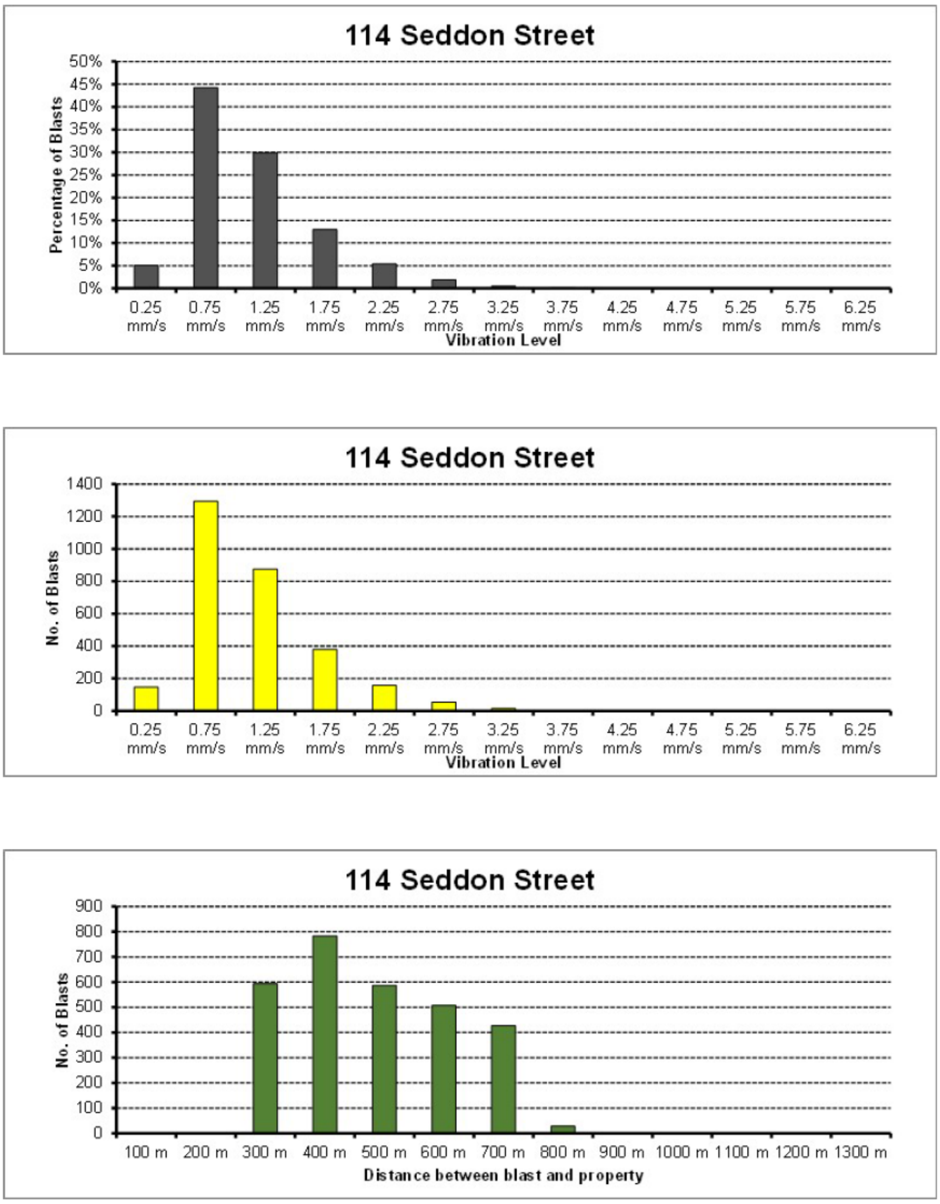

Figure 11 - Vibration envelope for 114 Seddon Street for blasting in 2020

10. RESULTS OF THE VIBRATION ASSESSMENT

Modelling results are given as a series of vibration contours for each of the different mining areas. The plates in Appendix A to C show the expected vibration contours for the planned open pit and underground operations. The contours are shown annually based upon the proposed mining schedule and therefore vary according to the planned mining areas within the year, including the depth of the operation. Each plate in Appendices A to C also shows the expected explosive weight that is calculated to comply with the 5mm/s 95%ile vibration criterion at each of the adjacent sensitive receivers around the blast area. The explosive quantities vary from less than 2 kilograms per delay, through to a maximum calculated weight of 30 kilograms. For development blasting, the maximum weight is capped according to a standard 3.6 metre advance length.

The vibration contours are shown for levels varying between 2mm/s and 5mm/s and are calculated based upon the maximum calculated explosive weights and the specific vibration relationship for the particular mining area.

Appendix D shows a series of plates for the complete Project Martha (open pit and two underground operations) for years between 2020 and 2030. Blasting does not occur from all of the three project areas in each year, but rather varies according to the mining schedule.

In simple terms, where a vibration contour of say 2mm/s is shown, all properties between the blasting area and the extent marked by this contour are predicted to receive vibration at some stage during the year at a level of vibration that exceeds 2mm/s. The modelling therefore identifies the maximum expected level of vibration that residents could be expected to receive in each year, irrespective of the source of the blasting. The vibration may occur from small scale blasting at nearby locations or from larger scale blasting at a location farther from the property. The same applies for other vibration contour levels.

Where a particular contour for a given vibration level is not shown, the contour does not '*daylight'* on the surface and modelling predicts this level of vibration is not reached.

The modelled results for each of Project Martha orebodies are assessed separately for each of the projects in the following Sections 10.1 to 10.3.

10.1. Martha Phase 4 Pit

Phase 4 of the Martha Open Pit is set to commence in 2022. The blasting is scheduled for 8 years with completion of the lower limits of the pit in 2029. Blasting commences on the upper pit rim of the north wall crest of the pit. Explosive weights will be low, varying from less than 2.5 kilograms through to approximately 15 kilograms. The reduced scale of blasting is required to comply with the 5mm/s level at the adjacent residential properties. These explosive quantities are typical of those used for the 80 blasts associated with the north wall interim remediation blasting.

During the later stages, blasting will have progressed both deeper to RL910 and horizontally further from the nearest receivers to permit increased explosive weights with some sections of blasting in the deeper areas potentially able to use a maximum weight of 30 kilograms. In the final two years of the pit life, blasting is focused on the deeper centre sections of the pit where there are only minor, if any, restrictions on the scale of blasting.

Blasting at the Martha open pit over the previous 25 years has utilised explosive weights similar to those planned for the Phase 4 activities. There are some areas of the upper sections of the pit crest where the scale of blasting will necessarily be small to ensure compliance with the consent conditions. Other areas of the Phase 4 project will permit a larger scale of blasting consistent with that practiced at Martha during the recent years of mining.

The vibration contours presented for each year of mining show those areas affected around the Martha pit (refer Appendix D). The vibration contours will extend further from the existing pit crest as the Phase 4 project expands the pit crest by approximately 40 metres. The extent of impact is comparable to that of previous Martha blasting given the explosive weights and blasting locations are similar.

As with other mining at Waihi, blasting will generally only produce perceptible levels of vibration when blasting in the immediate area of the receiver. When blasting on the northern wall of the pit, residents along the eastern side of the pit along Roycroft Street will receive low levels of vibration, generally considered imperceptible as a result of the small explosive weights and increased separation distance. The vibration contours therefore reflect worst case impacts and residents would not routinely be exposed to levels of vibration of this magnitude.

The assessment concludes that the planned scale of mining can comply with the proposed conditions with respect to vibration limits and therefore ensure the protection of amenity.

10.2. Martha Underground

The Martha Underground operation, excluding Rex, is planned to include development blasting for establishing the accesses together with the larger scale production blasting required for the winning of the ore and mining of waste rock.

The development blasting has been assessed and extends over the full life of the mine, commencing in 2020 and finishing in 2030. Development blasting occurs in all years, with the exception of 2027 and 2028 where activities are restricted to production blasting only. In all of the Martha Underground, development blasting can proceed unrestricted with advance lengths of 3.6 metres. Development blasting for the Correnso operation typically uses explosive quantities of 5 kilograms and permits advances of around 3 metres. Similar quantities of explosive and lengths of advance are anticipated for the planned Martha Underground mine.

Production blasting for the Martha Underground is larger scale than development blasting and yields greater quantities of material (broken ore) through the use of larger explosive quantities. The scheduling for the Martha Underground shows production blasting commencing in 2020 and continuing in all years through to completion in 2030. The six year period between 2023 and 2028 is associated with geographically diverse blasting with stoping occurring over a distance of more than 500 metres. The early blasting up until 2027 occurs beneath the centre of the existing Martha pit, but extending towards the southern wall over time. In the later three years of the underground, blasting progresses beyond the existing open pit crest and nearer to properties along Roycroft Street.

For those production blasts prior to 2028, the mining concentrates on stopes below the existing Martha open pit and the explosive weight for most of these production blasts is potentially more than 25 kilograms with only a few mining blocks requiring lower explosive weights. For the planned production blasting after 2028, the mining areas progress towards the south-east and this necessitates a reduced scale of mining. With the exception of a few stopes, blasting can proceed with explosive weights of more than 10 kilograms.

The vibration contours for the Martha Underground show perceptible levels of vibration extend around the mining areas (refer Appendix A). The contours are similar to the blasting in the northern areas of the Correnso orebody where residents towards the south were not affected, a similar situation will occur for the Martha Underground. Not all stope blasting will be noticeable to persons directly around the Martha Underground. Unlike Correnso where properties were located above the stopes, the majority of the stope blasting for the Martha Underground will occur several hundred metres in plan distance from properties.

When compared to previous blasting at Favona, Trio and Correnso, the explosive quantities are similar to the modelled weights for the Martha Underground. The blast designs required to achieve the necessary production rates will therefore be similar also. Given the method of mining and permissible range of explosive weights, the modelling confirms the Martha Underground can be effectively blasted and remain compliant with conditions that ensure the protection of amenity.

10.3. Rex Orebody

Mining of the Rex orebody will utilise similar mining methods to the Martha Underground with both development and production blasting. A similar scale of development blasting is proposed with explosive weights of around 6 kilograms and advances of 3 to 3.5 metres planned where compliance with the vibration criterion permits.

Development blasting for Rex is scheduled to commence in 2020 and continue for three years until completion in 2022. Some of the initial stages of development are nearer to the surface and require low explosive weights of less than 2 kilograms to achieve compliance. Where the permissible explosive weight for sections of development is reduced, the lengths of advance achieved in these areas will be correspondingly reduced to between 1.5 and 3 metres. Similar decreases in advance as part of the Favona mining have been required to mitigate poor ground conditions so mining with these parameters is consistent with previous methods. Development blasting at depth can be designed with the maximum explosive weight.

Stope production blasting is scheduled to commence in 2020 following the development blasting. The location of Rex and the proximity to residential receivers limits the explosive weights to between 5 and 10 kilograms in the first year of production. As mining advances from the northern to southern limits of the orebody, and from the low to the upper levels, the explosive quantities reduce to less than 2.5 kilograms. These sections are likely to require cut and fill type methods of mining.

The associated vibration contours are limited to small overall extents as a result of the low explosive quantities (refer Appendix C). The "*footprint*" of the contours is small with a resulting small zone of potential impact.

Although the scale of blasting will be small to accommodate the reduced separation distance between the blasting and nearest properties, the assessment confirms the Rex orebody can be effectively blasted and remain compliant and therefore ensure the protection of amenity.

11. OVERPRESSURE ASSESSMENT

Overpressure monitoring has been completed infrequently at the Martha operation. The data set is therefore small and insufficient to develop a site specific regressed relationship between the measured level, distance and explosive quantity.

Other groups, most notably the United States Bureau of Mines (USBM)[20], have however proposed relationships showing the expected level of overpressure as a function of distance and explosive quantity. A common reference equation for estimating the overpressure is shown below:

$$dBL = 164 - 24 \times \log\left(\frac{d}{\sqrt[3]{w}}\right)$$

The form of the over pressure relationship is consistent with the Australian Standards AS2187.2. These relationships have been used elsewhere in assessing blasting impacts and whilst they provide an indication of the likely level, it is generally accepted that over pressure prediction is more difficult than estimating vibration levels as there are multiple other factors that impact upon the maximum measured level.

Based on the above equation, shown in *Figure **12*** is the estimated distance between the blasting activities and the point of measurement to comply with varying limits of overpressure for varying quantities of explosive. The data in *Figure **12*** are based on explosive weights per blasthole varying between 2.5 kilograms and 20 kilograms. Whilst explosive weights of 30 kilograms could be used in the centre of the pit, the residents will be further shielded from the over pressure effects by the pit wall preventing a direct line of sight between the blast and the property.

[20] Siskind, D.E., Stachura, V.J., and Stagg, M.S., 1980. "*Structure Response and Damage Produced by Airblast from Surface Mining*", United States Bureau of Mines, Report of Investigations No 8485.

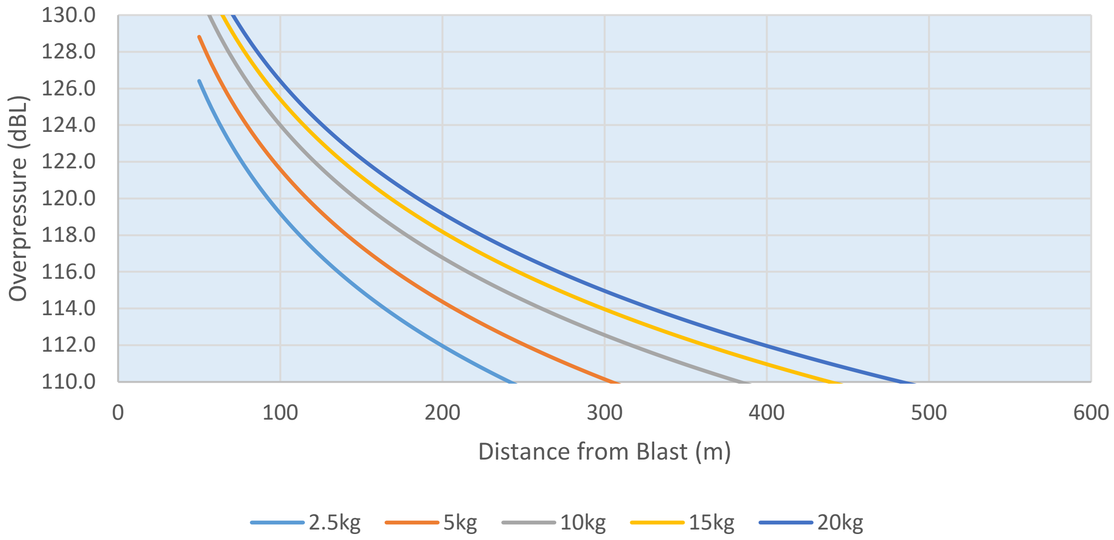

Figure 12 - Estimated vibration and air overpressure levels as a function of distance

Figure ***12*** indicates that when blasting at the crest of the newly formed MP4, the separation distance between the blast and the properties is around 100 metres. With the requirement to use small explosive weights of less than 2.5 kilograms to comply with the vibration criterion, the expected overpressure levels will be less than 120dBL.

12. FLYROCK ASSESSMENT

There are two potential sources of flyrock from blasthole patterns:

- Vertical face;
- Horizontal surface.

High velocity rock movement from the vertical face can occur if blastholes are drilled too close to the vertical face, enabling the high pressure gases to easily burst free. Where there is a free vertical face, the blasthole orientation should be reviewed prior to the blast to identify any instances where the distance to a free face may be insufficient to prevent flyrock. Where possible, the preferred direction of any movement of blasted material should also be towards the center of the pit and away from sensitive receivers. There are few scenarios where this would not be achieved for MP4.

Given that the majority of the blasting for the MP4 operation will remain confined with no free face, the possibility of flyrock is restricted to that originating from the horizontal surface around the collar region. Whilst flyrock remains a very critical component of any blast design process, the nature of the blasting at Waihi eliminates many of the contributing factors to accidents that have been observed at other sites where flyrock has been reported.

12.1. Martha Flyrock Instances

Blasting at the Martha operation has been continually and successfully completed over a thirty year period with no instances of flyrock being propelled outside of the nominated exclusion zone, aside from that originating from a single hole, or perhaps a small group of holes, within a pattern initiated on the 29th June 2007. In this instance, flyrock was scattered over an area of approximately 30 to 40 metres outside of the blast exclusion zone with some of the particles landing on the mine offices in Moresby Avenue and a commercial property in Seddon Street. No injuries occurred. The distance from the blast area to the mine offices was calculated as approximately 300 metres.

The event was reviewed and key findings and conclusions presented to the Hauraki District Council. The key findings included:

- Some blastholes were inadequately stemmed to only around 50% of the design stemming length.
- Some blastholes were overcharged or the explosive placed in the incorrect horizon within the blasthole.
- Some holes were incorrectly loaded with emulsion noted as coming from the collar of the hole as the stemming material was being lowered.
- Probe holes were not located and stemmed prior to the blast.
- Some collars of the blasthole were higher than designed and lead to a higher powder factor.

Adjustments to the Vibration Management Plan were adopted and implemented to mitigate these identified flyrock causes. Blasting has continued in the areas for the following ten year period between 2007 and 2017 without further incident.

The same level of detail and key steps within the current Vibration Management Plan will be adopted for MP4 blasting.

12.2. Flyrock Modelling

An engineered flyrock model based upon projectile motion and rock ejection velocities has been developed and applied to Project Martha. The model incorporates the results of more than ten different documented research projects specifically aimed at estimating flyrock ejection velocities, flyrock ranges and/or safety exclusion zones. These models account for both blast designs, in particular the proximity of the explosive column to the free face, and fluid dynamics code addressing projectile motion and air resistance (drag) of the ejected blast fragments. The models incorporate code to best estimate flyrock ranges and corresponding safe exclusion zones. The presented results are based on probabilistic analyses and estimate the likely landing position of possible ejected rock fragments based upon their equivalent size.

The uncontrolled movement of rock from the horizontal surface (*ie* ejection of rock around the collar) represents the only possible source of flyrock given the confined nature of the Waihi blasting. Confined blasting (ie. without a free face) virtually eliminates the possibility of flyrock from the vertical face, although the propensity for flyrock from the collar region increases and necessitates an increased uncharged collar to better control rock movement from around the collar. The degree of control can be achieved by increasing the depth of burial of the explosive charges.

As blasting moves nearer to the pit crest limits, it is considered appropriate to increase the length of the uncharged collar as a function of the blasthole diameter. The current ratio of 22 (2000mm/89mm) is considered appropriate with respect to controlling flyrock for the blasting in general however each blast should be assessed separately in recognition of the previous blast performance. Blasting in built up areas where control of flyrock is critical commonly employs an uncharged collar length equivalent to between 30 and 35 times the blasthole diameter, or for an 89mm diameter blasthole, 2.7metres. These ratios are as per the Australian Standard AS2187.2 for the control of flyrock from blasting.

The flyrock modeling indicates that for a 2.5 metre bench with an uncharged collar of 2 metres and an explosive weight per blasthole of 2.5 kilograms, flyrock is controlled to within approximately 65 metres of the blasthole collar. As the depth of the blasthole increases and with a corresponding increase in the weight of the explosive to around 10 kilograms, the extent of flyrock reduces slightly as a result of the increased uncharged blasthole collar.

Where increased explosive weights are possible and potentially 30 kilograms could be used, the flyrock zone increases marginally to around a distance of 70 metres.

Plate C shows the results of the flyrock outcomes for the three explosive weights of 2.5, 10 and 25 kilograms. The modeled landing positions for flyrock are based upon the calculated trajectories and a

Created using TunnelTRAP Software

Martha Phase 4 blasting area

SCALE

0 100 200 300 400 500m

Project Description: PROJECT MARTHA - Modelled extent of flyrock from blasting at the in the Martha Phase 4 pit with an explosive weight of 2.5 kilograms, 10 kilograms and 25 kilograms

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OCEANAGOLD WAIHI OPERATION

Plate No. C	Date Drawn: **21 February 2018**
Revision History R1: Original	**Ref No: Report drawings 2018**
	Job No: HP1712-6

probabilistic component accounting for the fragment size, direction and velocity are shown for three blasting locations. The probabilistic component of the model estimates flyrock ranges based upon a combination of operating conditions and therefore predicts the outermost envelope of flyrock landing points.

The predicted flyrock ranges are based upon a detailed flyrock model that considers flyrock distances based upon ejection velocities, particle size and sphericity and whether from the collar or front row origin. Whilst best engineering procedures would clearly dictate that site data should continue to be used to supplement the model and verify the predicted results, the model is considered to produce appropriate preliminary expectations of flyrock ranges for varying particle sizes. The probabilistic component of the model estimates flyrock ranges based upon a combination of operating conditions and therefore predicts the outermost envelope of flyrock landing points.

13. RECOMMENDED MITIGATION MEASURES

The analyses have reasonably guaranteed that the levels of vibration from the blasting will comply with the proposed 5mm/s criteria at all potentially sensitive locations. In the event that the analyses have underestimated the level of vibration, the geology differs from that which has been used in the calculations to develop the relationship between vibration level, distance and explosive quantity, or other unknown factors lead to increased levels of vibration, several mitigation procedures are available and could include:

- Limiting the quantity of explosive by further reducing the length of the blasthole;
- Using multiple explosive decks per blasthole, each separated by a column of inert material, to reduce the quantity of explosive contributing to the peak vibration level
- Adjustments to the mine design to limit the length of the explosive column initiated at single nominal time;
- Adjustments to the method of mining, such as using cut and fill or other smaller scale methods;
- Reducing the blasthole diameter;
- Adjustments to the initiation sequence
- Alternative explosive types, including both low density products and cartridge explosives;

Similar types of adjustments have on occasions been previously implemented as part of the mining process at Waihi. Variations in the ground type have often necessitated changes to the blasting approach. Importantly, the mine design has shown flexibility and adaptability to account for these changes. There are no aspects of the proposed Project Martha designs that suggest similar mitigation measures could not be implemented should they be necessary to reduce vibration impacts to ensure compliance with the proposed vibration criteria.

13.1. Flyrock Mitigation Measures

The Hauraki District Council proposed a number of mitigation measures that were to be implemented after the June 2007 incident to specifically address flyrock control. The recommendations included:

- Stemming is increased from 2.0 to 2.4 metres within 350 metres of restricted area.
- Stemming to be measured and hand loaded.
- Where hole overcharged or under-stemmed, matting or earth cover to be used.
- All blasts to be videoed.
- RC drill holes and probes to be stemmed.

These recommendations, with the exception of increasing the uncharged collar length for all blasts, have been adopted and included as a task within the current effective Vibration Management Plan. Where the potential zone of flyrock from a blast encompasses the road areas, such as Cambridge and/or Bulltown Roads, or the pit rim walkway, a mitigation measure could include the temporary closure for a period of 5 minutes around the blast time. Details of any temporary closures could be presented in the Vibration Management Plan.

13.1. Other Non-blast Design Mitigation Measures

The continuation of blast notification procedures presently undertaken should continue. These currently include:

- Six-monthly notice in the local paper;
- Daily updates on the web page;
- The offer of an automated alarm system comprising modified restaurant coasters that play music;
- Telephone calls and SMS messages;
- Consistency in timing to help normalise/acclimate people to the blasting.

For the open pit blasting, a siren will also be sounded to alert persons of the impending blast.

14. VIBRATION MONITORING

The monitoring equipment for demonstrating vibration compliance will remain unchanged from current practices which have been shown to be appropriate. Vibration monitoring systems capable of reporting the vibration level from each of three orthogonally arranged sensors together with the instantaneous vector sum value will continue to be used to record the amplitude of vibration for blasting events in the frequency spectra between 2 and 200Hz. The monitoring units will operate continuously, detecting any increase in vibration above a pre-set threshold value. For the monitoring of blasting events, it is reasonable to record only events above around 0.75mm/s as traffic, stock and domestic animals can easily produce values exceeding a 0.75mm/s vibration threshold.

In agreement with the Australian Standards AS2187.2-2006, and in particular Section J, the transducers will be placed in the ground rather than on the structure. At each of the monitoring sites, the sensors will be firmly attached to the ground to ensure adequate coupling between the ground and the sensor. The proposed monitoring sites will be selected on the basis of:

- Proximity to the blasting area, ensuring that the potentially sensitive privately owned properties are appropriately monitored.
- A monitoring location that will offer a secure area that will minimise the possibility of interference from the public.
- Provide an accurate indication of the vibration level.

Plate D identifies the proposed monitoring sites which best achieve the objectives indicated above for Project Martha. Where possible, and they are considered to provide a representative location, it would be beneficial to maintain the existing monitoring sites. This allows a continuity of monitoring results to better determine any anomalous vibration zones.

Additional monitoring sites may be considered as a result of further monitoring that identifies anomalous regions that are not adequately covered by the monitoring network, or justified concerns by residences that warrant additional monitoring locations. For these purposes, a fleet of roving monitors will be utilised. These matters are already and can be addressed in the Vibration Management Plan.

The proposed vibration condition requires that the level of vibration for all blasts is monitored and the peak level of vibration at <u>each</u> location comply at the 95th percentile with 5mm/s. The same will apply for the 1mm/s limit for underground blasts for maintenance/safety purposes. The percentile calculation is based upon all recorded vibration data that exceeds the pre-set threshold level set in the Vibration

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● Project Martha blasting area

SCALE

0 150 300 450 600 750m

Project Description: PROJECT MARTHA - Proposed vibration monitoring locations for Project Martha noting that not all locations are required to be simultaneously operational

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OCEANAGOLD WAIHI OPERATION

Plate No. D

Revision History

R1: Original

Date Drawn: **21 February 2018**

Ref No: Report drawings 2018

Job No: HP1712-6

Management Plan. Where the level of vibration does not exceed the threshold level of vibration, the blast is not included in the calculation of the 95th percentile statistics.

The monitoring vibration threshold level will be listed in the Vibration Management Plan to accommodate any future changes that may be required as a consequence of the elevated vibration at the monitoring site. The monitoring history at Waihi over the previous 15 years has demonstrated that a vibration threshold level of 0.5 to 0.75mm/s ensures that all blasts that have generated a perceptible level of vibration are recorded, but with minimum extraneous events attributable to the other non-blast related sources.

The blasting results from all of the monitoring locations will be displayed on OGNZL's web page. It is proposed to use an aerial photograph showing each of the monitoring locations with a pop-up menu showing the blast events and recorded vibration levels similar to which has been implemented for Correnso. OGNZL's web page is shown in *Figure **13***. It is also proposed to include the 95th percentile calculation for each location as part of the pop-up menu.

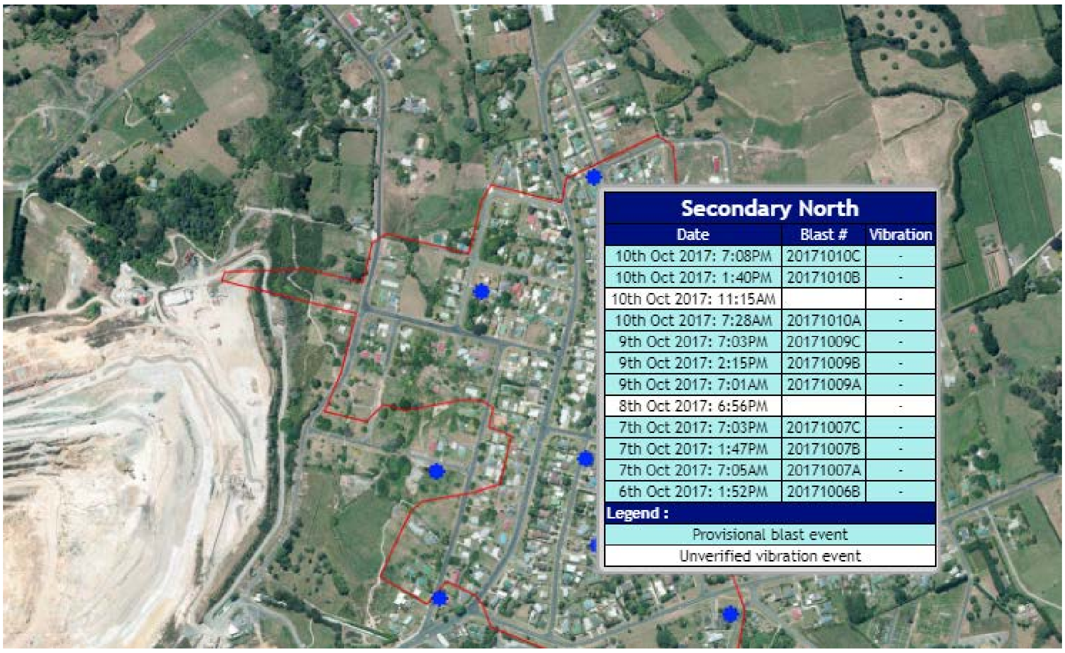
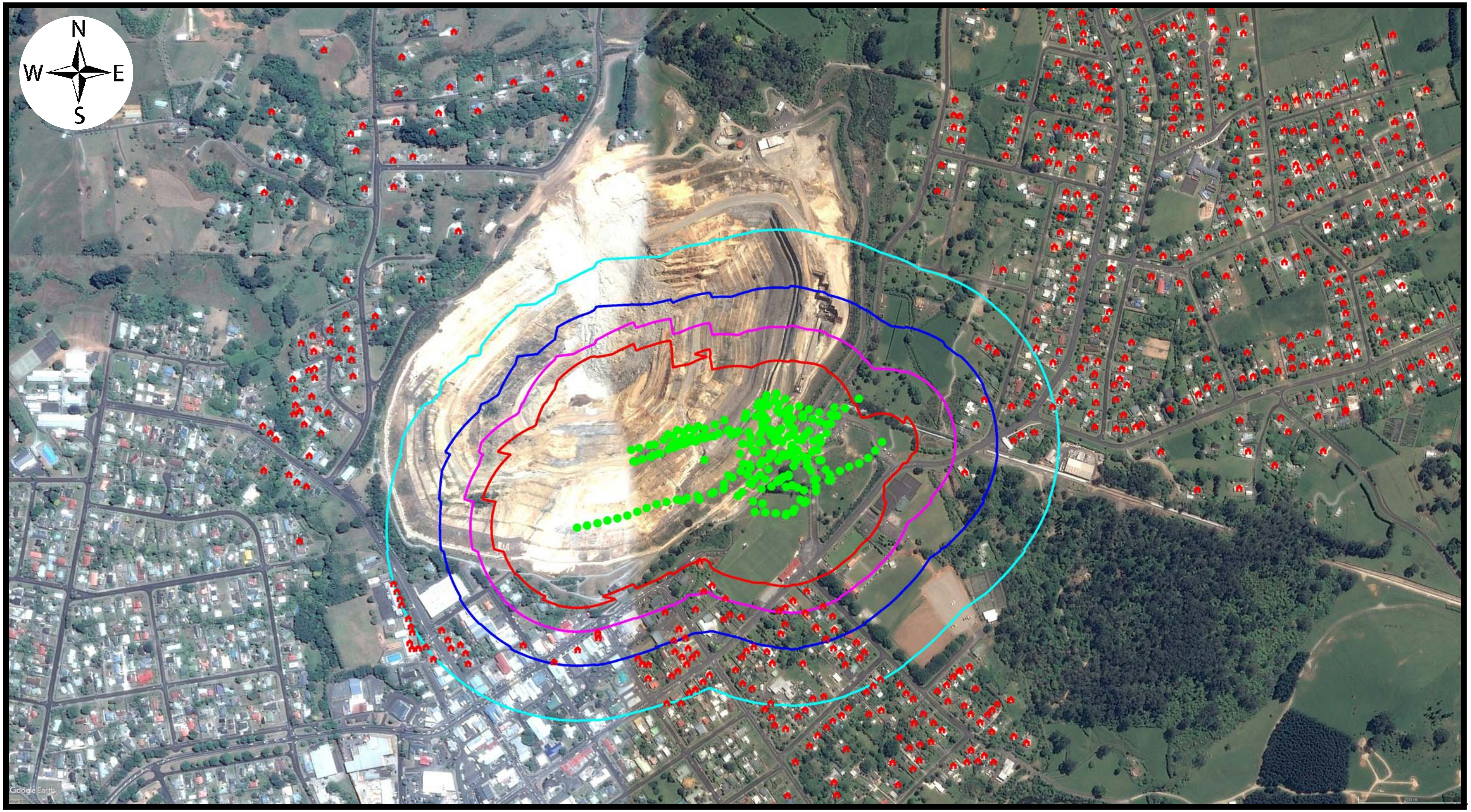


Figure 13 – OGNZL's web page showing measured vibration levels for each monitoring site

15. APPENDIX A – MARTHA UNDERGROUND VIBRATION CONTOURS

A B C D E F G H I J K L M N



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SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 7 kilograms
- Between 6 and 7 kilograms
- Between 5 and 6 kilograms
- Between 4 and 5 kilograms
- Between 3 and 4 kilograms
- Between 2 and 3 kilograms
- Between 1 and 2 kilograms
- Less than 1 Kilogram

Project Description: MARTHA UNDERGROUND DEVELOPMENT - Mining in 2020 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. A

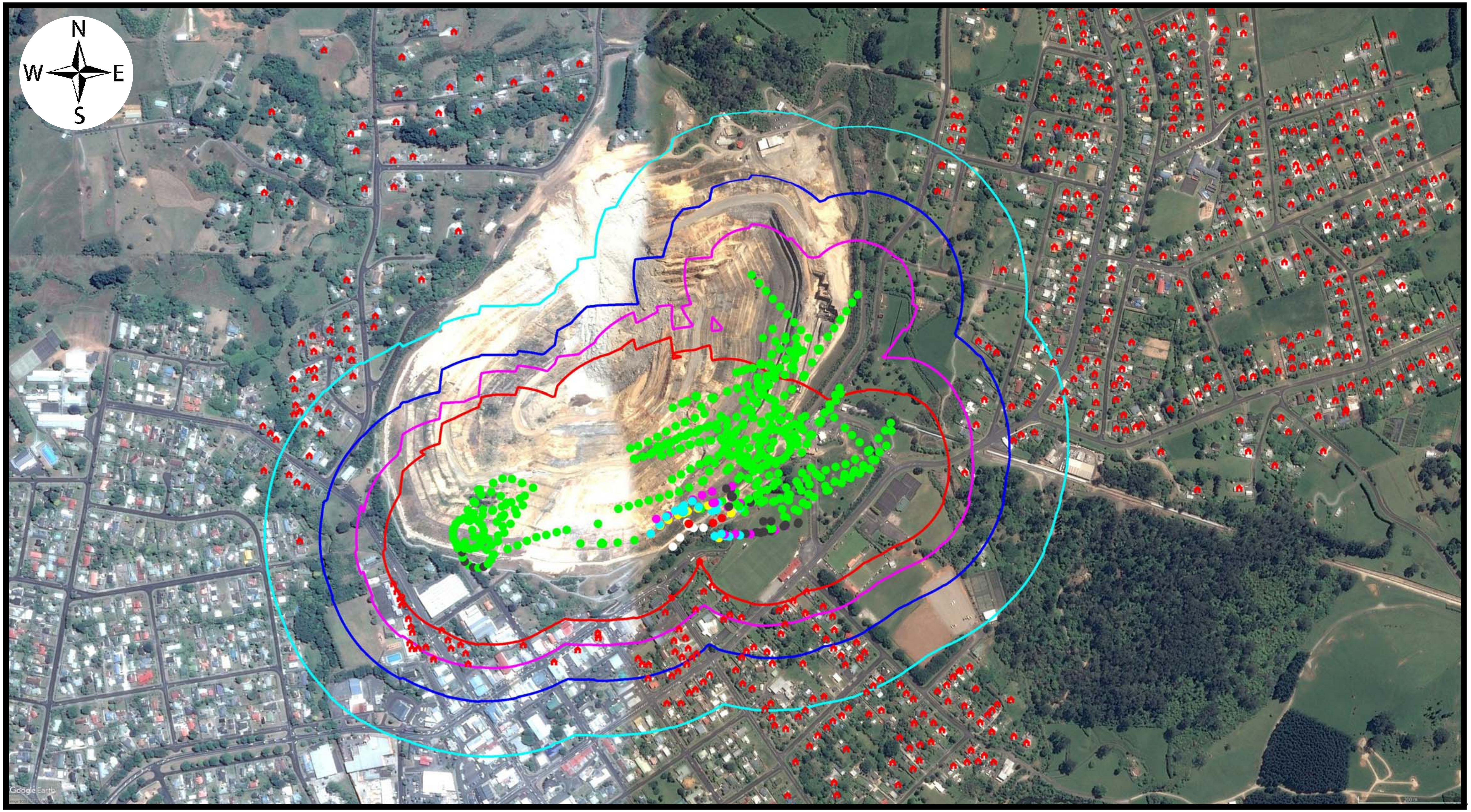
Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

Compliance Properties

Explosive Quantities

- More than 7 kilograms
- Between 6 and 7 kilograms
- Between 5 and 6 kilograms
- Between 4 and 5 kilograms
- Between 3 and 4 kilograms
- Between 2 and 3 kilograms
- Between 1 and 2 kilograms
- Less than 1 Kilogram

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Project Description: MARTHA UNDERGROUND DEVELOPMENT - Mining in 2021 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. B

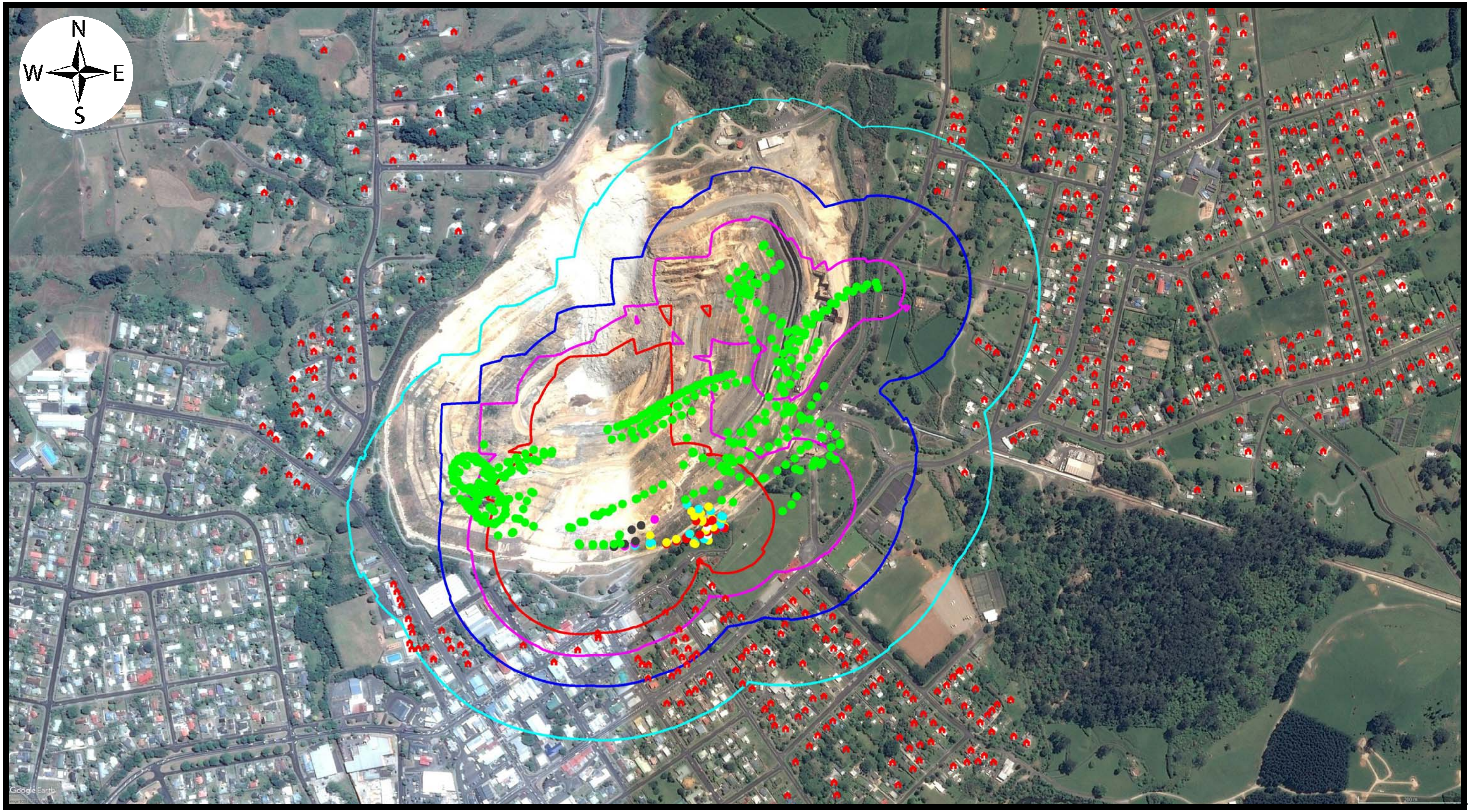
Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 7 kilograms
- Between 6 and 7 kilograms
- Between 5 and 6 kilograms
- Between 4 and 5 kilograms
- Between 3 and 4 kilograms
- Between 2 and 3 kilograms
- Between 1 and 2 kilograms
- Less than 1 Kilogram

Project Description: MARTHA UNDERGROUND DEVELOPMENT - Mining in 2022 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. C

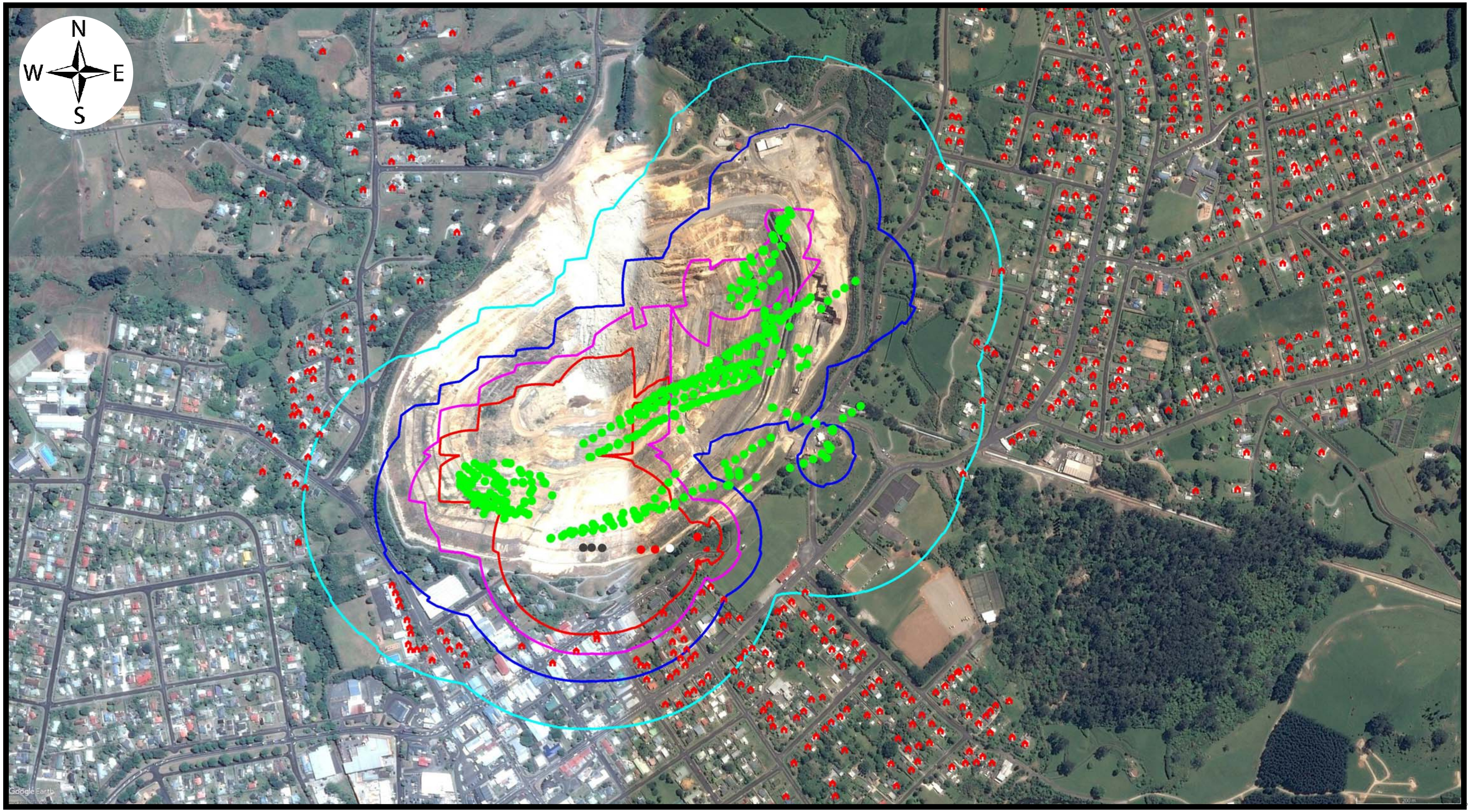
Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 7 kilograms
- Between 6 and 7 kilograms
- Between 5 and 6 kilograms
- Between 4 and 5 kilograms
- Between 3 and 4 kilograms
- Between 2 and 3 kilograms
- Between 1 and 2 kilograms
- Less than 1 Kilogram

Project Description: MARTHA UNDERGROUND DEVELOPMENT - Mining in 2023 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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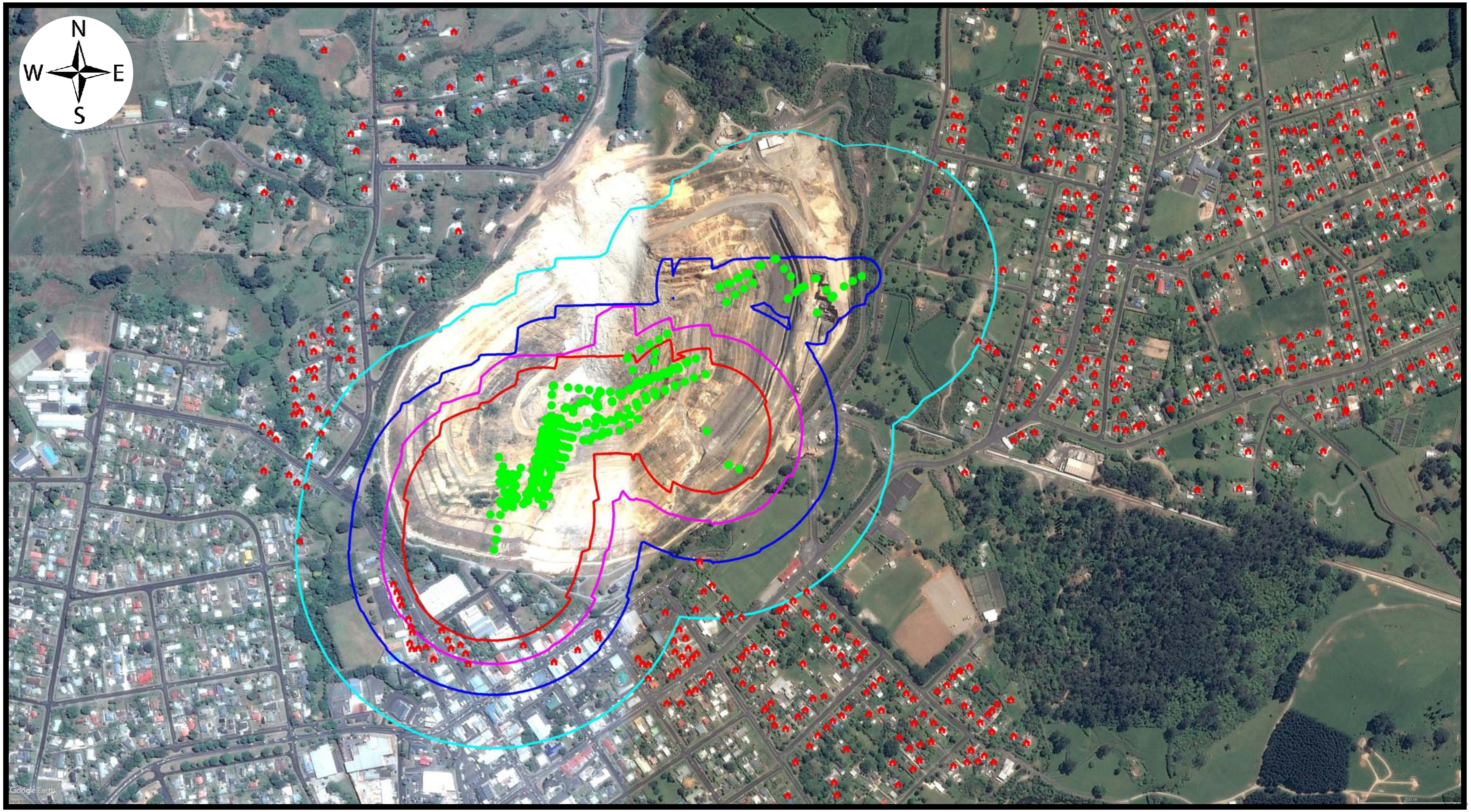
Plate No. D	Date Drawn: **9 January 2018**
Revision History R1: Original	**Ref No: Martha Project**
	Job No: HP1712-6



Created using TunnelTRAP Software

Compliance Properties

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Explosive Quantities

- More than 7 kilograms
- Between 6 and 7 kilograms
- Between 5 and 6 kilograms
- Between 4 and 5 kilograms
- Between 3 and 4 kilograms
- Between 2 and 3 kilograms
- Between 1 and 2 kilograms
- Less than 1 Kilogram

Project Description: MARTHA UNDERGROUND DEVELOPMENT - Mining in 2024 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. E

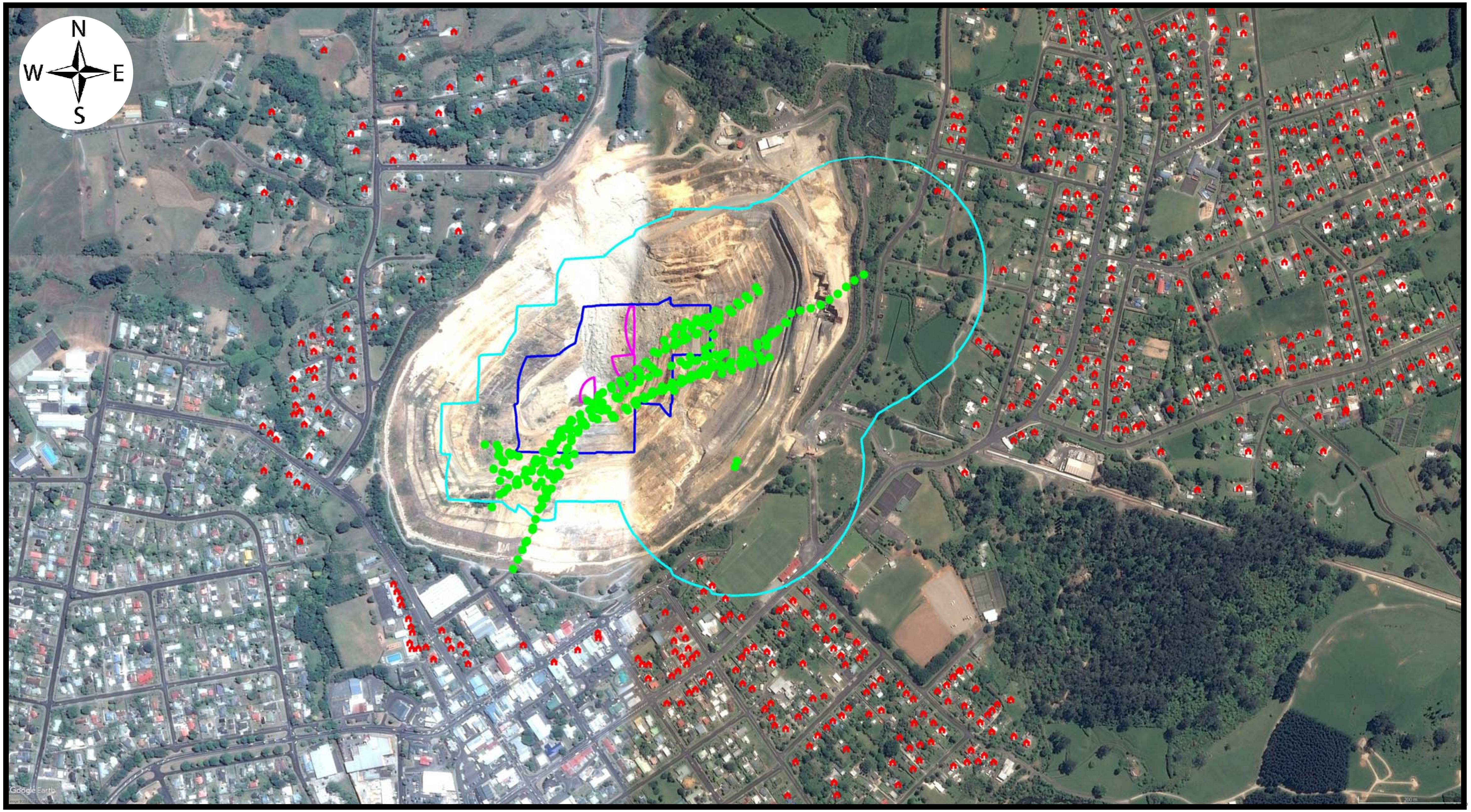
Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



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SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 7 kilograms
- Between 6 and 7 kilograms
- Between 5 and 6 kilograms
- Between 4 and 5 kilograms
- Between 3 and 4 kilograms
- Between 2 and 3 kilograms
- Between 1 and 2 kilograms
- Less than 1 Kilogram

Project Description: MARTHA UNDERGROUND DEVELOPMENT - Mining in 2025 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. F

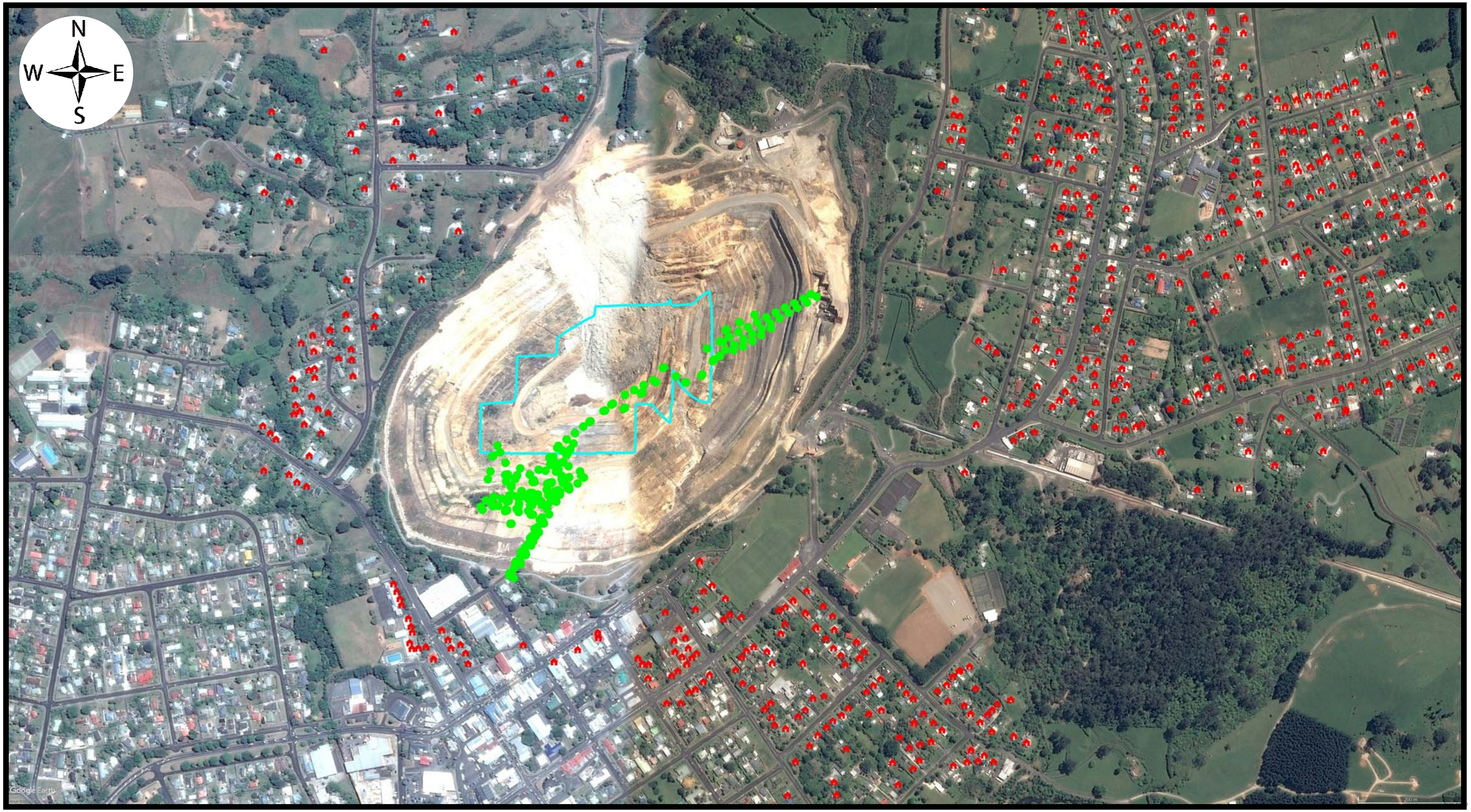
Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 7 kilograms
- Between 6 and 7 kilograms
- Between 5 and 6 kilograms
- Between 4 and 5 kilograms
- Between 3 and 4 kilograms
- Between 2 and 3 kilograms
- Between 1 and 2 kilograms
- Less than 1 Kilogram

Project Description: MARTHA UNDERGROUND DEVELOPMENT - Mining in 2026 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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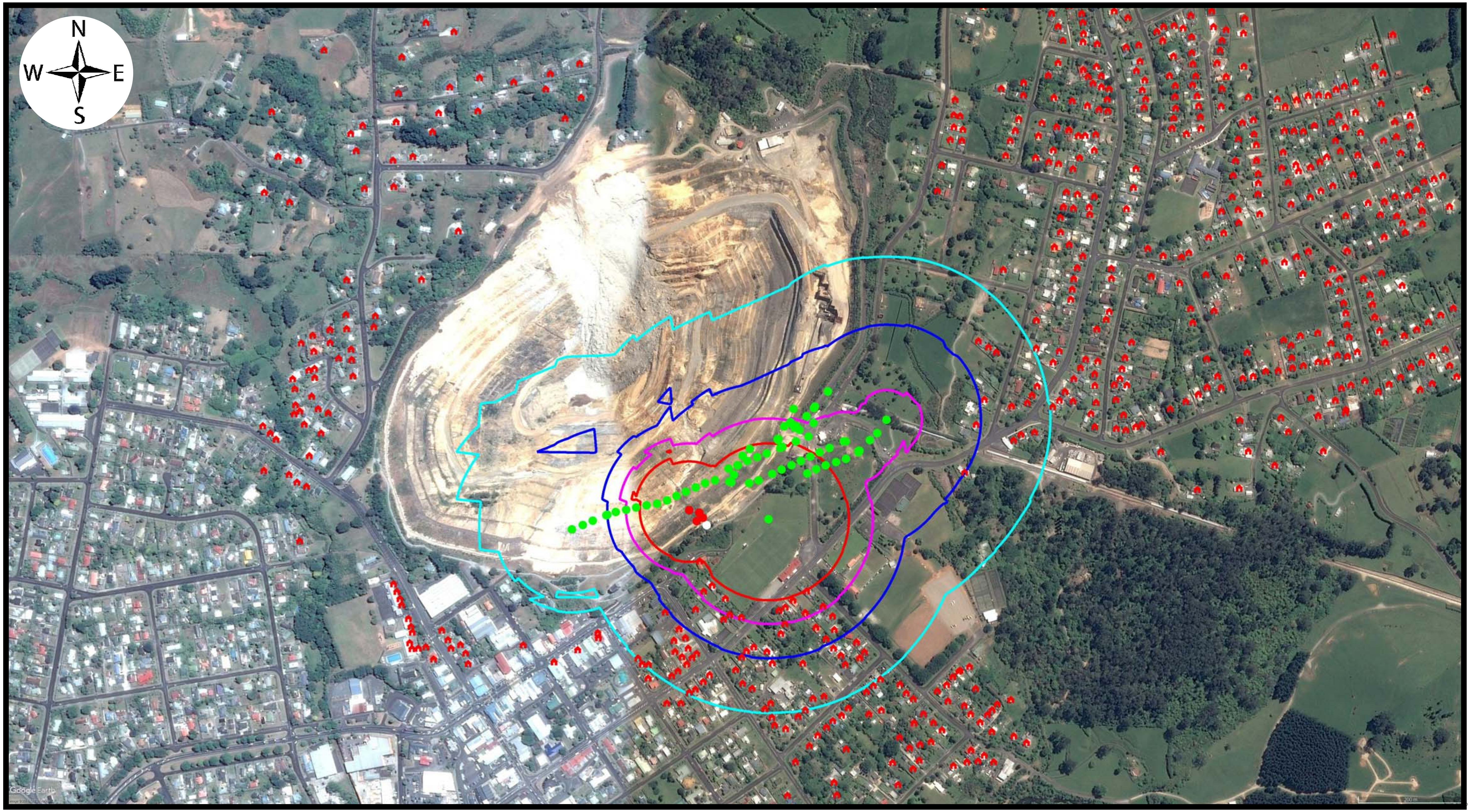
Plate No. G	Date Drawn: **9 January 2018**
Revision History R1: Original	**Ref No: Martha Project**
	Job No: HP1712-6

In preparing this drawing, HP have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request were complete, accurate and up to date. Where we have obtained information from a Government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware why any of the assumptions are incorrect.



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SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 7 kilograms
- Between 6 and 7 kilograms
- Between 5 and 6 kilograms
- Between 4 and 5 kilograms
- Between 3 and 4 kilograms
- Between 2 and 3 kilograms
- Between 1 and 2 kilograms
- Less than 1 Kilogram

Project Description: MARTHA UNDERGROUND DEVELOPMENT - Mining in 2029 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. H

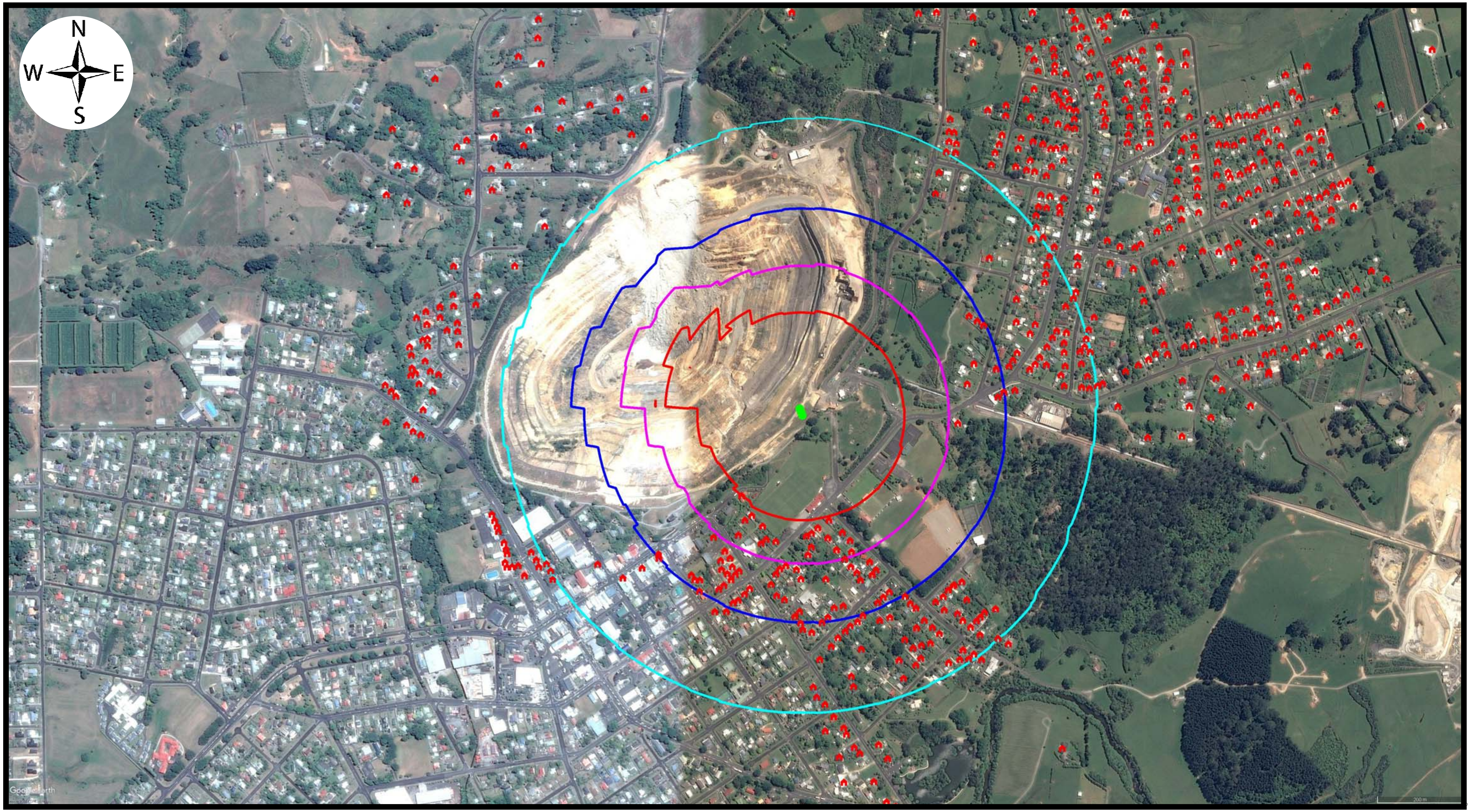
Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND VERTICAL - Mining in 2020 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. A

Revision History

R1: Original

Date Drawn: **2 January 2018**

Ref No: Martha Project

Job No: HP1712-6

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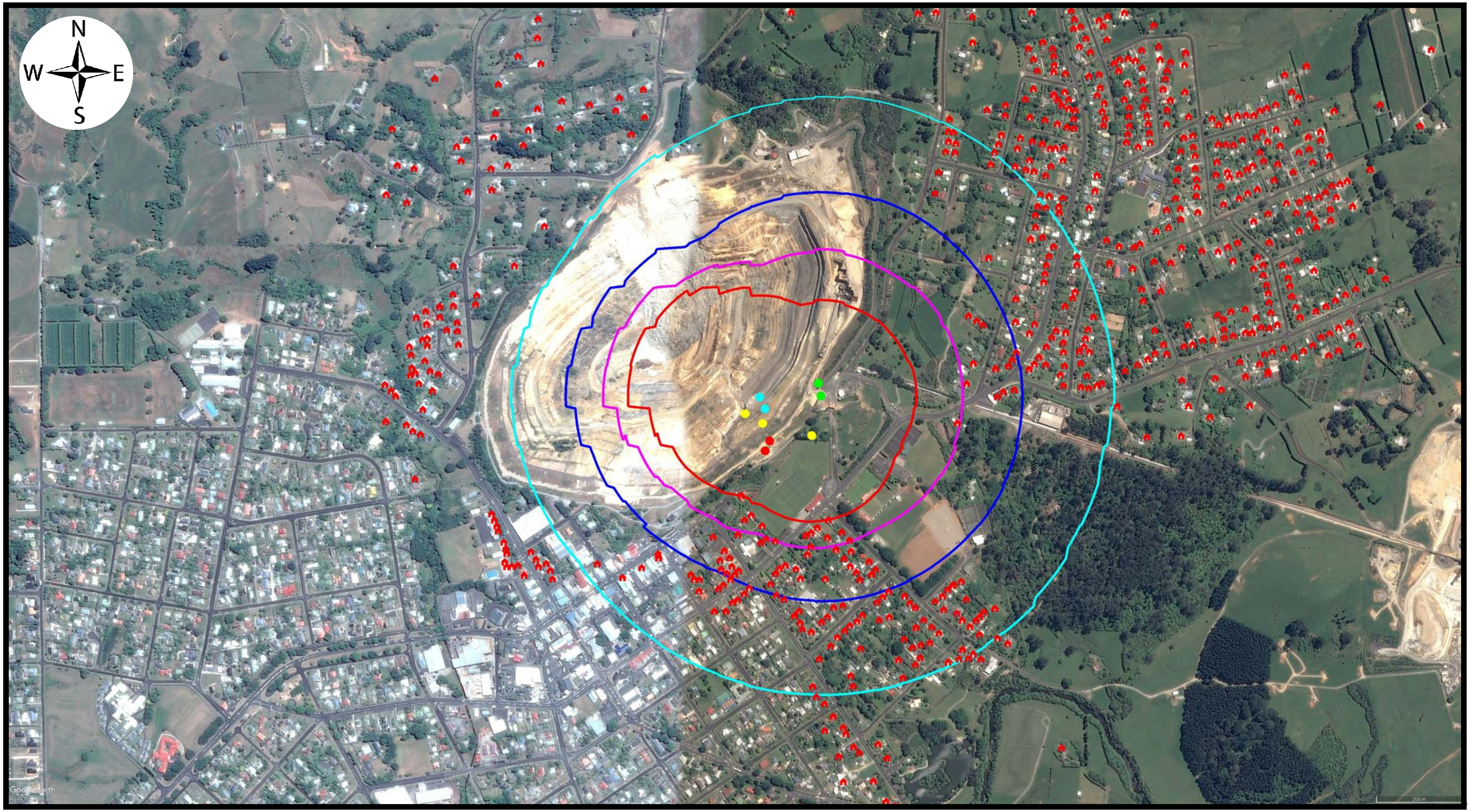

Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND VERTICAL - Mining in 2021 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. B

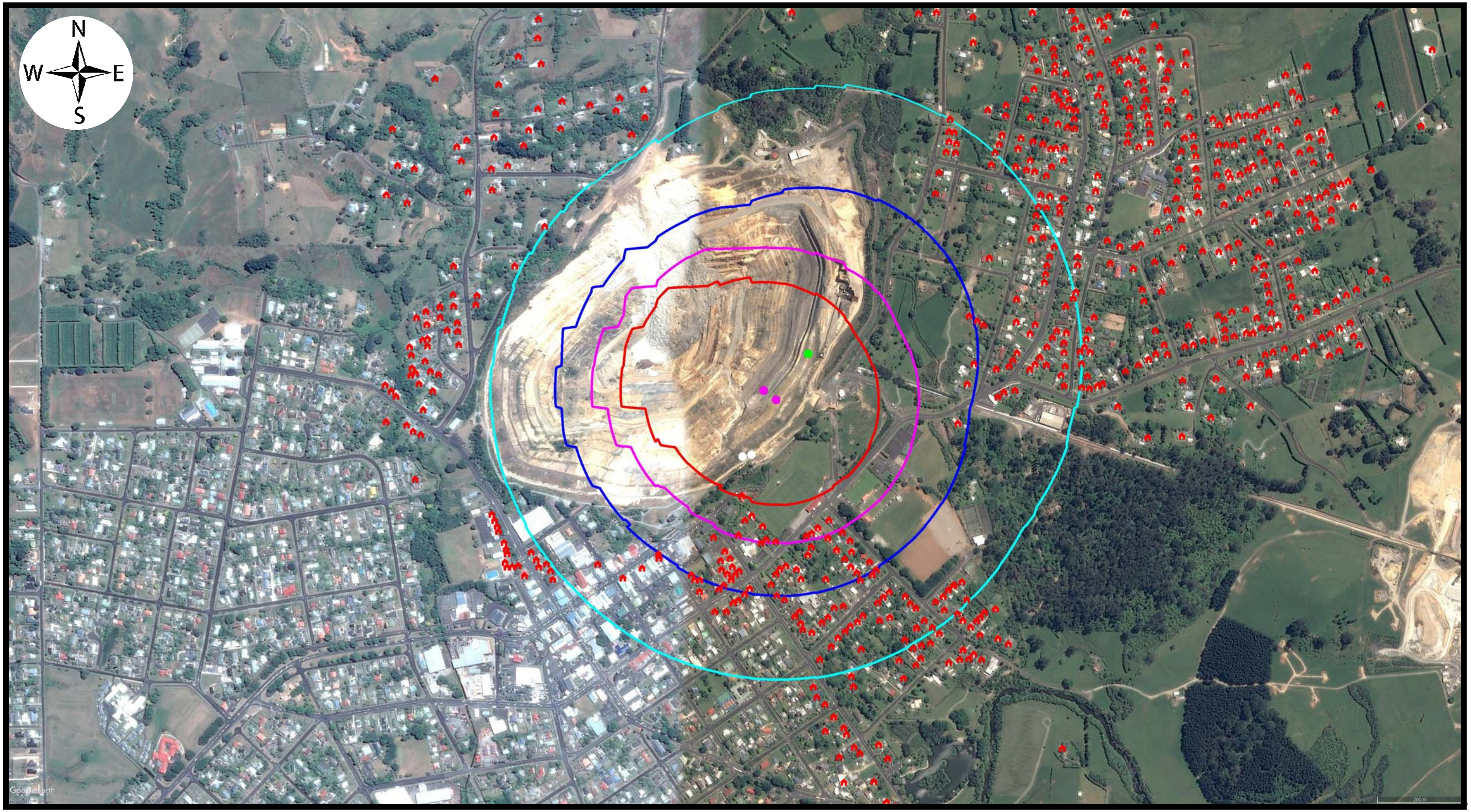
Revision History

R1: Original

Date Drawn: **2 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND VERTICAL - Mining in 2022 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. C

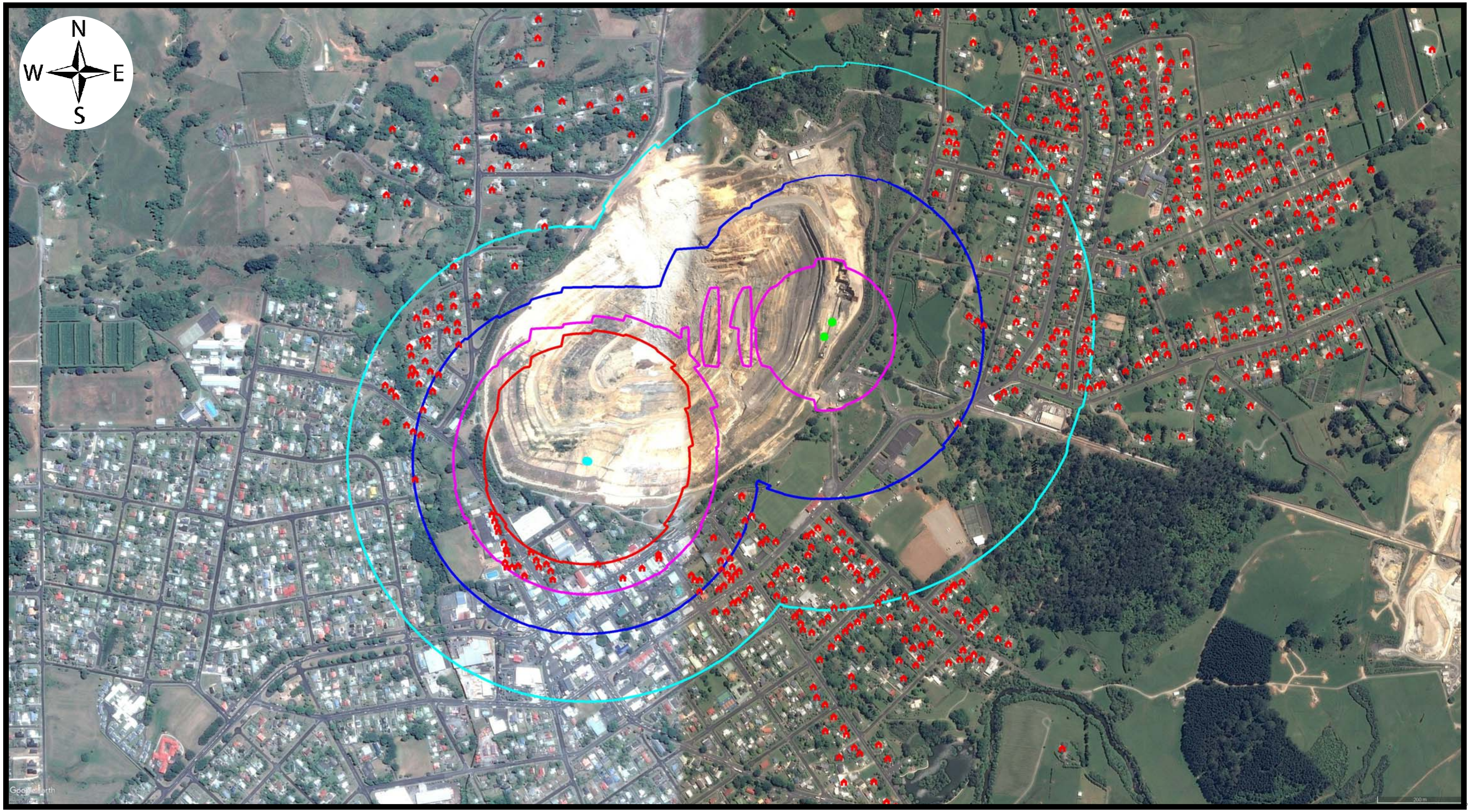
Revision History

R1: Original

Date Drawn: **2 January 2018**

Ref No: Martha Project

Job No: HP1712-6



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SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND VERTICAL - Mining in 2023 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. D

Revision History

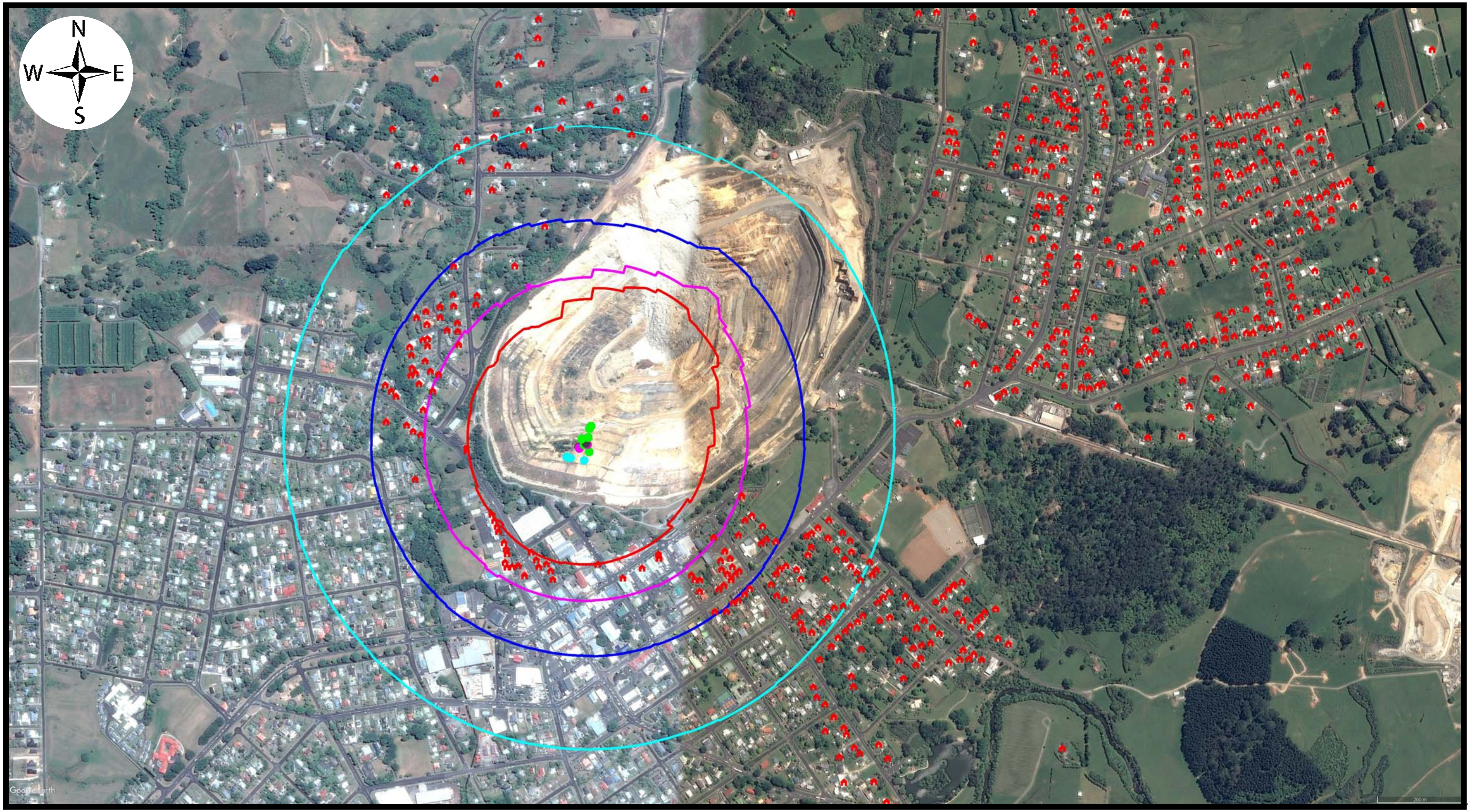
R1: Original

Date Drawn: **2 January 2018**

Ref No: Martha Project

Job No: HP1712-6

In preparing this drawing, HP have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request were complete, accurate and up to date. Where we have obtained information from a Government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware why any of the assumptions are incorrect.



Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND VERTICAL - Mining in 2024 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. E

Revision History

R1: Original

Date Drawn: **2 January 2018**

Ref No: Martha Project

Job No: HP1712-6

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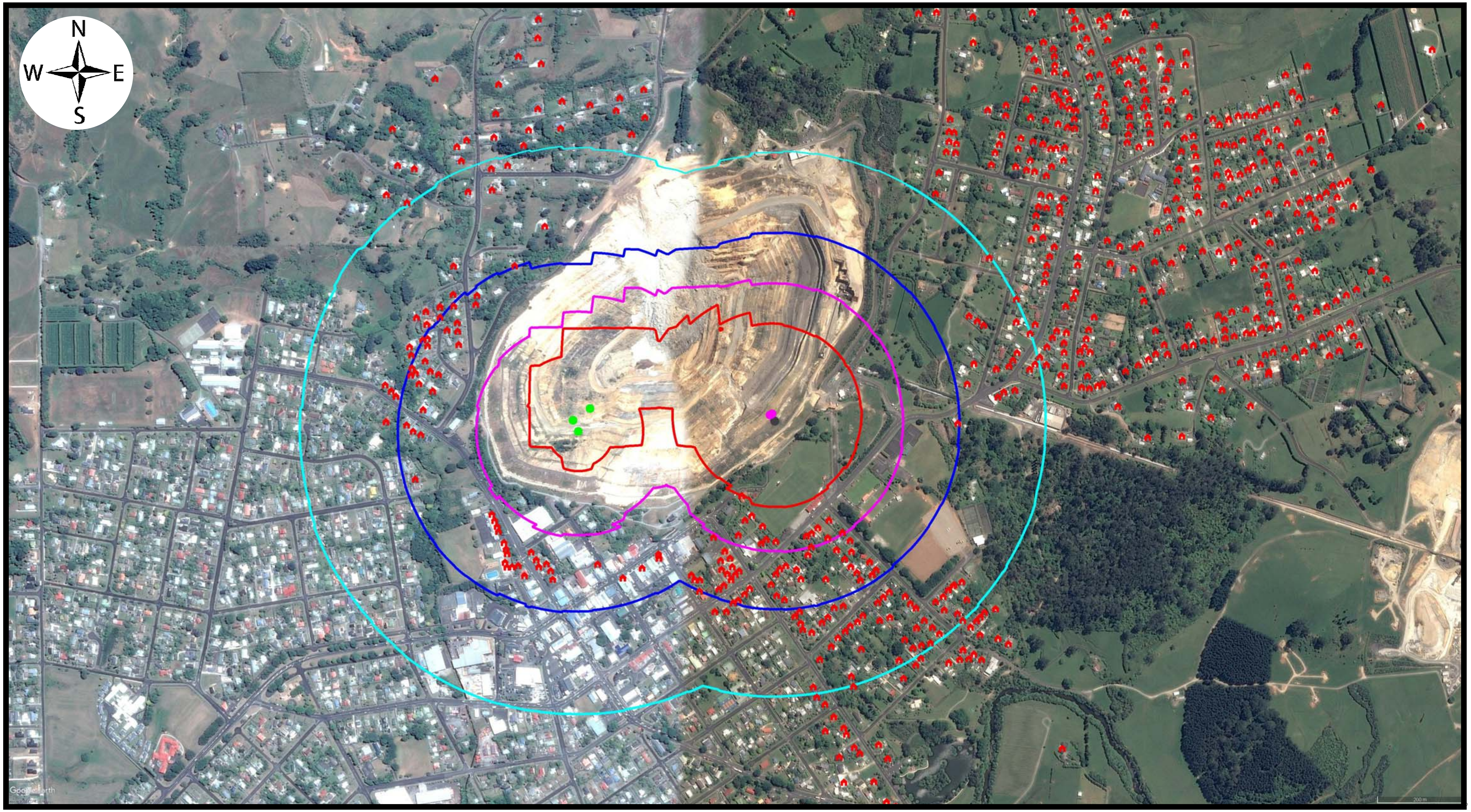

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SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND VERTICAL - Mining in 2025 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. F

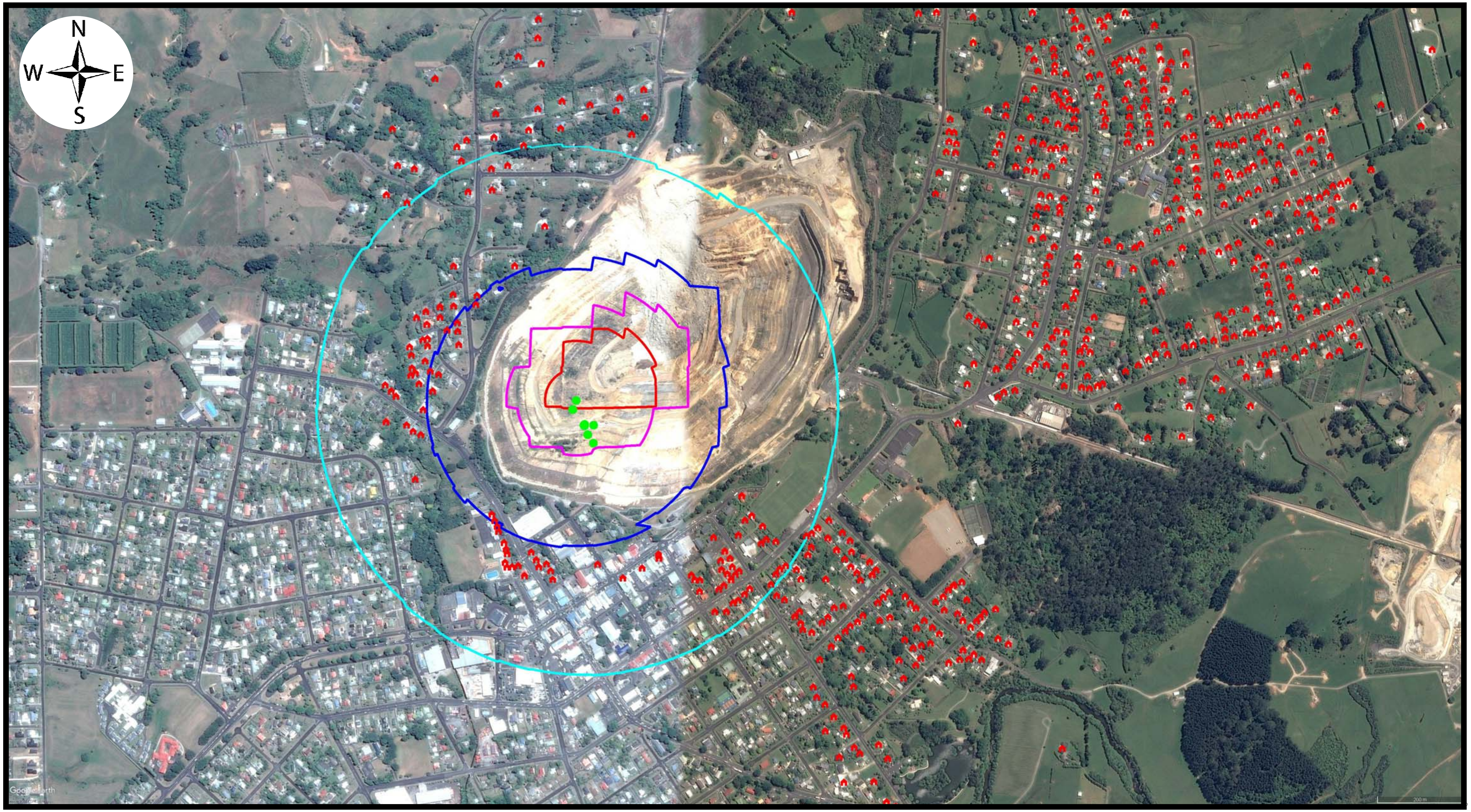
Revision History

R1: Original

Date Drawn: **2 January 2018**

Ref No: Martha Project

Job No: HP1712-6



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SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND VERTICAL - Mining in 2026 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. G

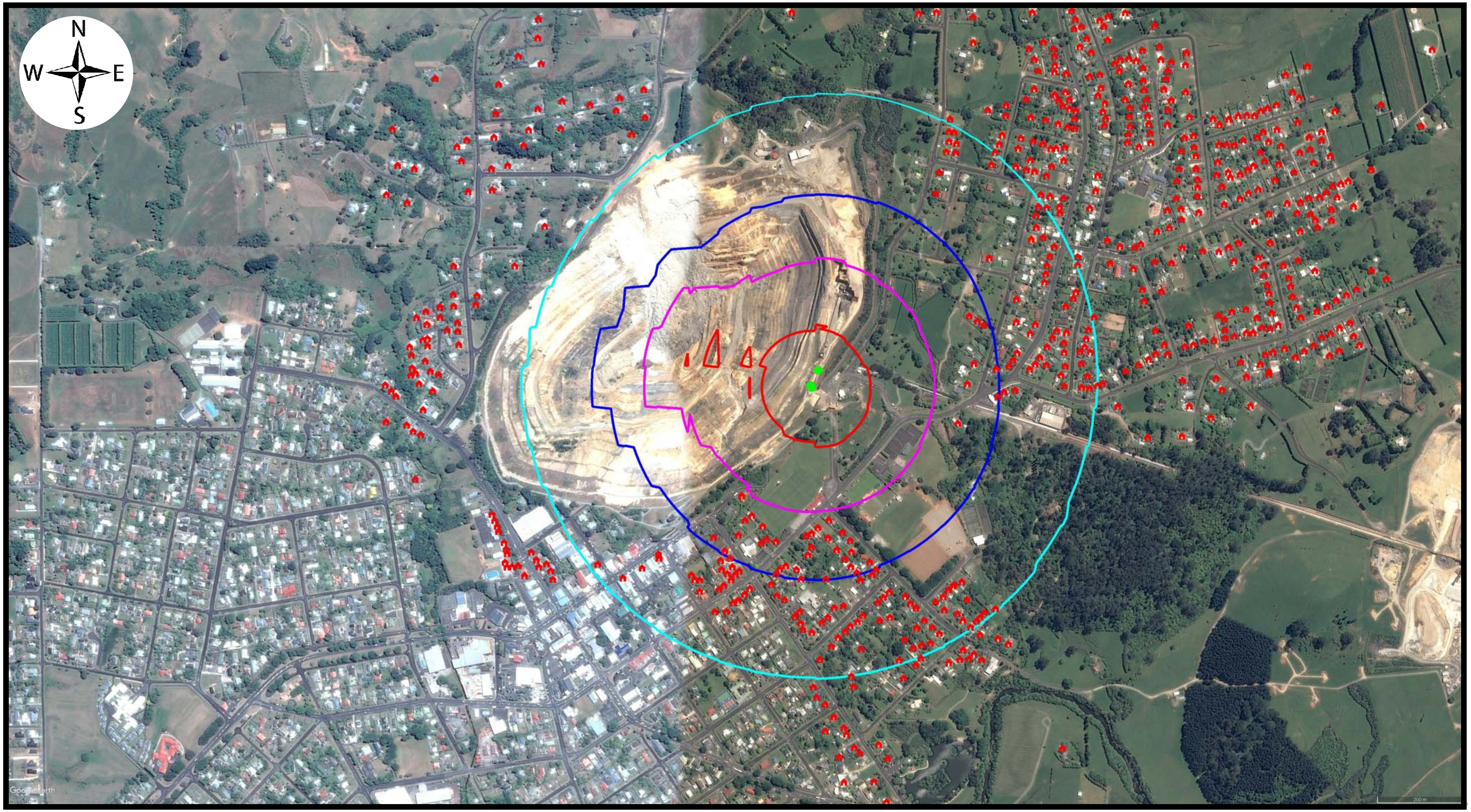
Revision History

R1: Original

Date Drawn: **2 January 2018**

Ref No: Martha Project

Job No: HP1712-6



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SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND VERTICAL - Mining in 2029 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. H

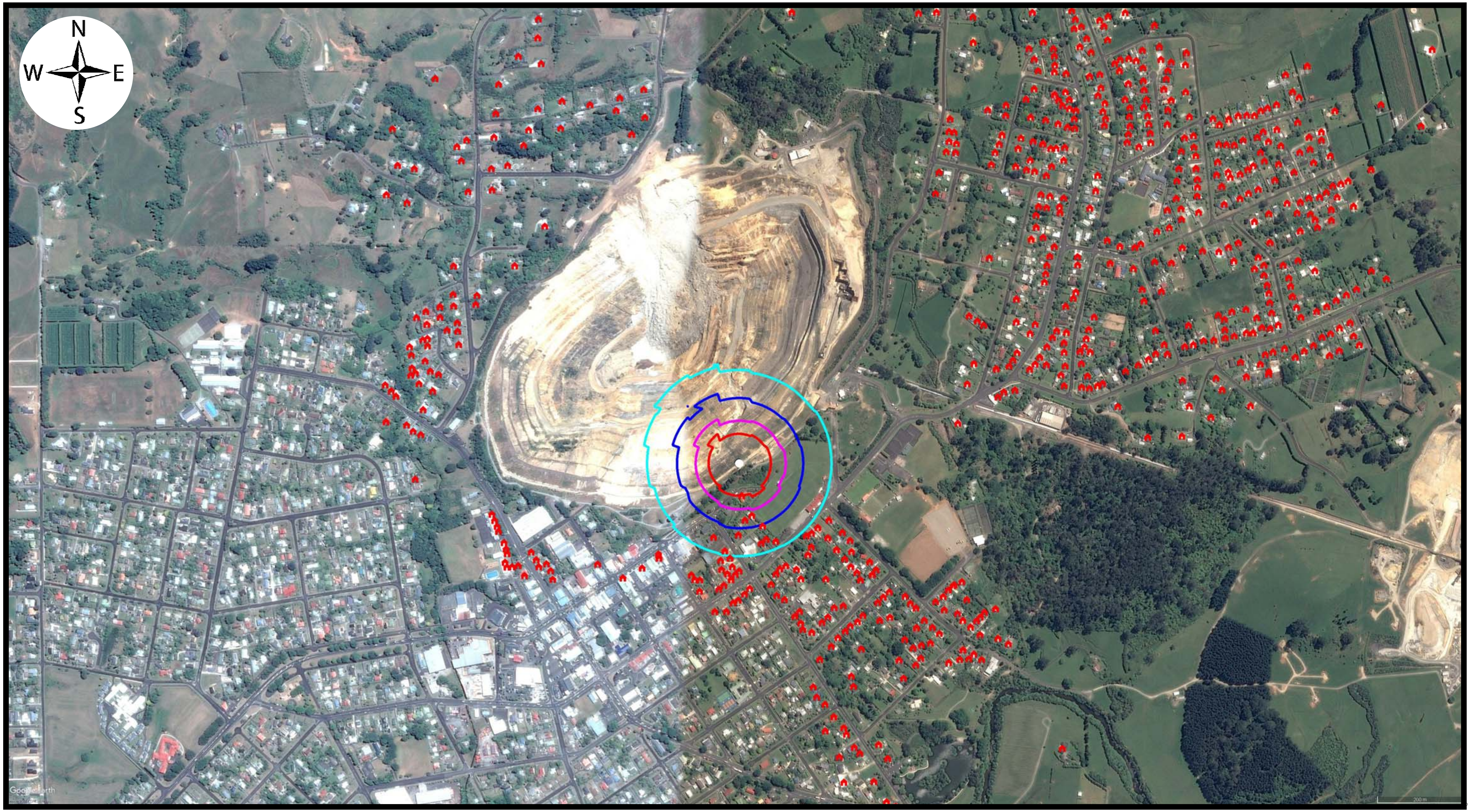
Date Drawn: 2 January 2018

Revision History

R1: Original

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND VERTICAL - Mining in 2030 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. I

Revision History

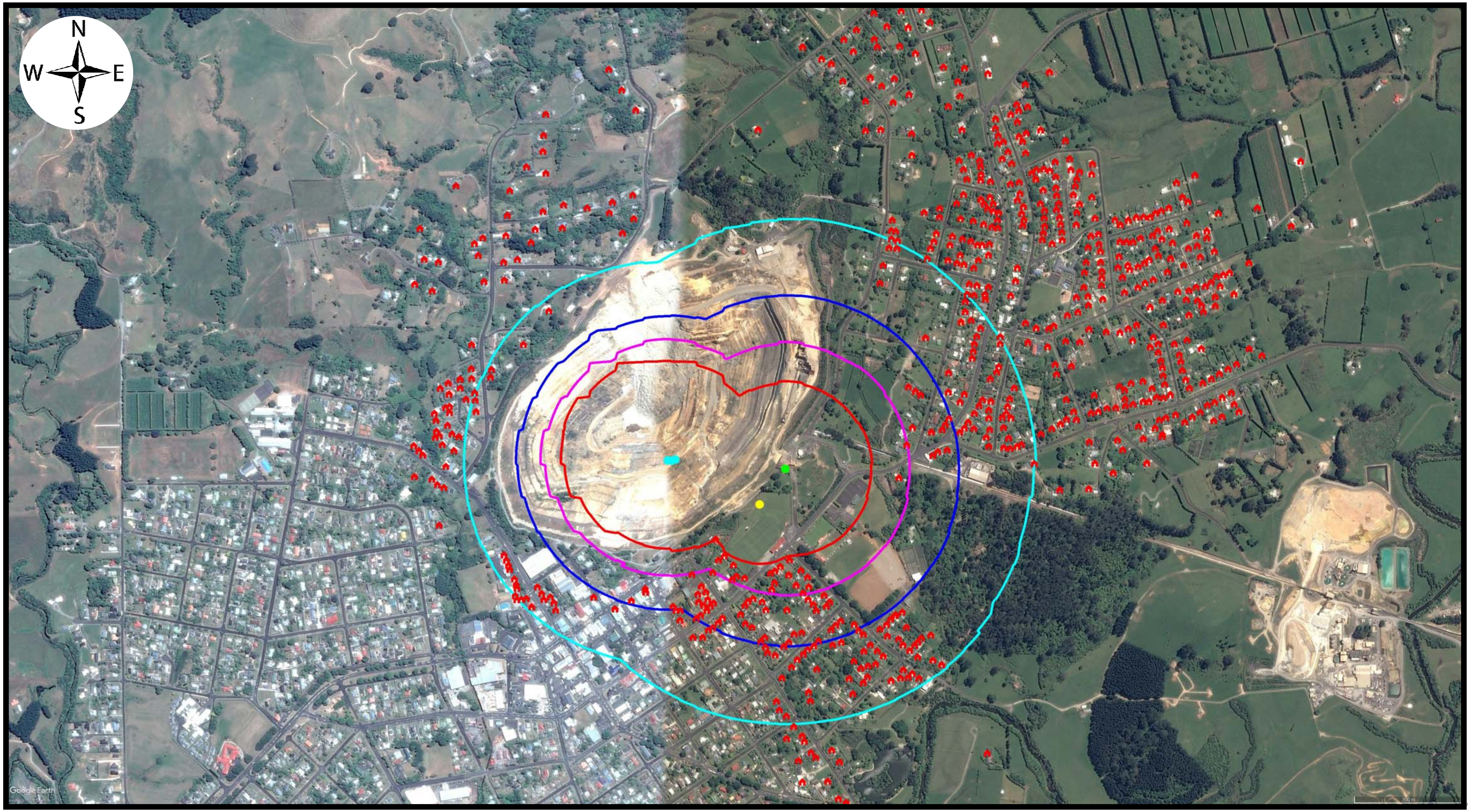
R1: Original

Date Drawn: **2 January 2018**

Ref No: Martha Project

Job No: HP1712-6

In preparing this drawing, HP have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request were complete, accurate and up to date. Where we have obtained information from a Government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware why any of the assumptions are incorrect.



Created using TunnelTRAP Software

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Project Description: MARTHA UNDERGROUND STOPING - Mining in 2020 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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WAIHI OPERATION

Plate No. A

Revision History

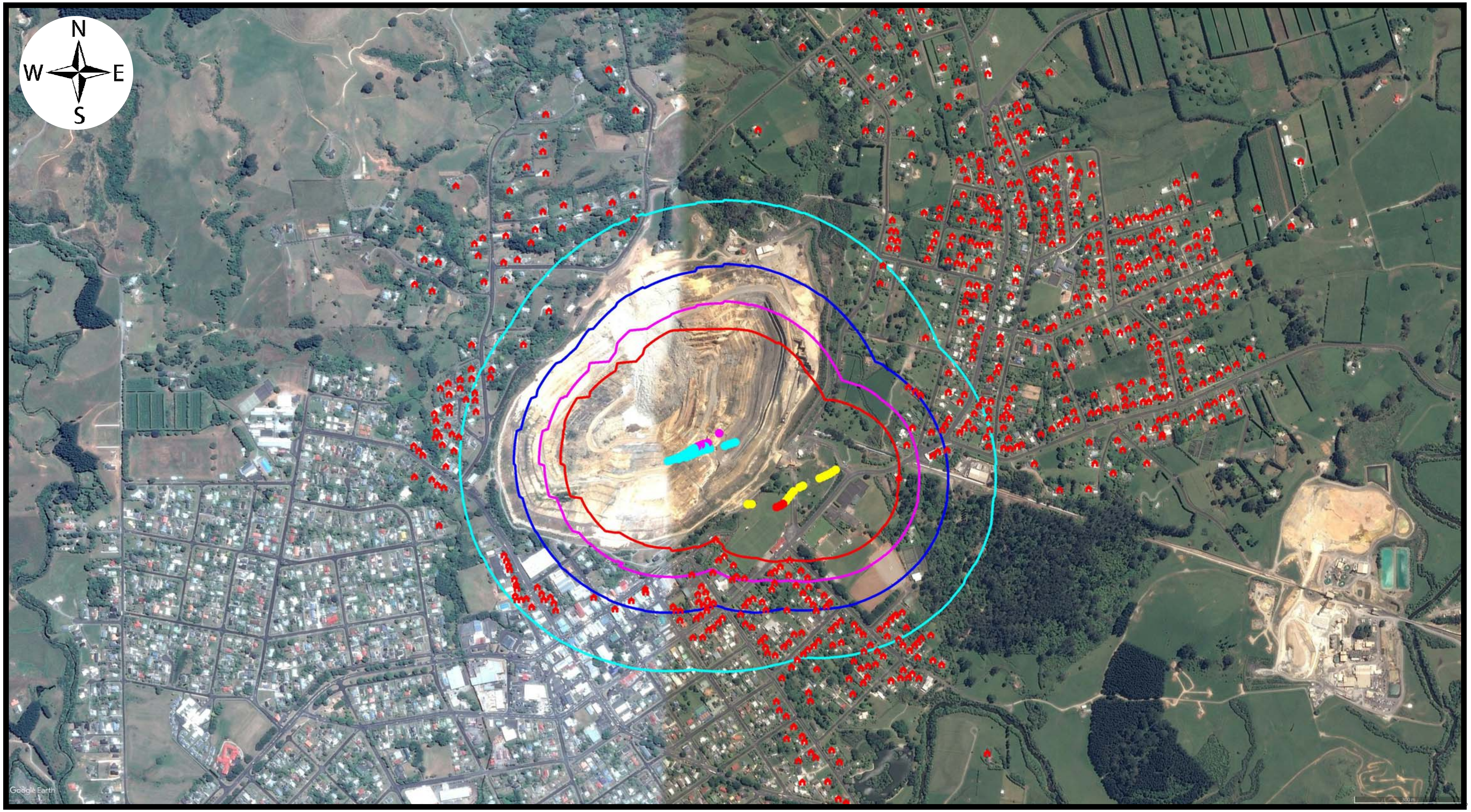
R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6

In preparing this drawing, HP have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request were complete, accurate and up to date. Where we have obtained information from a Government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware why any of the assumptions are incorrect.



Created using TunnelTRAP Software

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND STOPING - Mining in 2021 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. B

Revision History

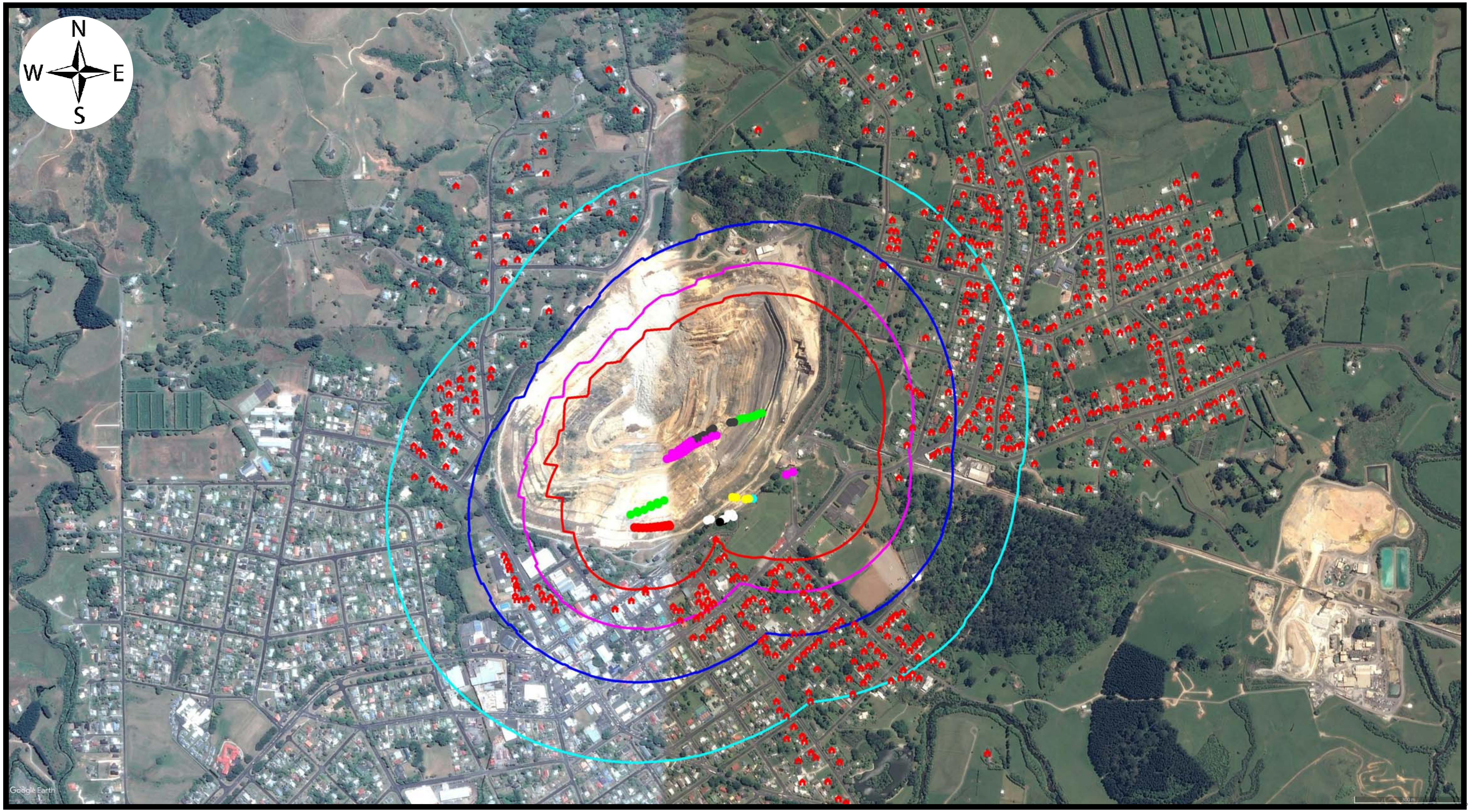
R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6

In preparing this drawing, HP have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request were complete, accurate and up to date. Where we have obtained information from a Government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware why any of the assumptions are incorrect.



Created using TunnelTRAP Software

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND STOPING - Mining in 2022 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. C

Revision History

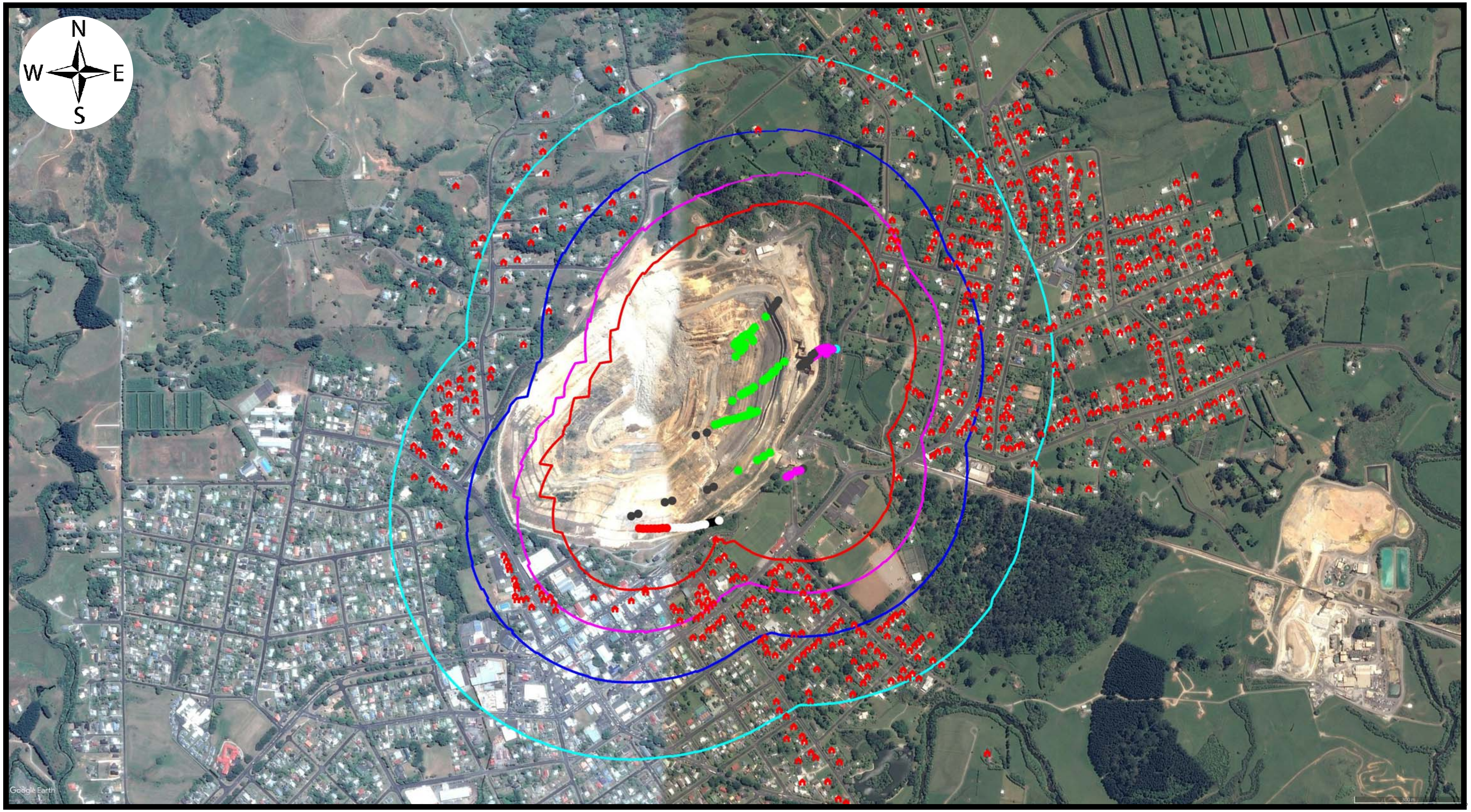
R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6

In preparing this drawing, HP have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request were complete, accurate and up to date. Where we have obtained information from a Government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware why any of the assumptions are incorrect.



Created using TunnelTRAP Software

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND STOPING - Mining in 2023 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. D

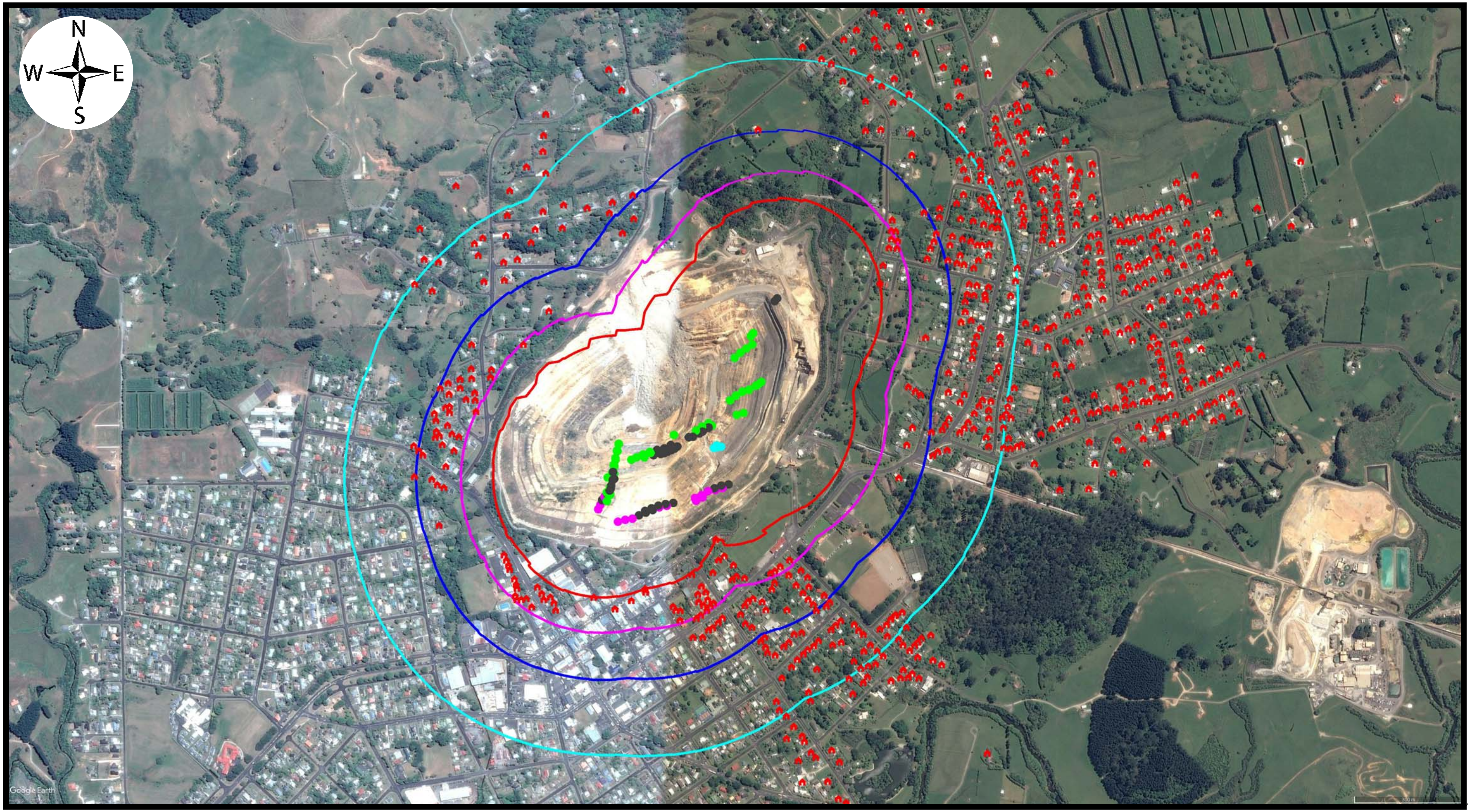
Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND STOPING - Mining in 2024 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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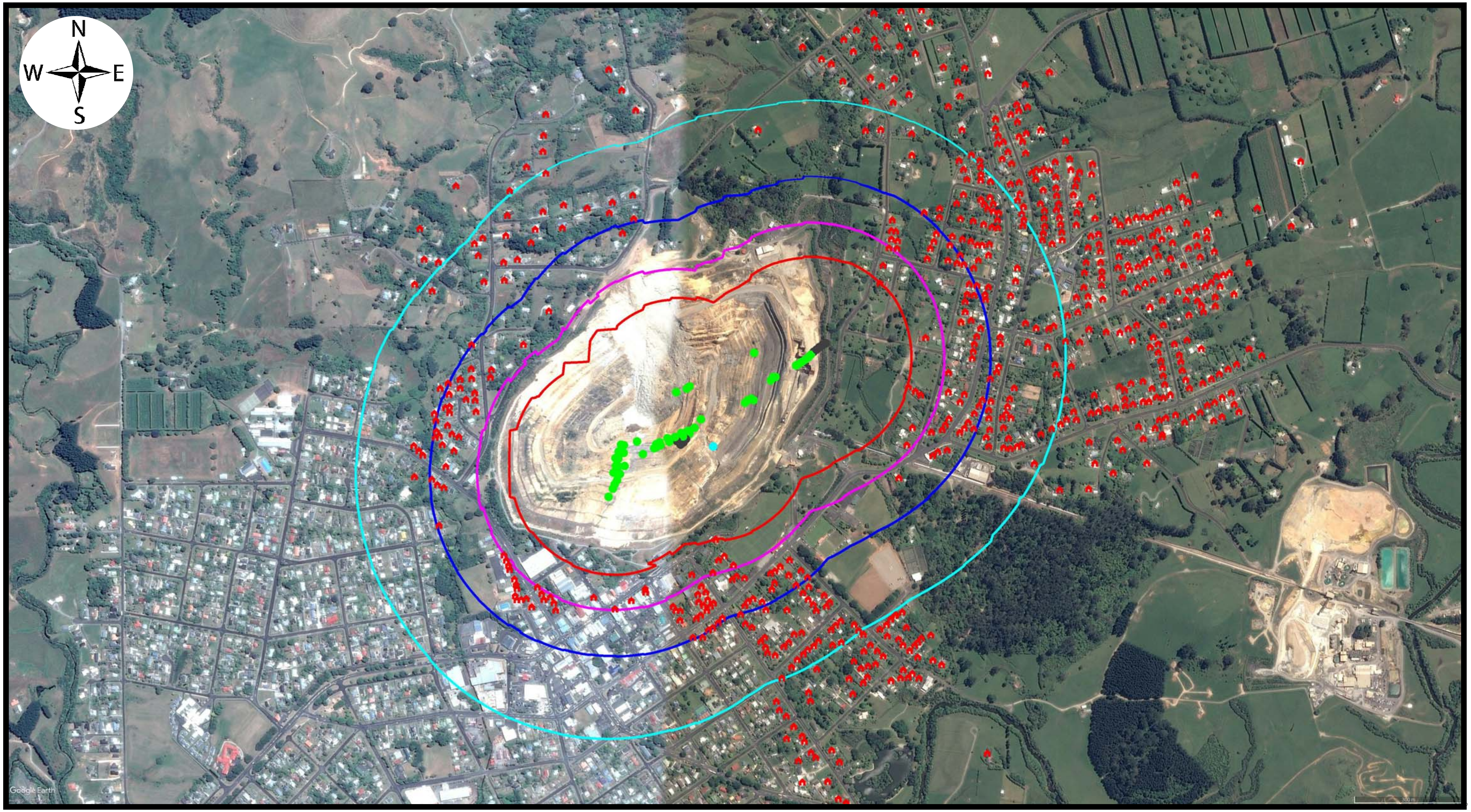
Plate No. E	Date Drawn: **9 January 2018**
Revision History R1: Original	**Ref No: Martha Project**
	Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND STOPING - Mining in 2025 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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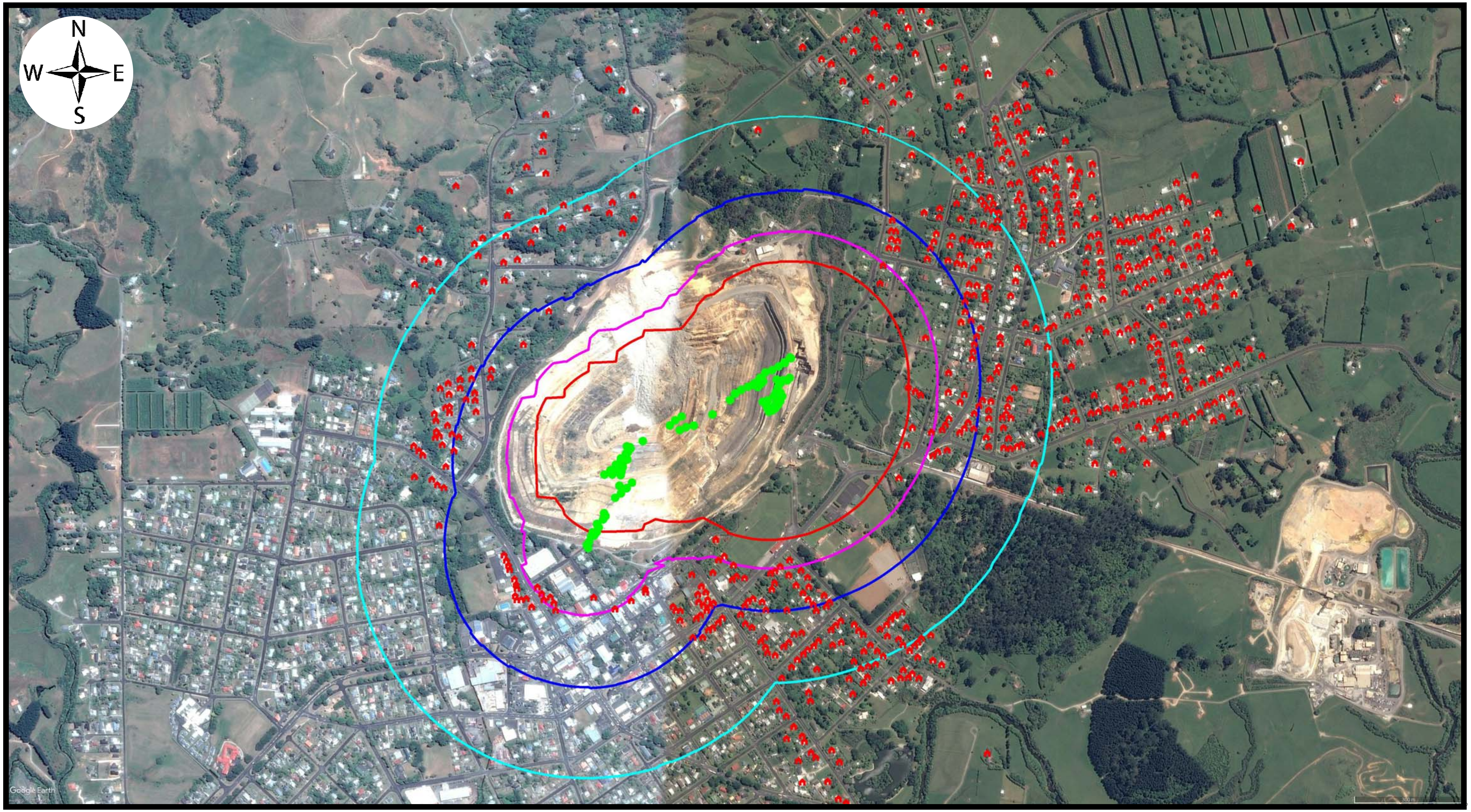
Plate No. F	Date Drawn: **9 January 2018**
Revision History R1: Original	**Ref No: Martha Project**
	Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND STOPING - Mining in 2026 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. G

Revision History

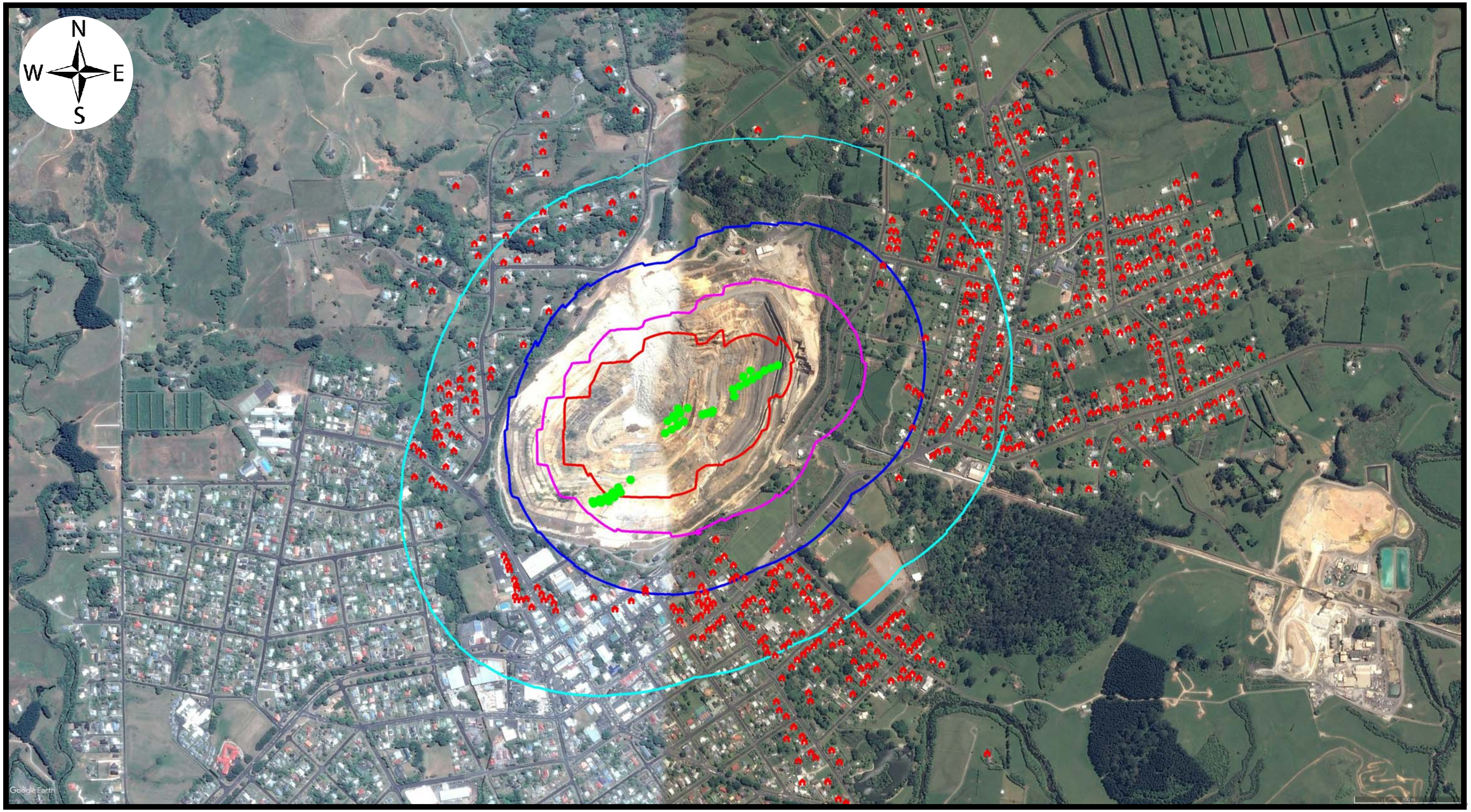
R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6

In preparing this drawing, HP have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request were complete, accurate and up to date. Where we have obtained information from a Government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware why any of the assumptions are incorrect.



Created using TunnelTRAP Software

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND STOPING - Mining in 2027 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. H

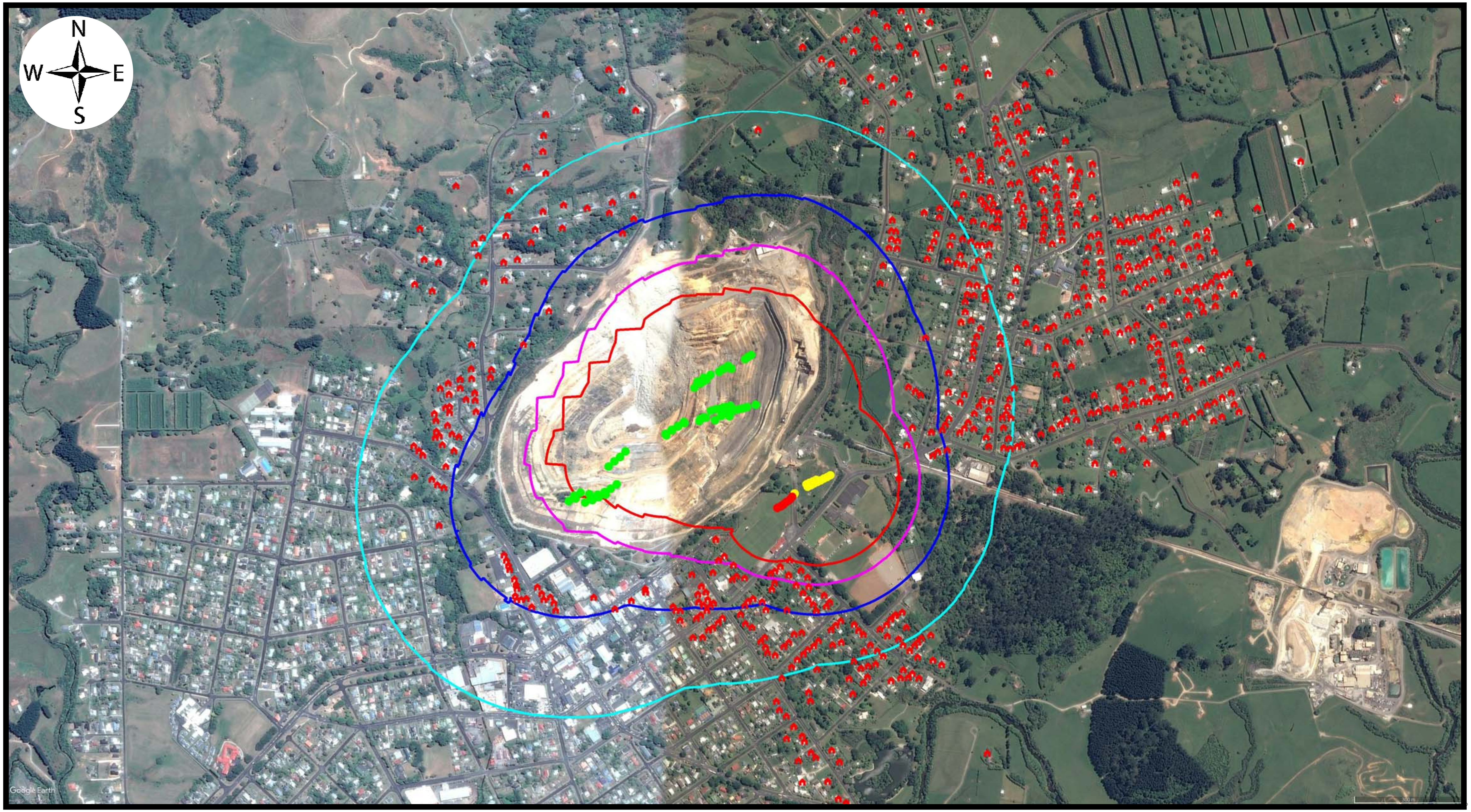
Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND STOPING - Mining in 2028 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. I

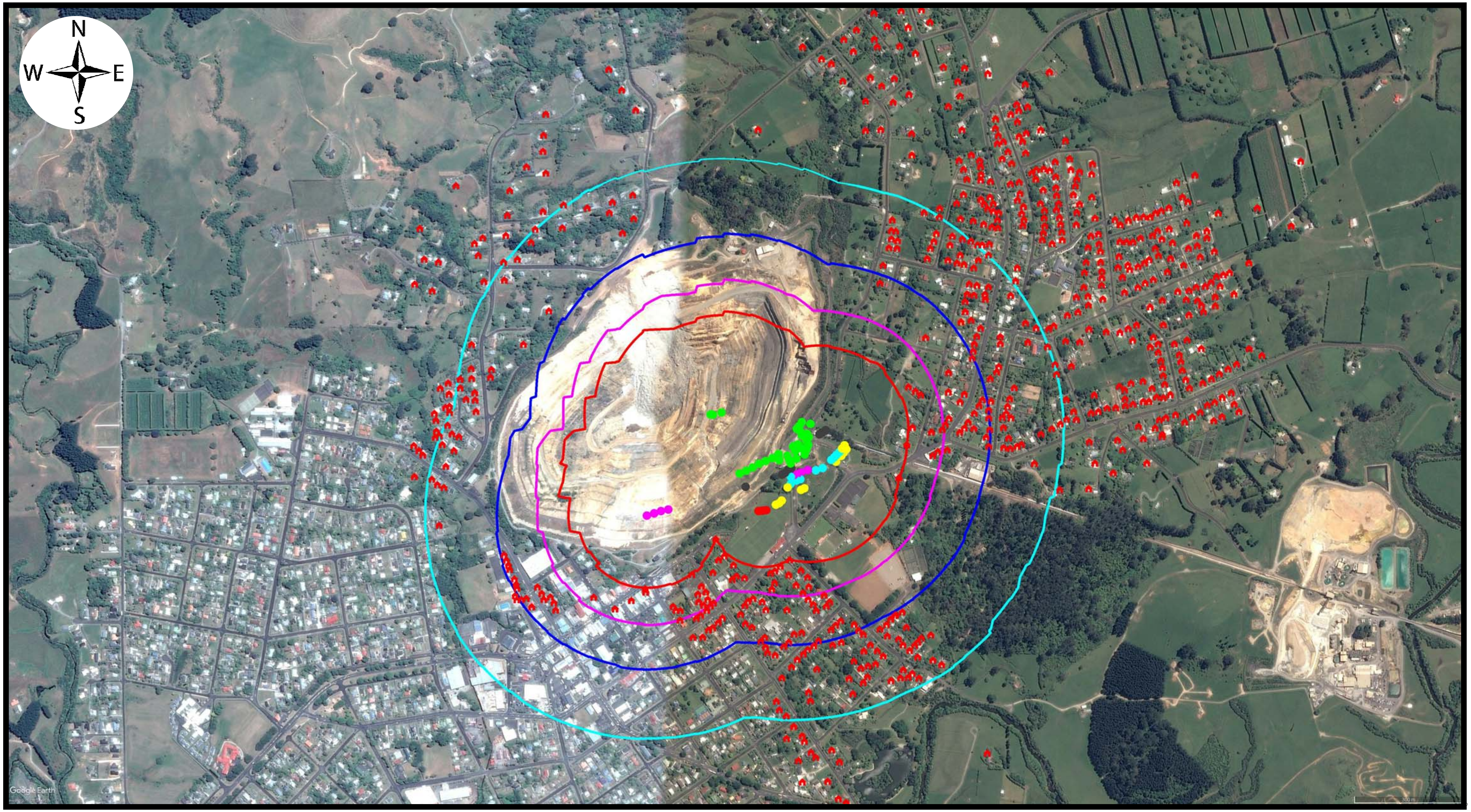
Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA UNDERGROUND STOPING - Mining in 2029 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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WAIHI OPERATION

Plate No. J

Revision History

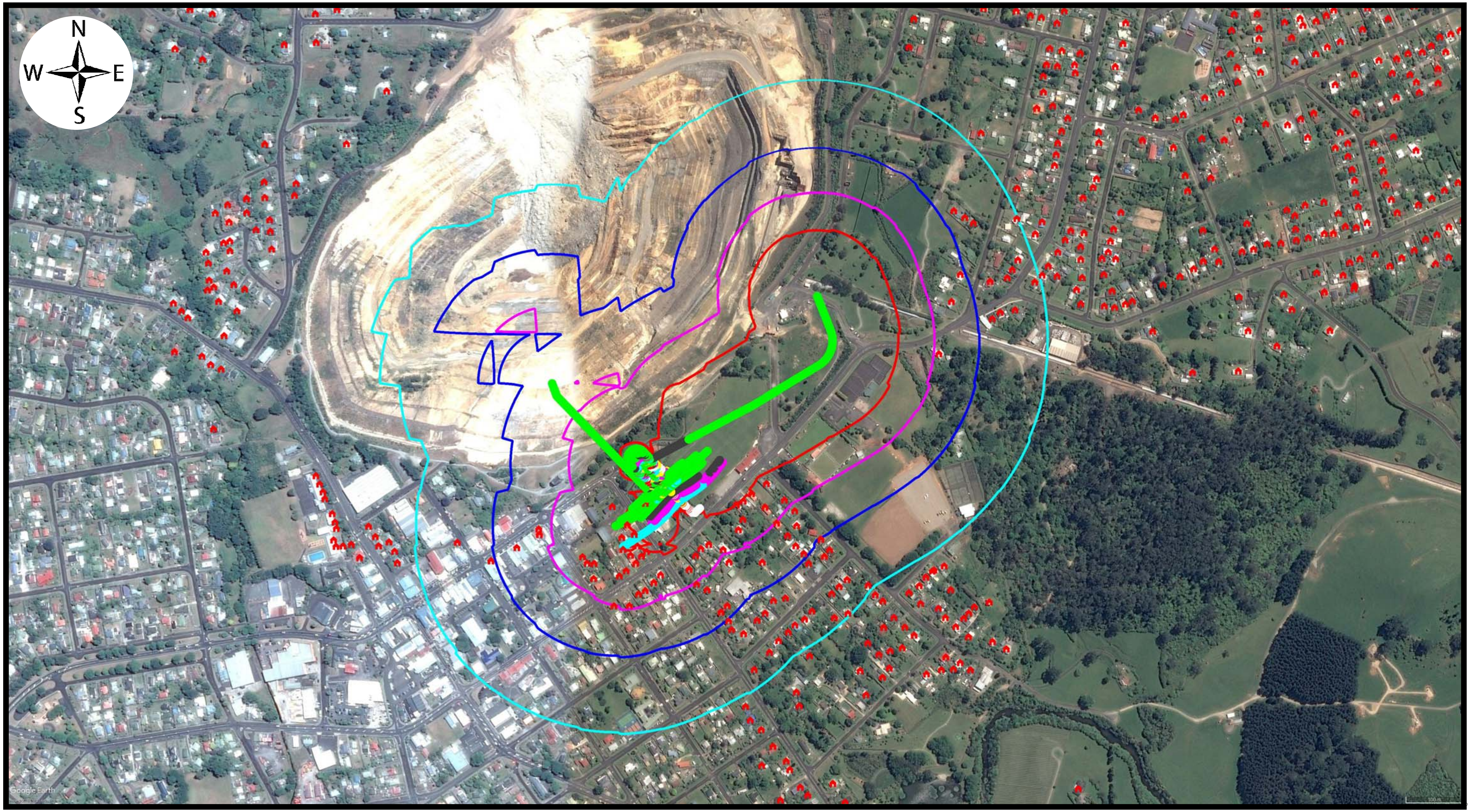
R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6

16. APPENDIX B – REX UNDERGROUND VIBRATION CONTOURS



Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 7 kilograms
- Between 6 and 7 kilograms
- Between 5 and 6 kilograms
- Between 4 and 5 kilograms
- Between 3 and 4 kilograms
- Between 2 and 3 kilograms
- Between 1 and 2 kilograms
- Less than 1 Kilogram

Project Description: REX UNDERGROUND DEVELOPMENT - Mining in 2020 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. A

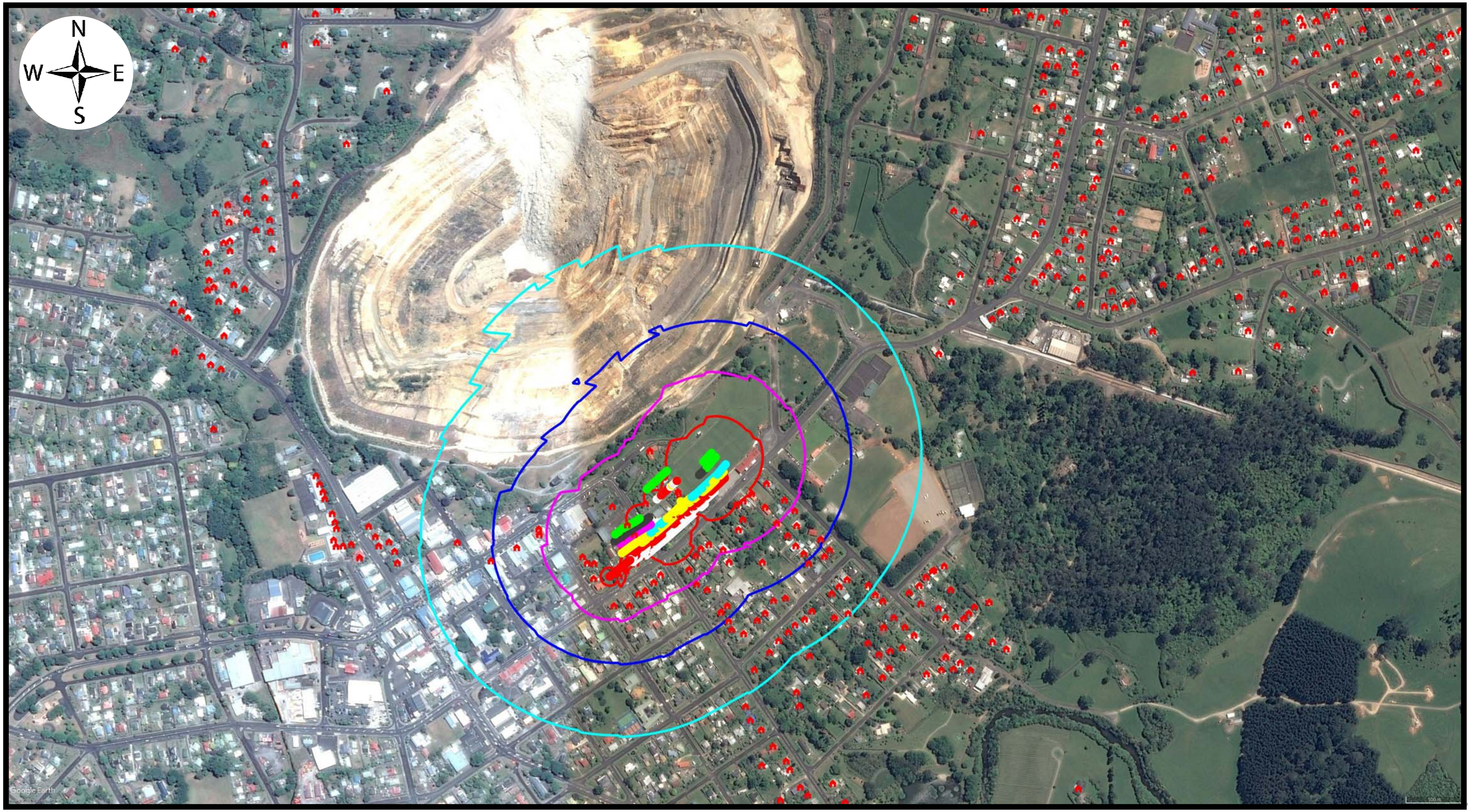
Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 7 kilograms
- Between 6 and 7 kilograms
- Between 5 and 6 kilograms
- Between 4 and 5 kilograms
- Between 3 and 4 kilograms
- Between 2 and 3 kilograms
- Between 1 and 2 kilograms
- Less than 1 Kilogram

Project Description: REX UNDERGROUND DEVELOPMENT - Mining in 2021 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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OCEANAGOLD
WAIHI OPERATION

Plate No. B

Date Drawn: 9 January 2018

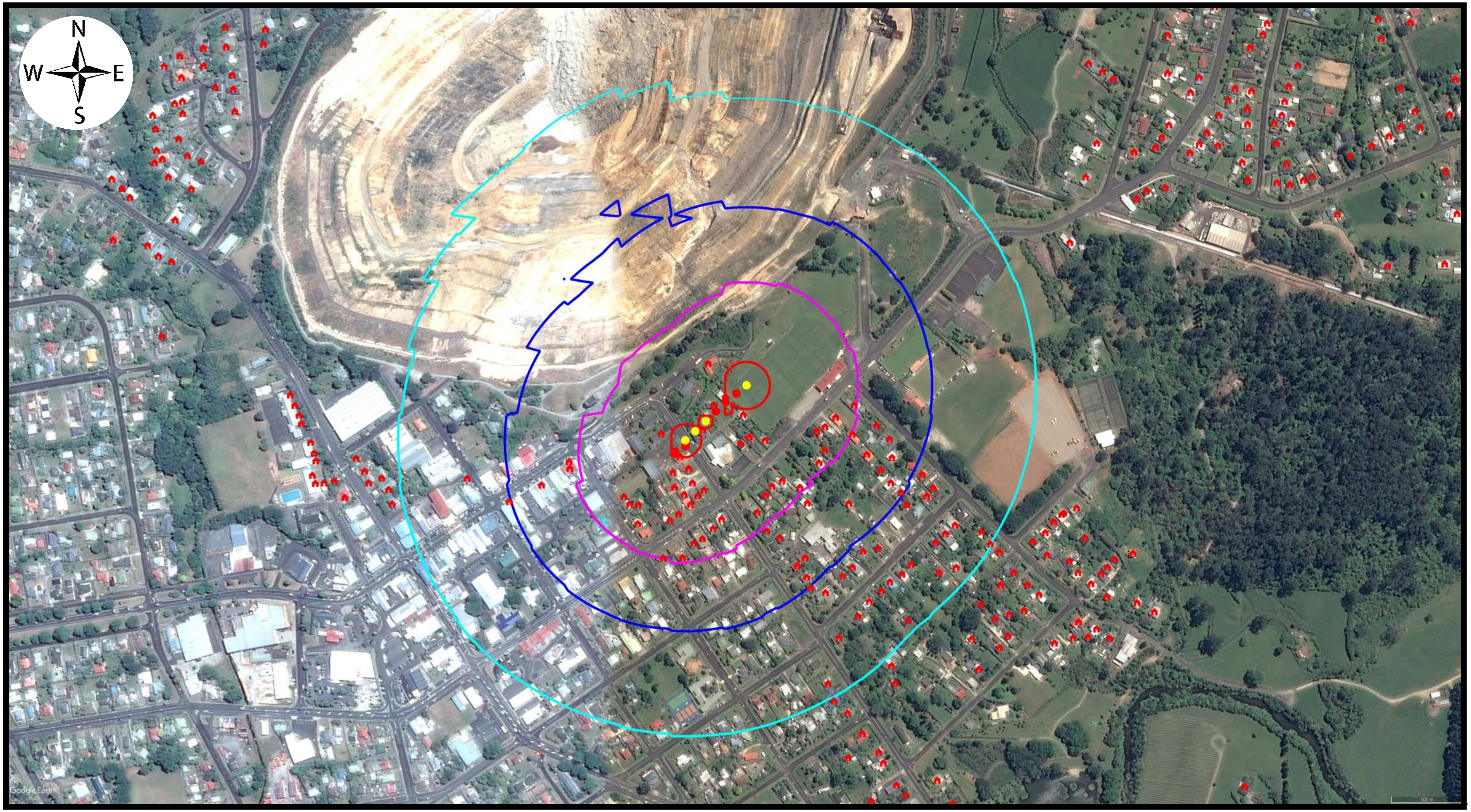
Revision History

R1: Original

Ref No: Martha Project

Job No: HP1712-6

In preparing this drawing, HP have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request were complete, accurate and up to date. Where we have obtained information from a Government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware why any of the assumptions are incorrect.



Created using TunnelTRAP Software

SCALE

0 50 100 150 200 250m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: REX UNDERGROUND STOPING - Mining in 2020 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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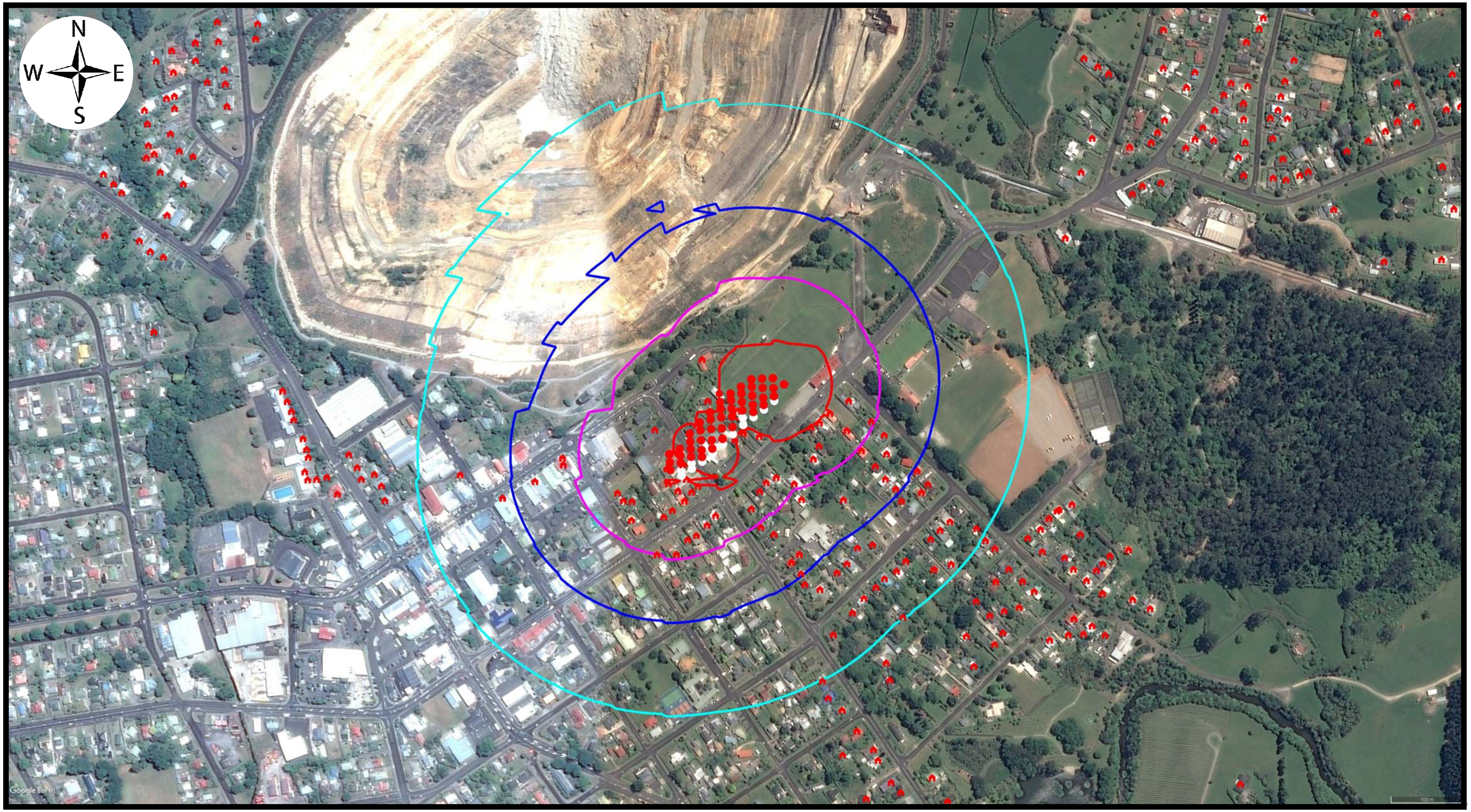
Plate No. A	Date Drawn: **9 January 2018**
Revision History R1: Original	**Ref No: Martha Project**
	Job No: HP1712-6

In preparing this drawing, HP have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request were complete, accurate and up to date. Where we have obtained information from a Government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware why any of the assumptions are incorrect.



Created using TunnelTRAP Software

SCALE

0 50 100 150 200 250m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: REX UNDERGROUND STOPING - Mining in 2021 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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OCEANAGOLD
WAIHI OPERATION

Plate No. B

Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6

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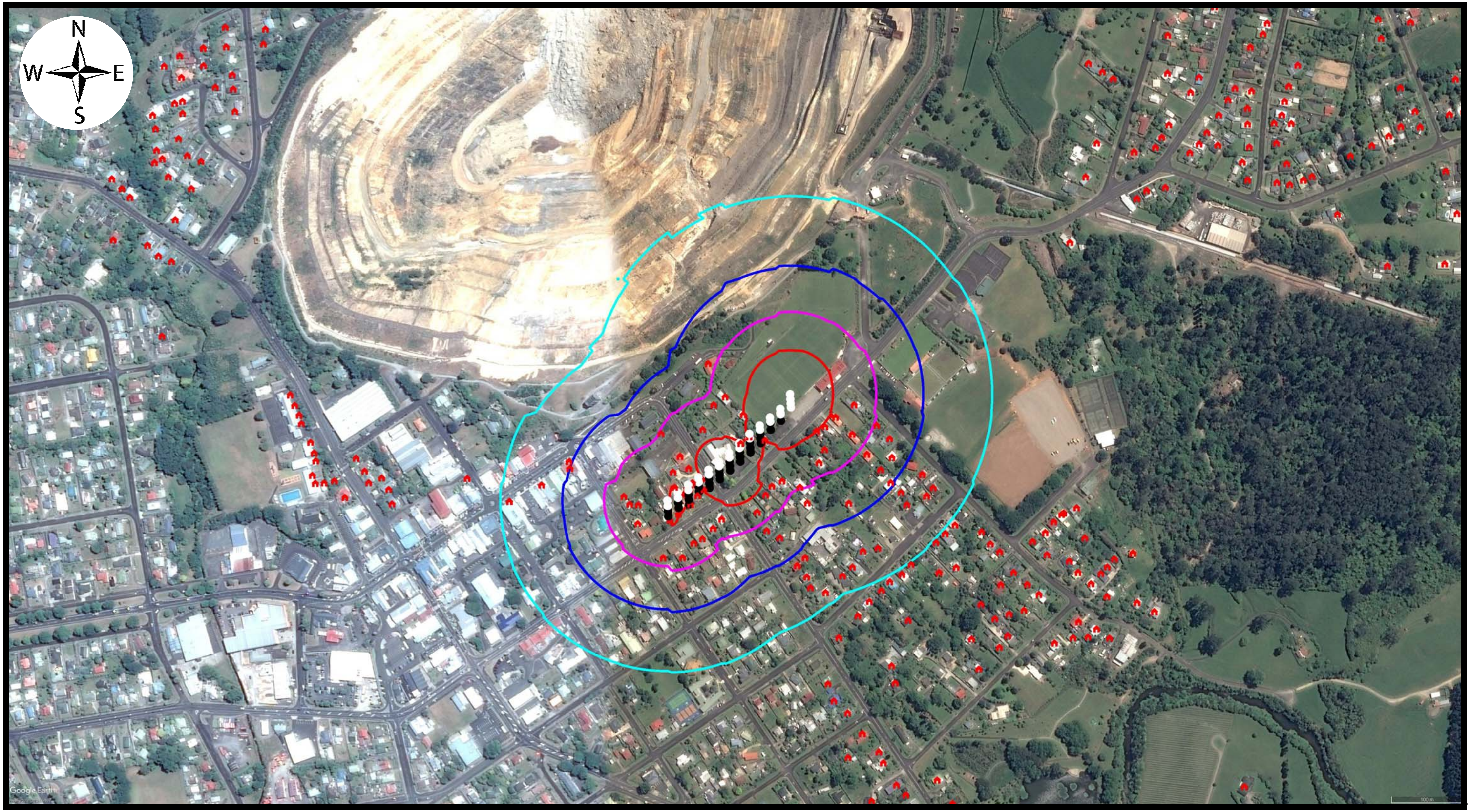

Created using TunnelTRAP Software

SCALE

0 50 100 150 200 250m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: REX UNDERGROUND STOPING - Mining in 2022 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. C

Revision History

R1: Original

Date Drawn: **9 January 2018**

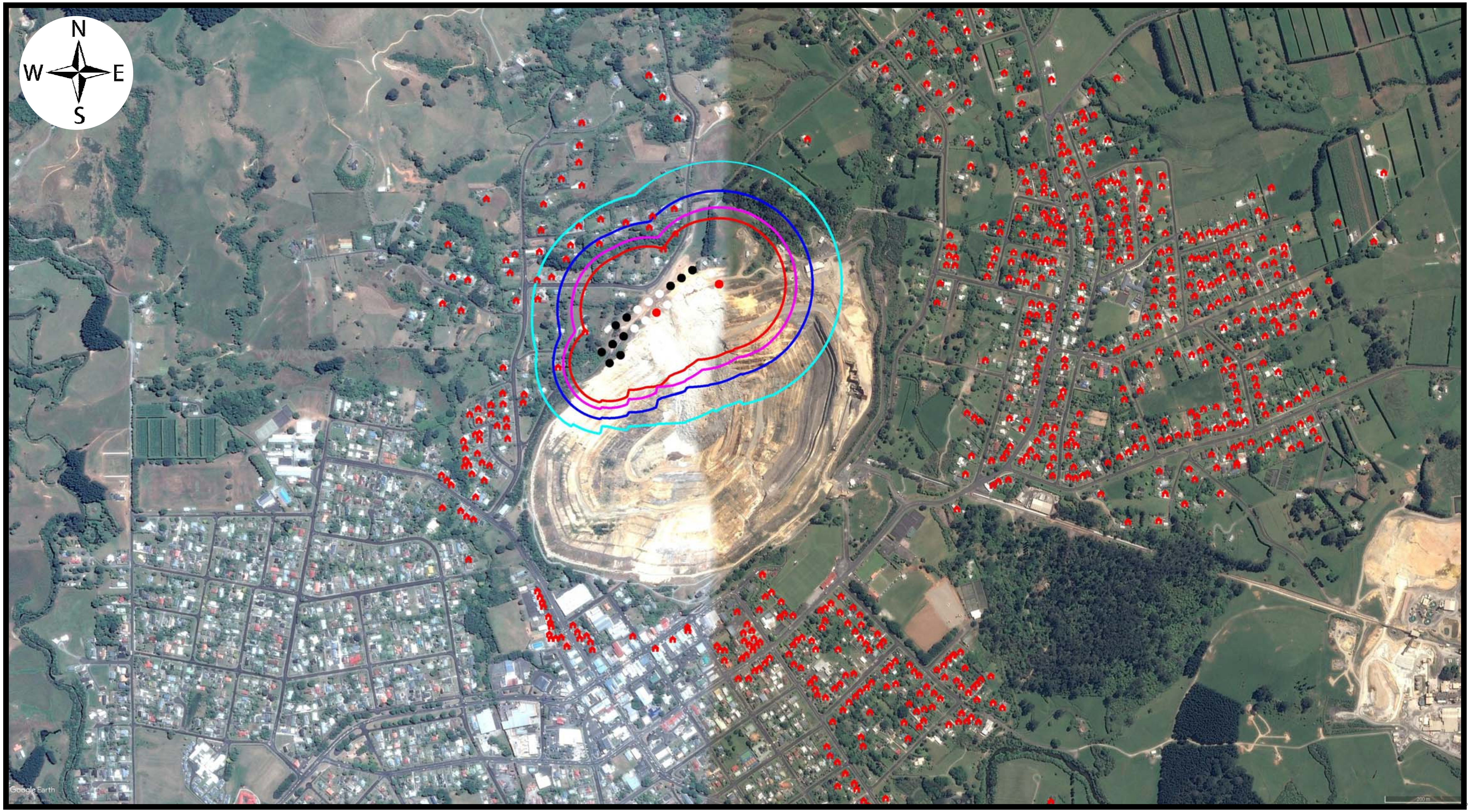
Ref No: Martha Project

Job No: HP1712-6

In preparing this drawing, HP have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request were complete, accurate and up to date. Where we have obtained information from a Government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware why any of the assumptions are incorrect.

17. APPENDIX C – MARTHA PHASE 4 OPEN PIT VIBRATION CONTOURS

A B C D E F G H I J K L M N



Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA PHASE 4 - Mining in 2022 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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OCEANAGOLD
WAIHI OPERATION

Plate No. A

Revision History

R1: Original

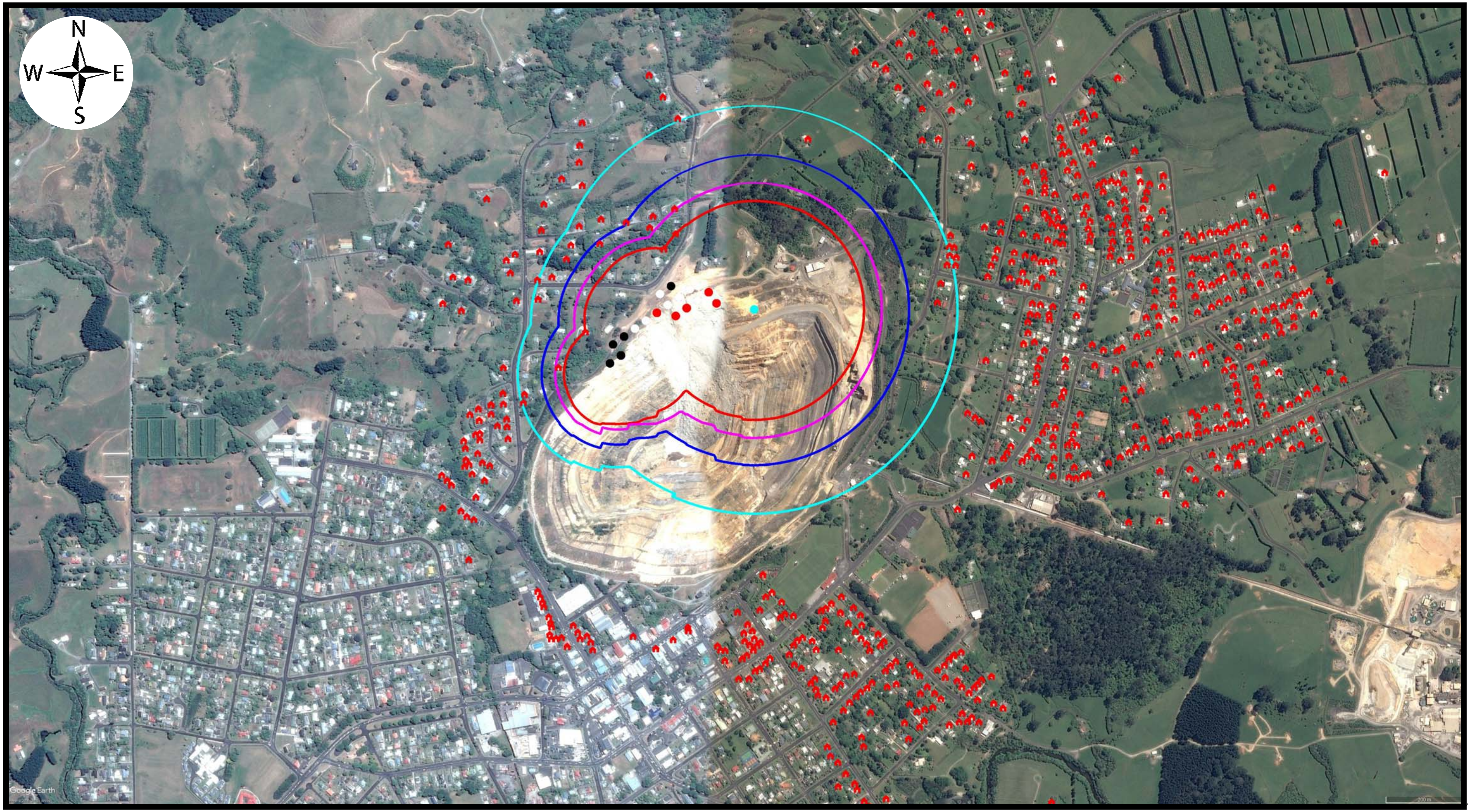
Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6

In preparing this drawing, HP have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request were complete, accurate and up to date. Where we have obtained information from a Government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware why any of the assumptions are incorrect.

A B C D E F G H I J K L M N



Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA PHASE 4 - Mining in 2023 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. B

Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6

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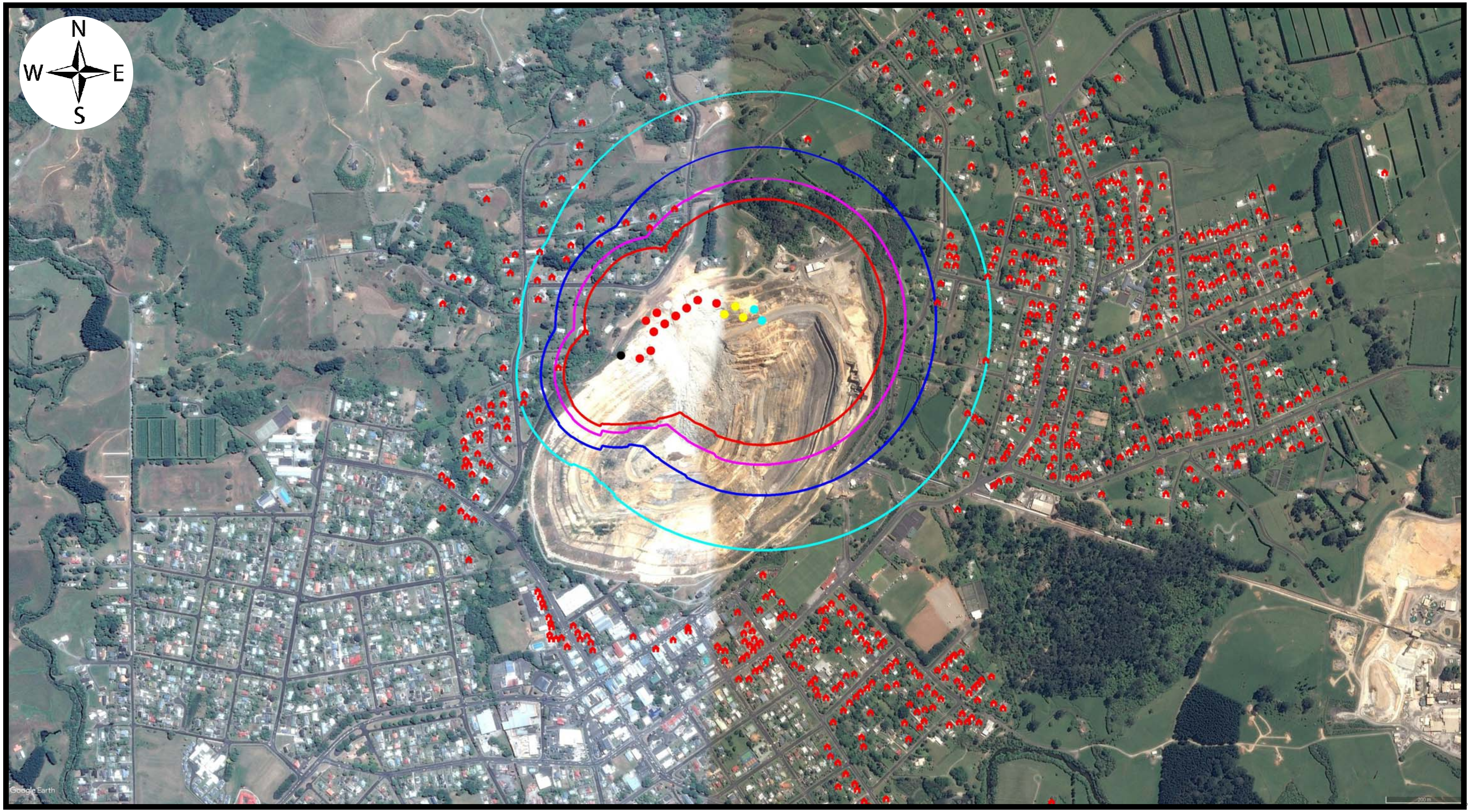

Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA PHASE 4 - Mining in 2024 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. C

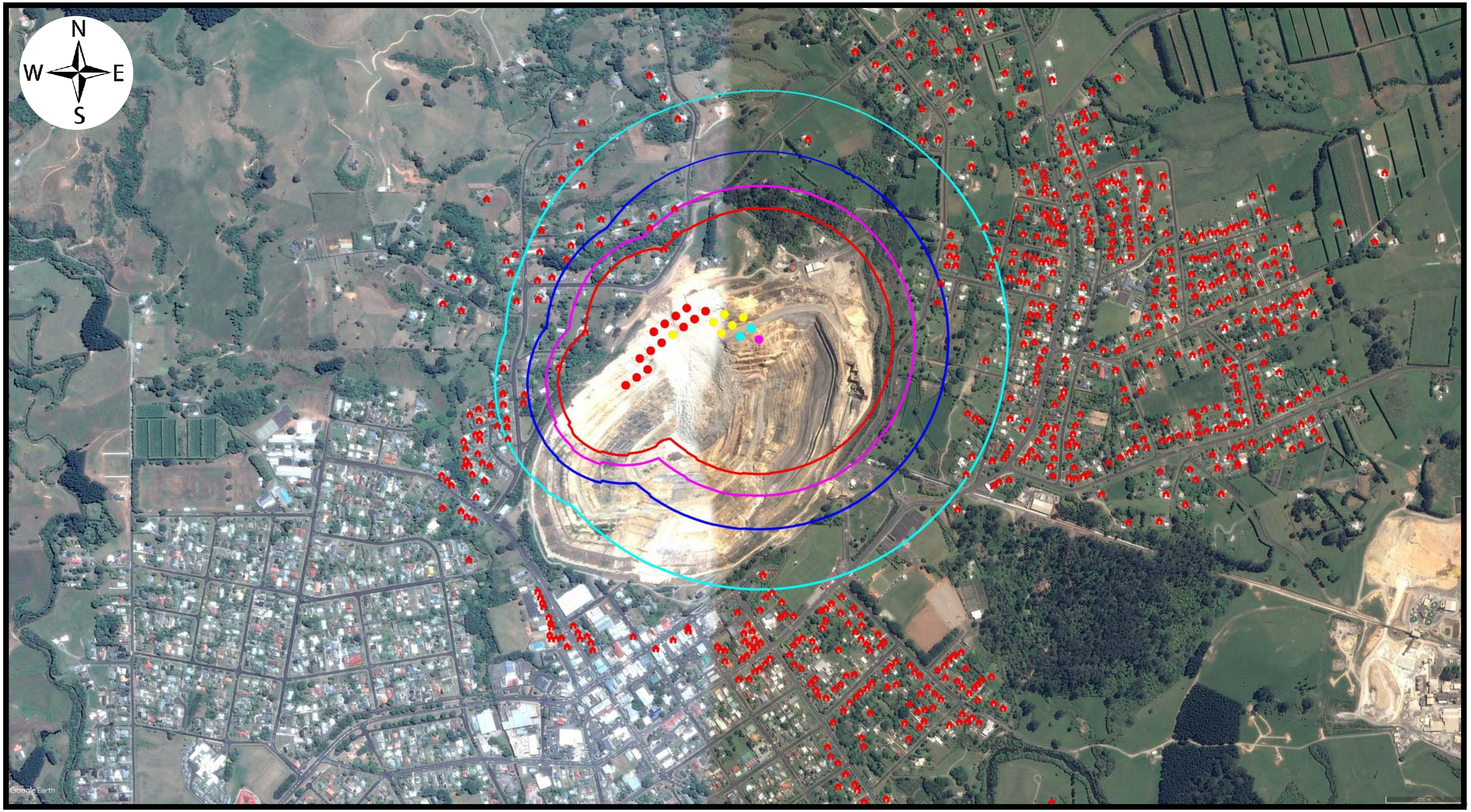
Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA PHASE 4 - Mining in 2025 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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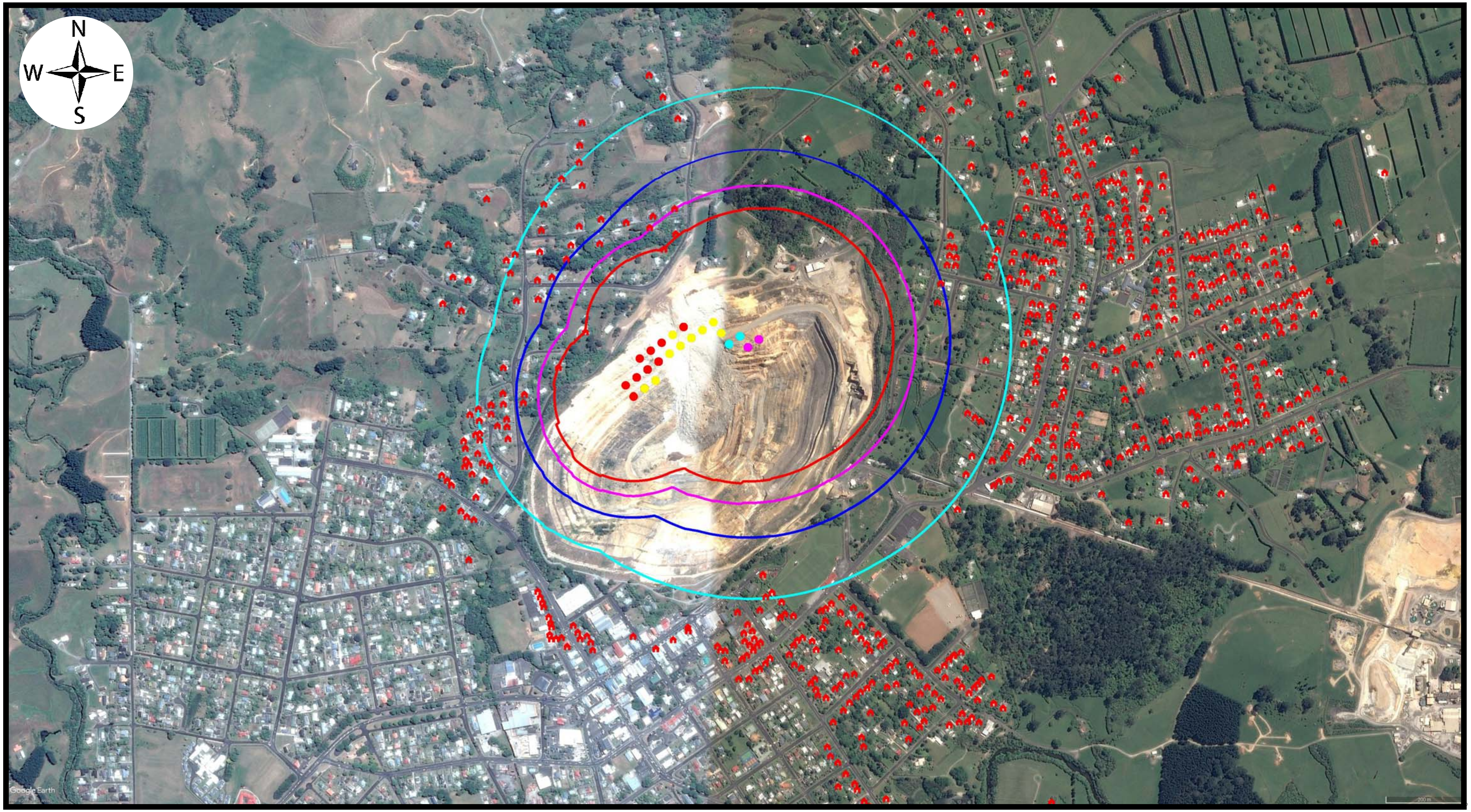
Plate No. D	Date Drawn: **9 January 2018**
Revision History R1: Original	**Ref No: Martha Project**
	Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA PHASE 4 - Mining in 2026 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. E

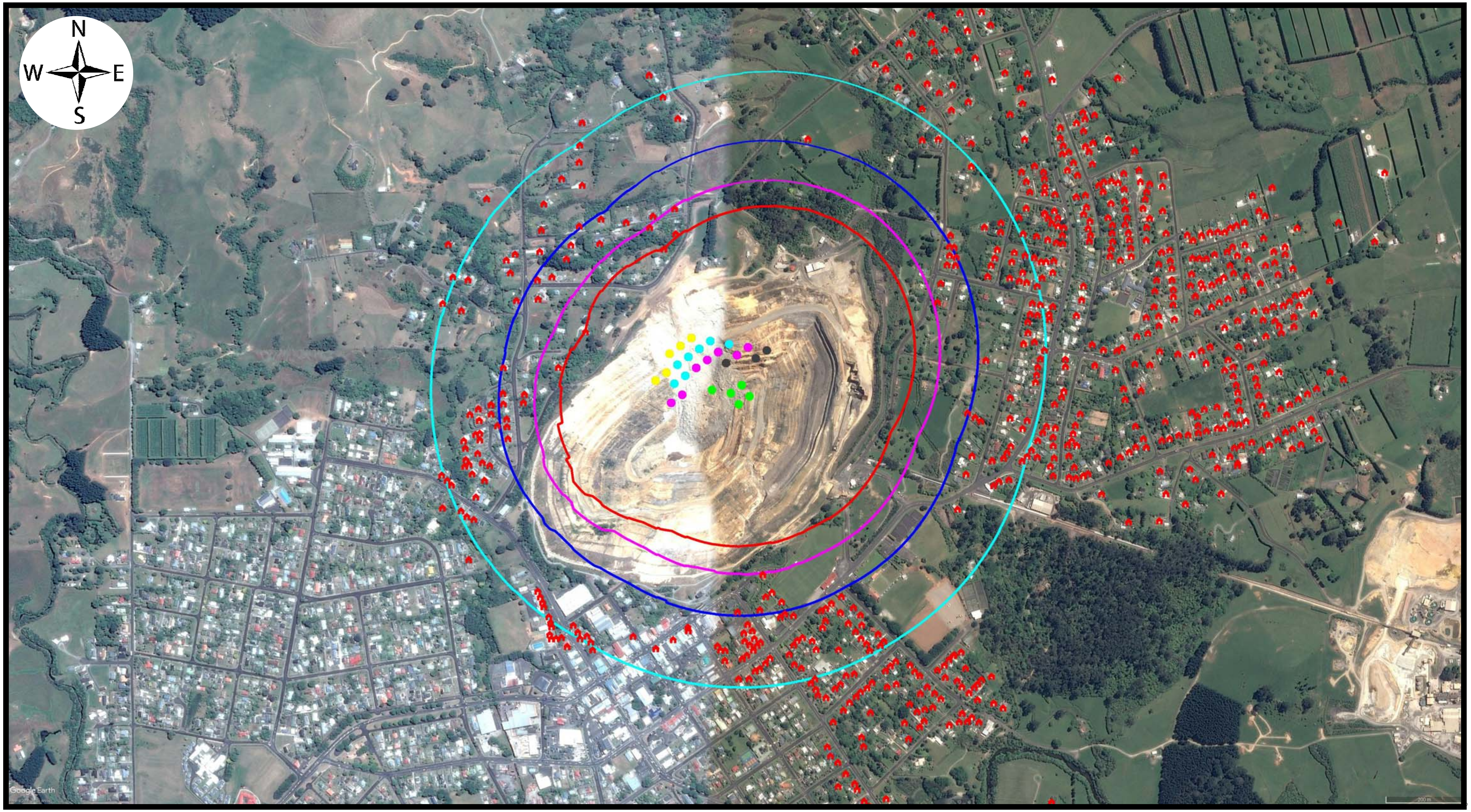
Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Project Description: MARTHA PHASE 4 - Mining in 2027 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. F

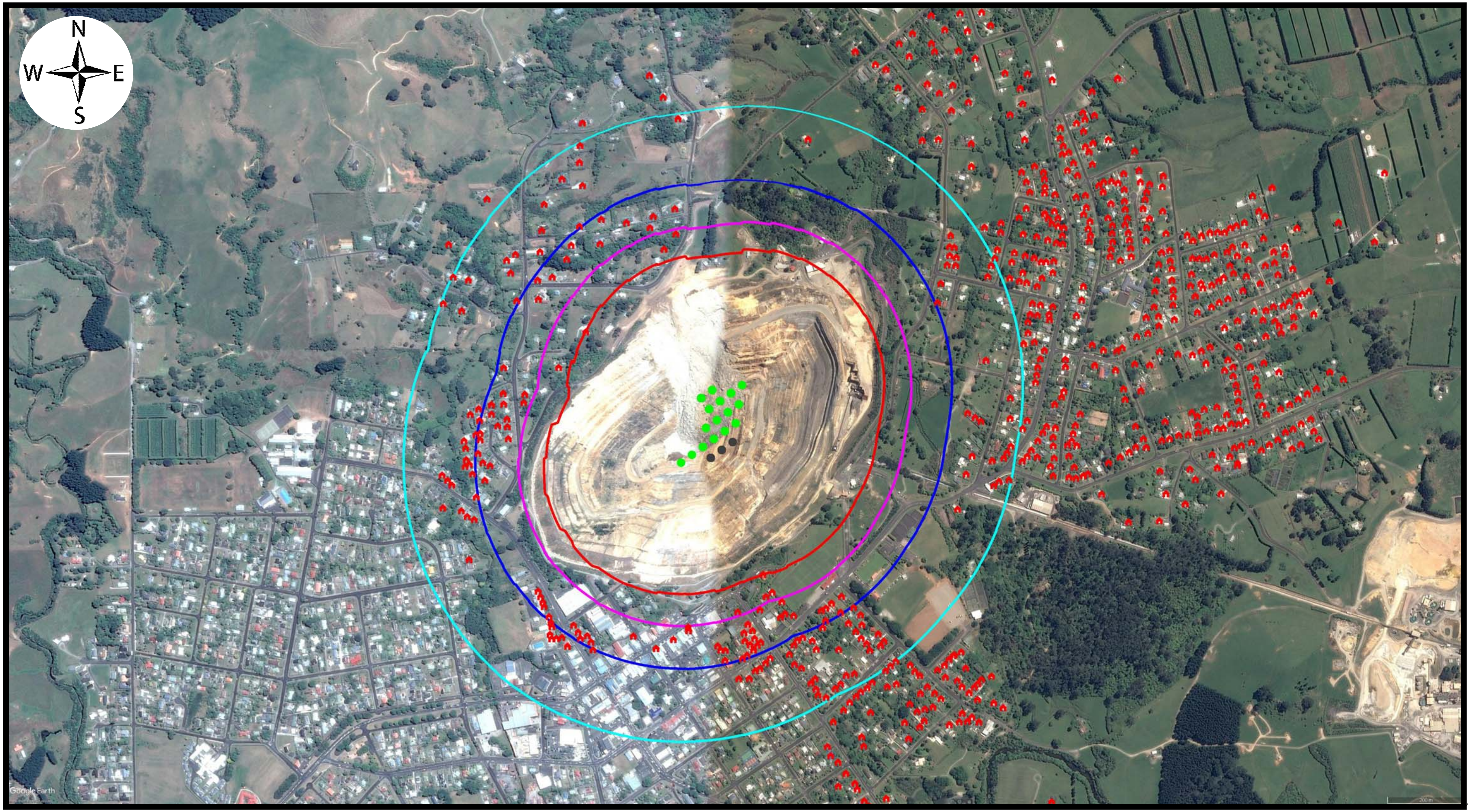
Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA PHASE 4 - Mining in 2028 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. G

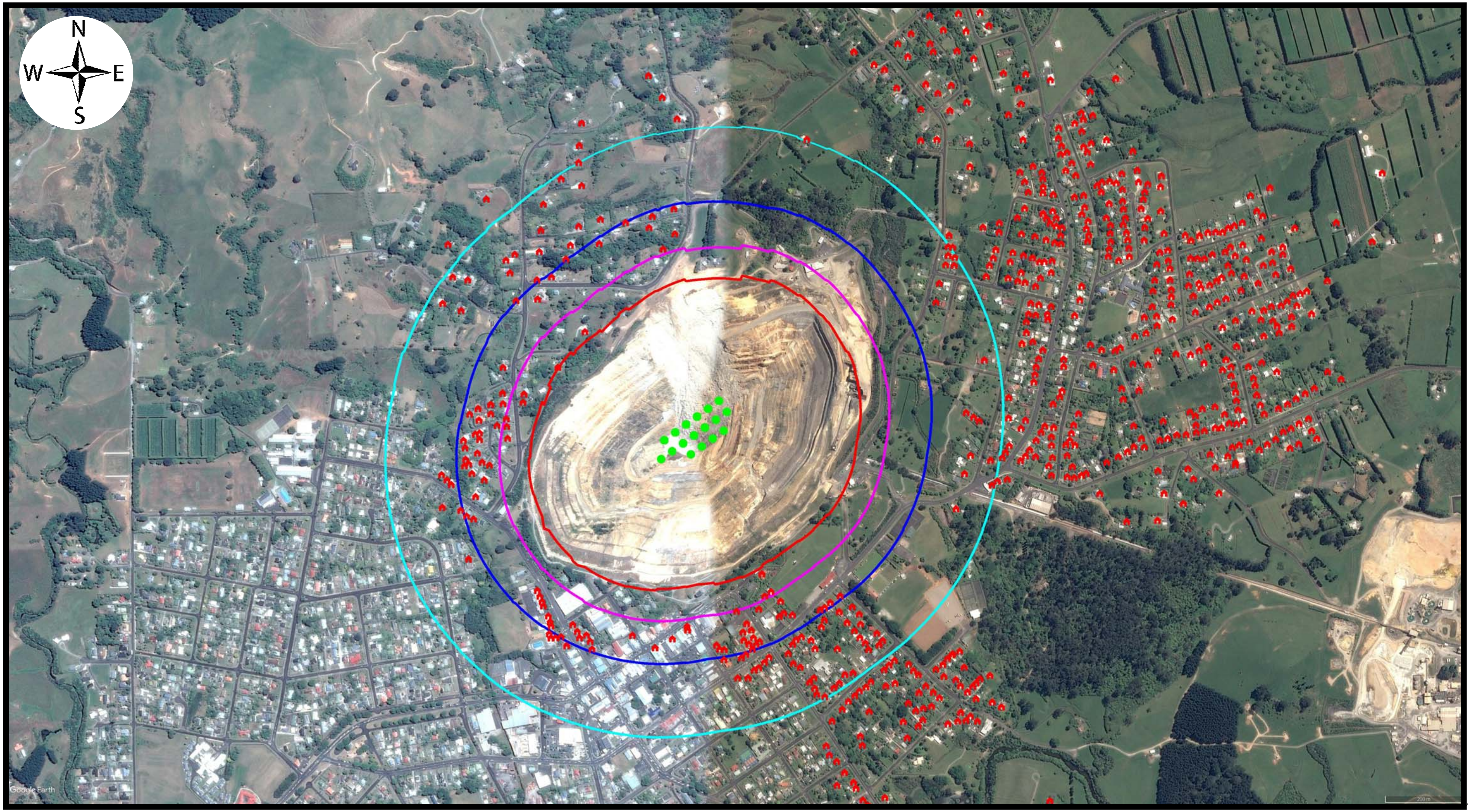
Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

SCALE

0 100 200 300 400 500m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Explosive Quantities

- More than 30 kilograms
- Between 25 and 30 kilograms
- Between 20 and 25 kilograms
- Between 15 and 20 kilograms
- Between 10 and 15 kilograms
- Between 5 and 10 kilograms
- Between 2.5 and 5 kilograms
- Less than 2.5 Kilogram

Project Description: MARTHA PHASE 4 - Mining in 2029 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. H

Revision History

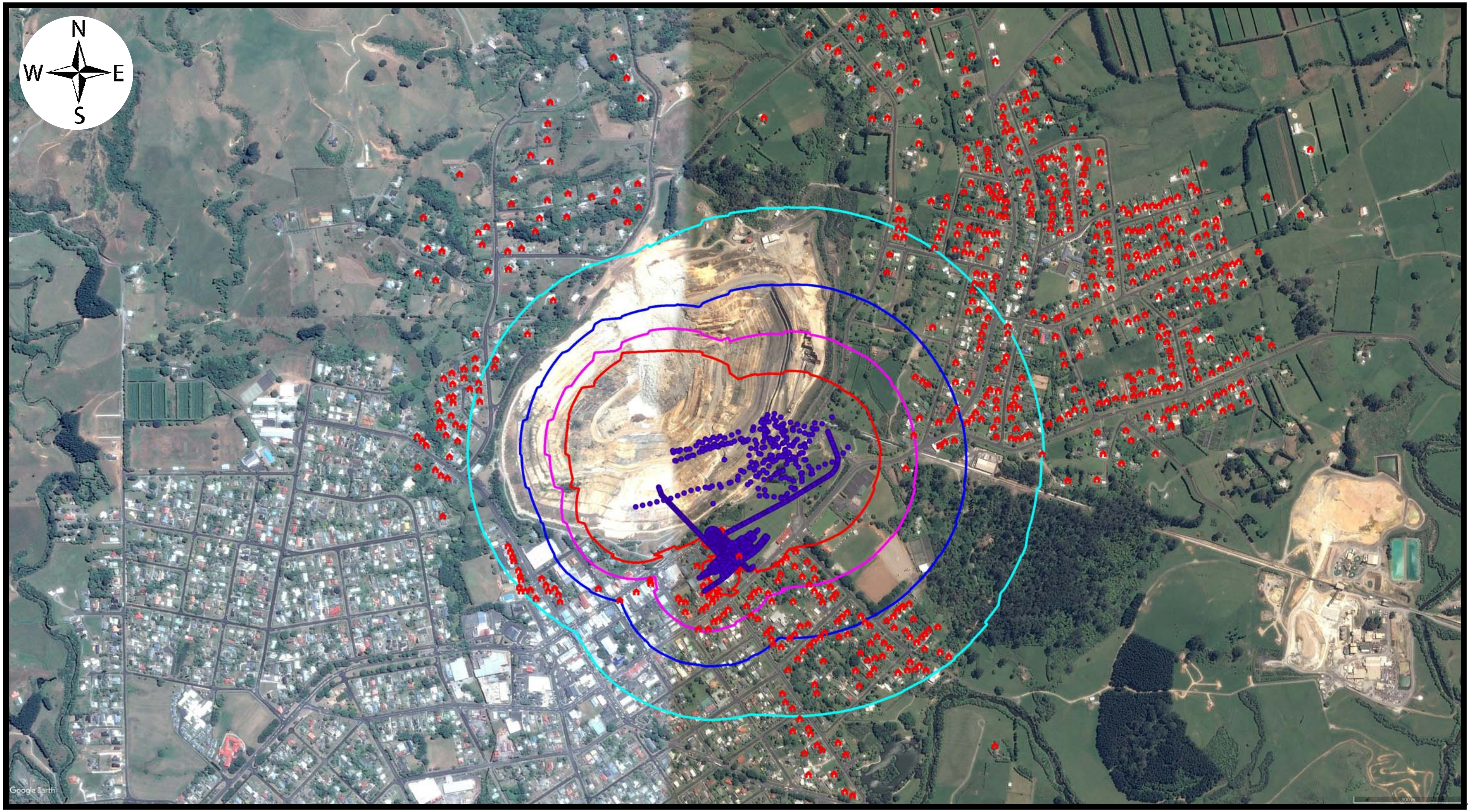
R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6

18. APPENDIX D – PROJECT MARTHA VIBRATION CONTOURS



Created using TunnelTRAP Software

Compliance Properties

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Blasting Areas

Project Description: MARTHA PROJECT - Mining in 2020 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. A

Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6

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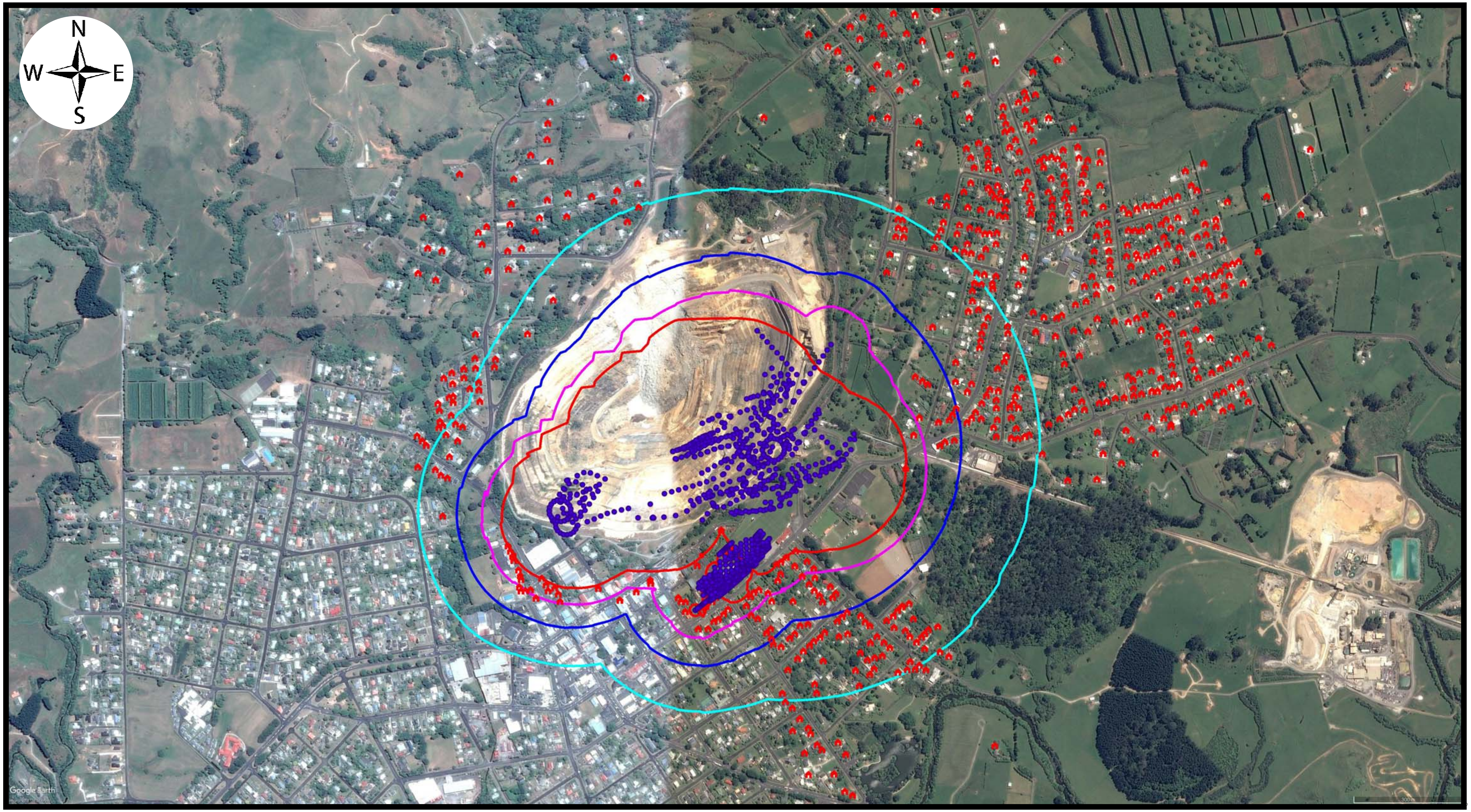

Created using TunnelTRAP Software

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Compliance Properties

Blasting Areas

Project Description: MARTHA PROJECT - Mining in 2021 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. B

Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6

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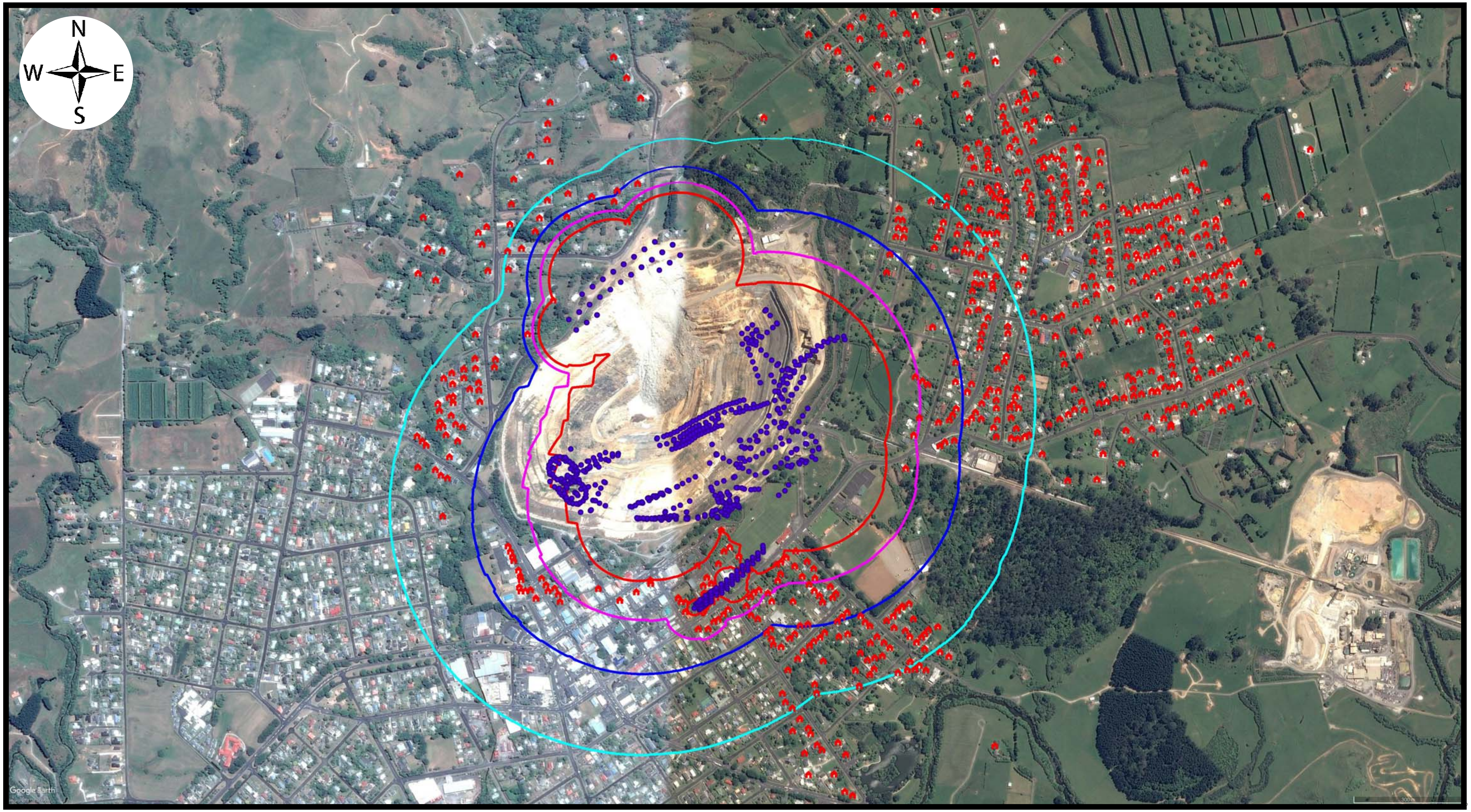

Created using TunnelTRAP Software

Compliance Properties

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Blasting Areas

Project Description: MARTHA PROJECT - Mining in 2022 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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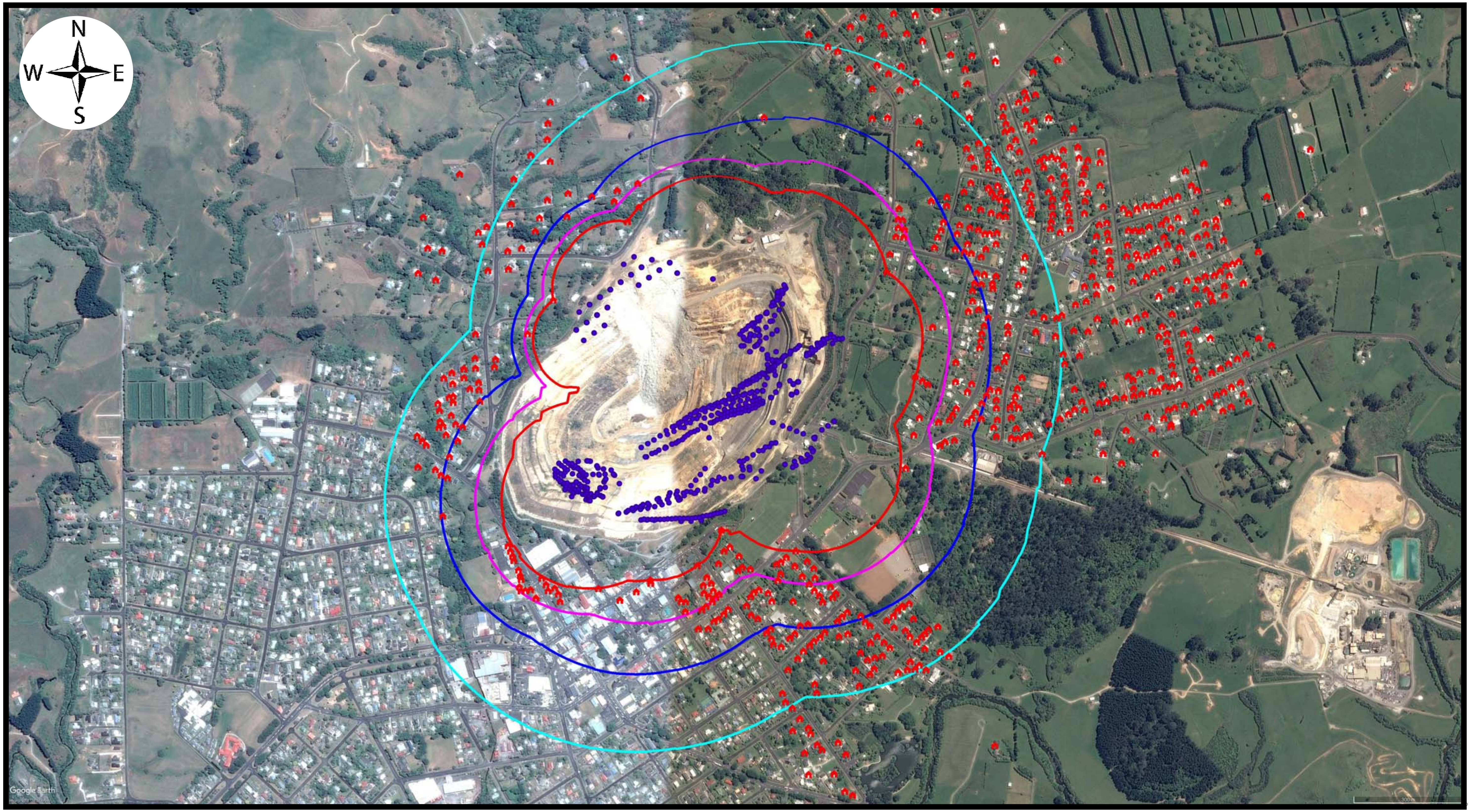
Plate No. C	Date Drawn: **9 January 2018**
Revision History R1: Original	**Ref No: Martha Project**
	Job No: HP1712-6



Created using TunnelTRAP Software

Compliance Properties

SCALE

0 150 300 450 600 750m

Blasting Areas

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Project Description: MARTHA PROJECT - Mining in 2023 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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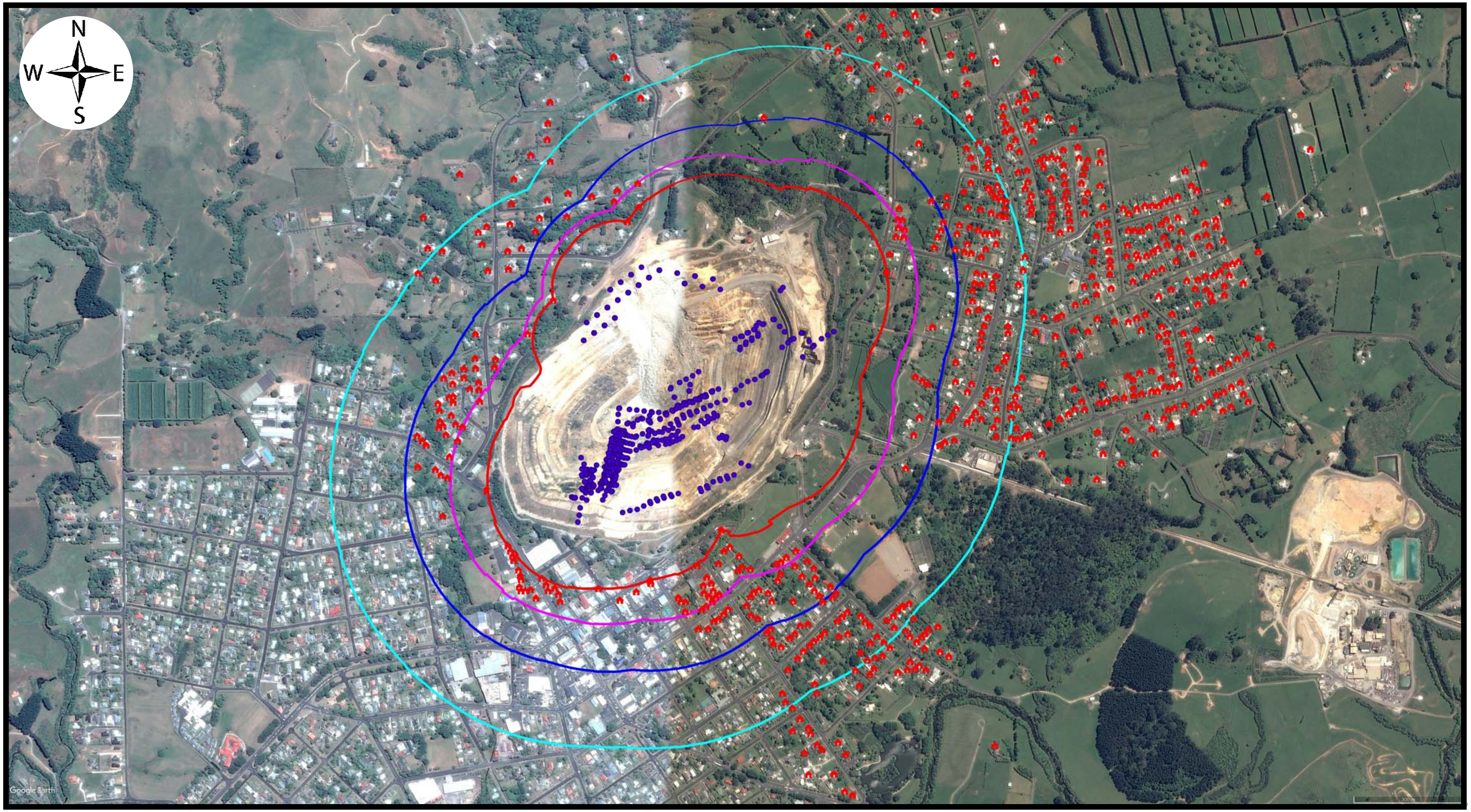
Plate No. D	Date Drawn: **9 January 2018**
Revision History R1: Original	**Ref No: Martha Project**
	Job No: HP1712-6



Created using TunnelTRAP Software

Compliance Properties

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Blasting Areas

Project Description: MARTHA PROJECT - Mining in 2024 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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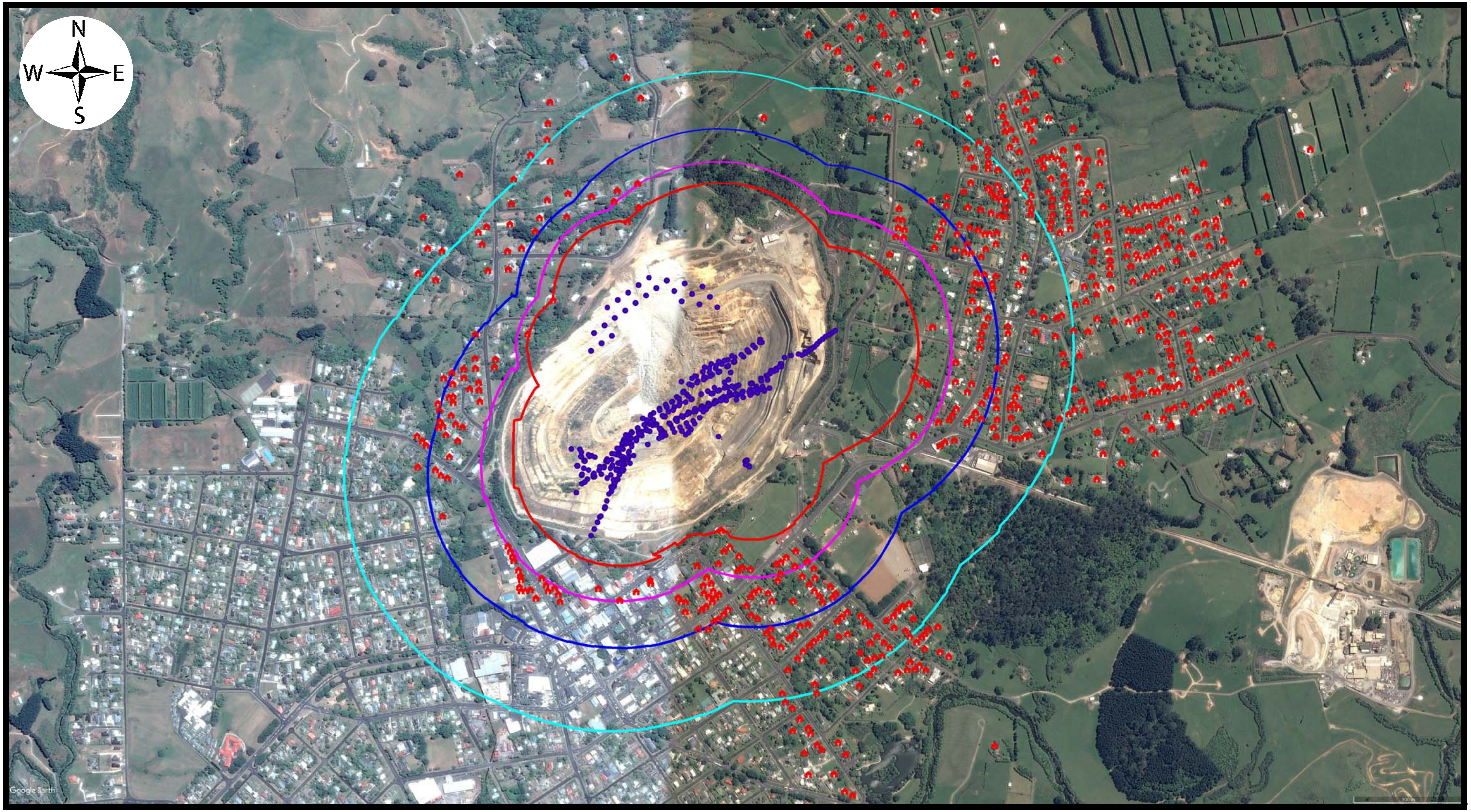
Plate No. E	Date Drawn: **9 January 2018**
Revision History R1: Original	**Ref No: Martha Project**
	Job No: HP1712-6



Created using TunnelTRAP Software

Compliance Properties

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Blasting Areas

Project Description: MARTHA PROJECT - Mining in 2025 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. F

Date Drawn: **9 January 2018**

Revision History

R1: Original

Ref No: Martha Project

Job No: HP1712-6

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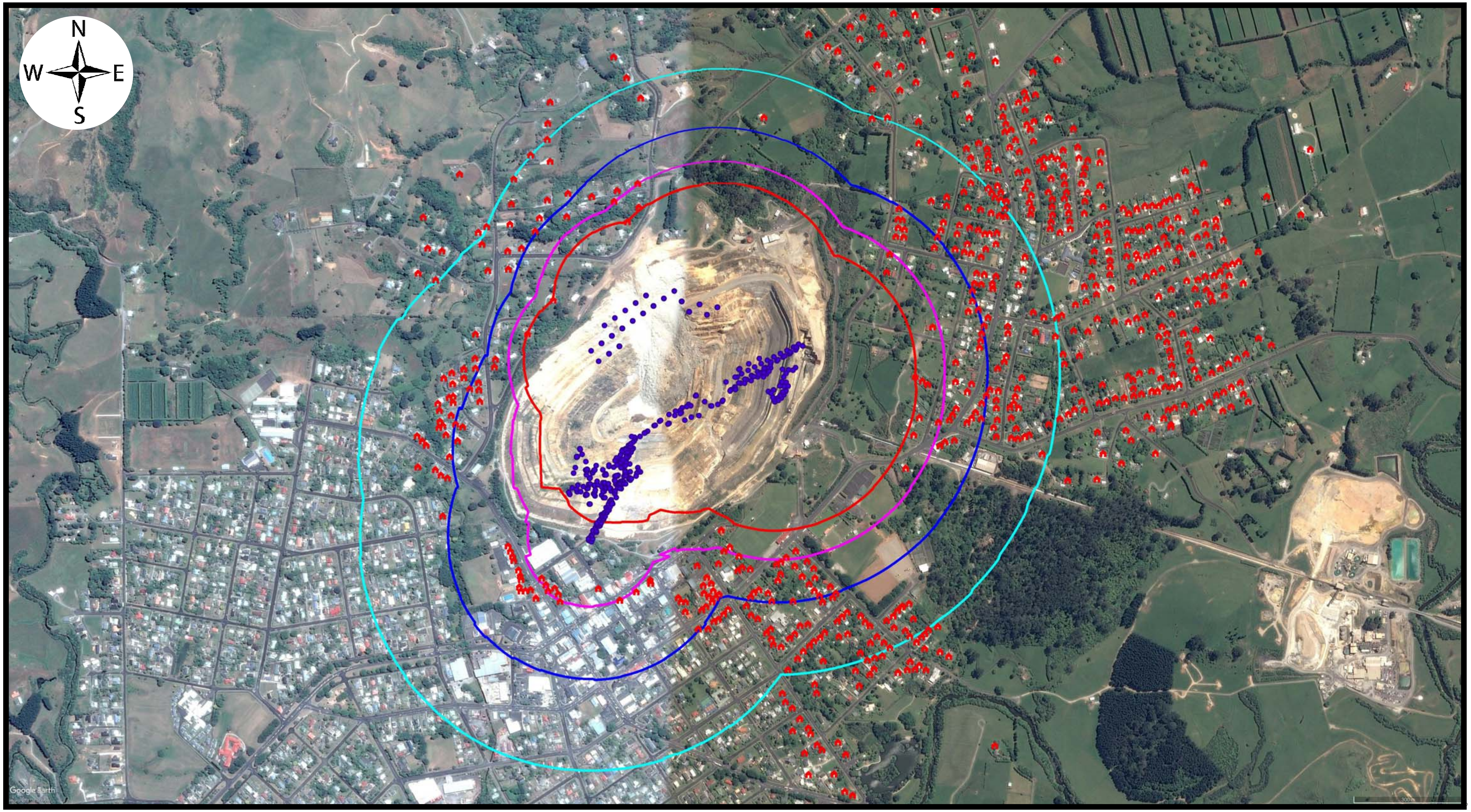

Created using TunnelTRAP Software

Compliance Properties

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Blasting Areas

Project Description: MARTHA PROJECT - Mining in 2026 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. G

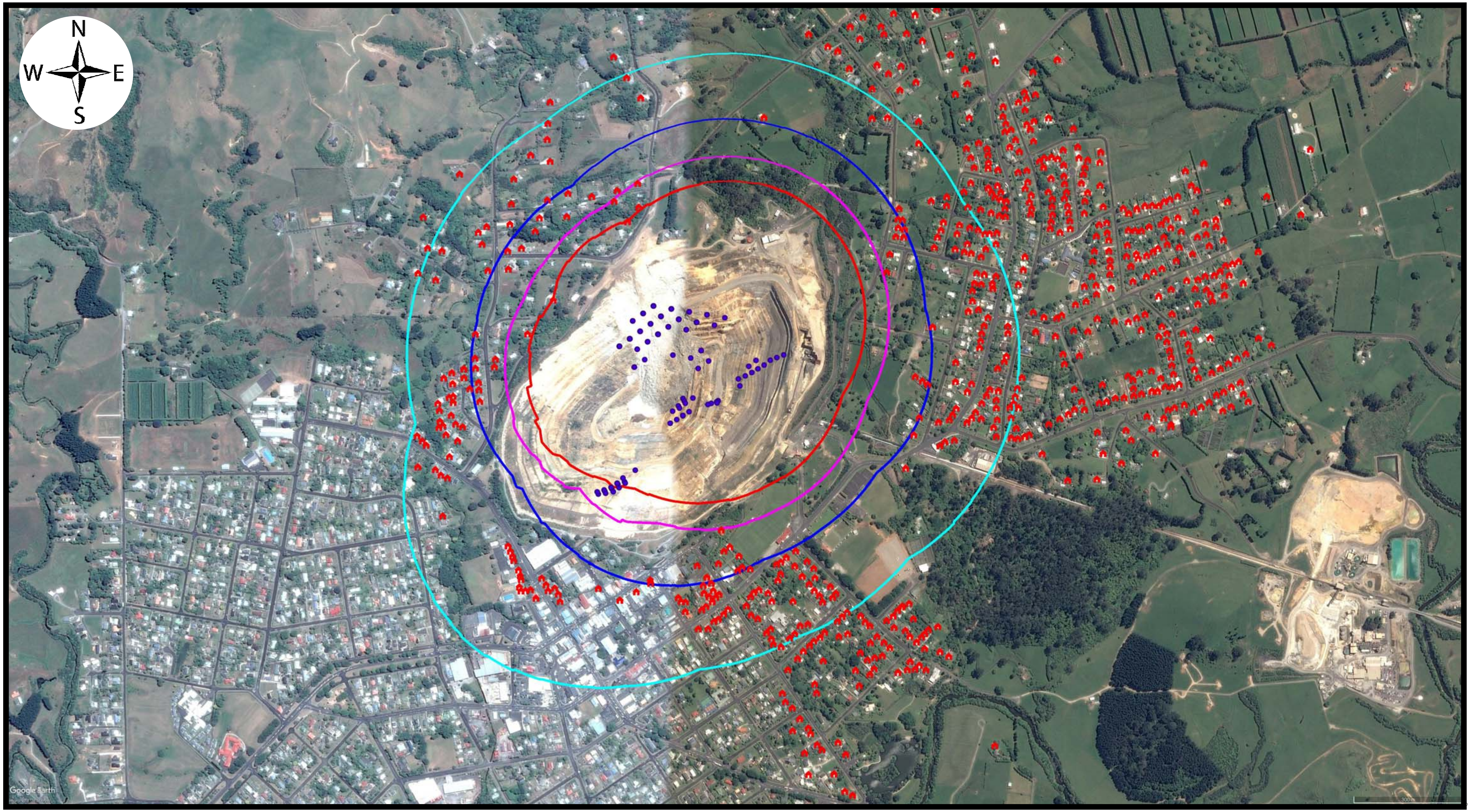
Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

Compliance Properties

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Blasting Areas

Project Description: MARTHA PROJECT - Mining in 2027 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. H

Revision History

R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6

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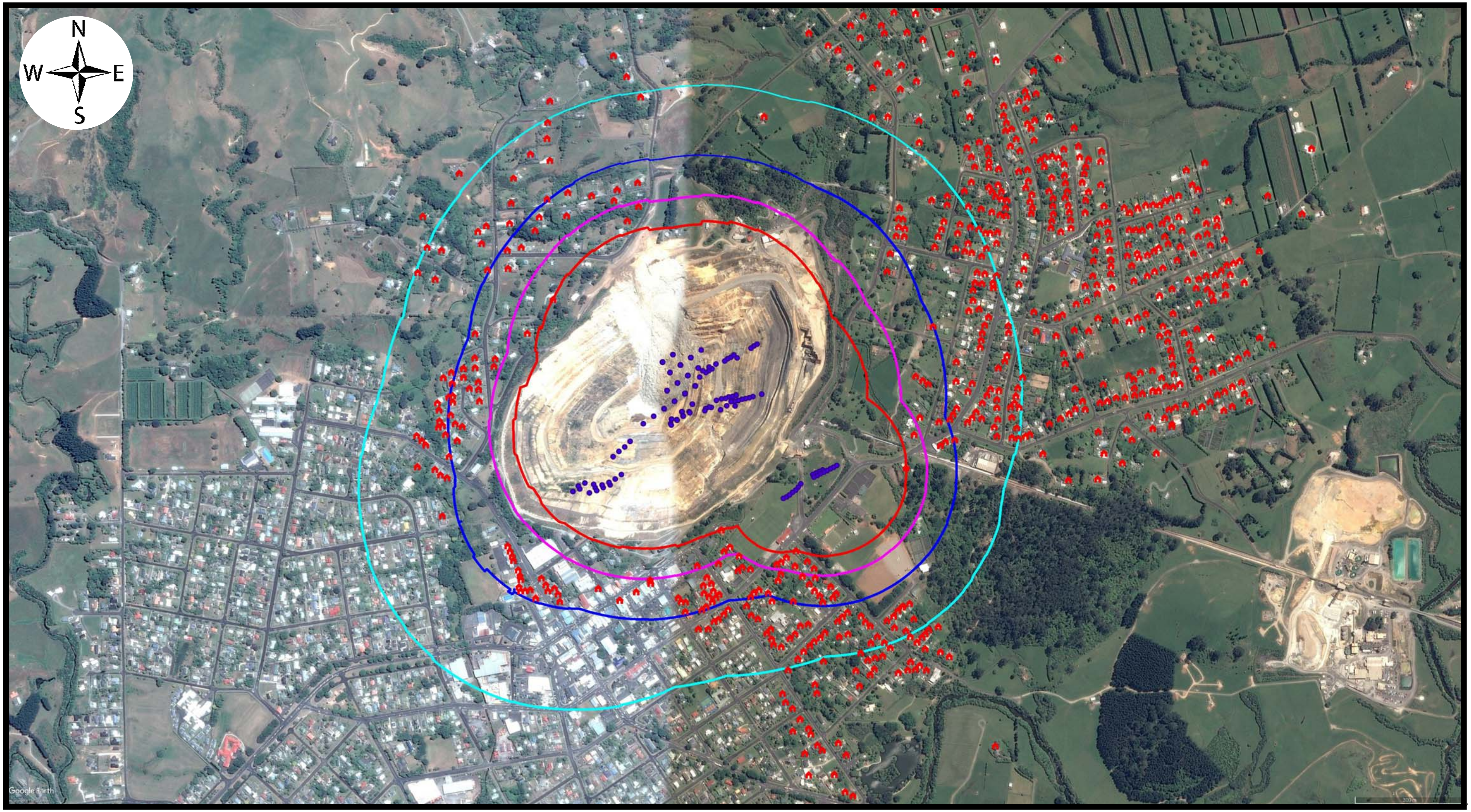

Created using TunnelTRAP Software

Compliance Properties

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

5 mm/s Vibration Contour
4 mm/s Vibration Contour
3 mm/s Vibration Contour
2 mm/s Vibration Contour

Blasting Areas

Project Description: MARTHA PROJECT - Mining in 2028 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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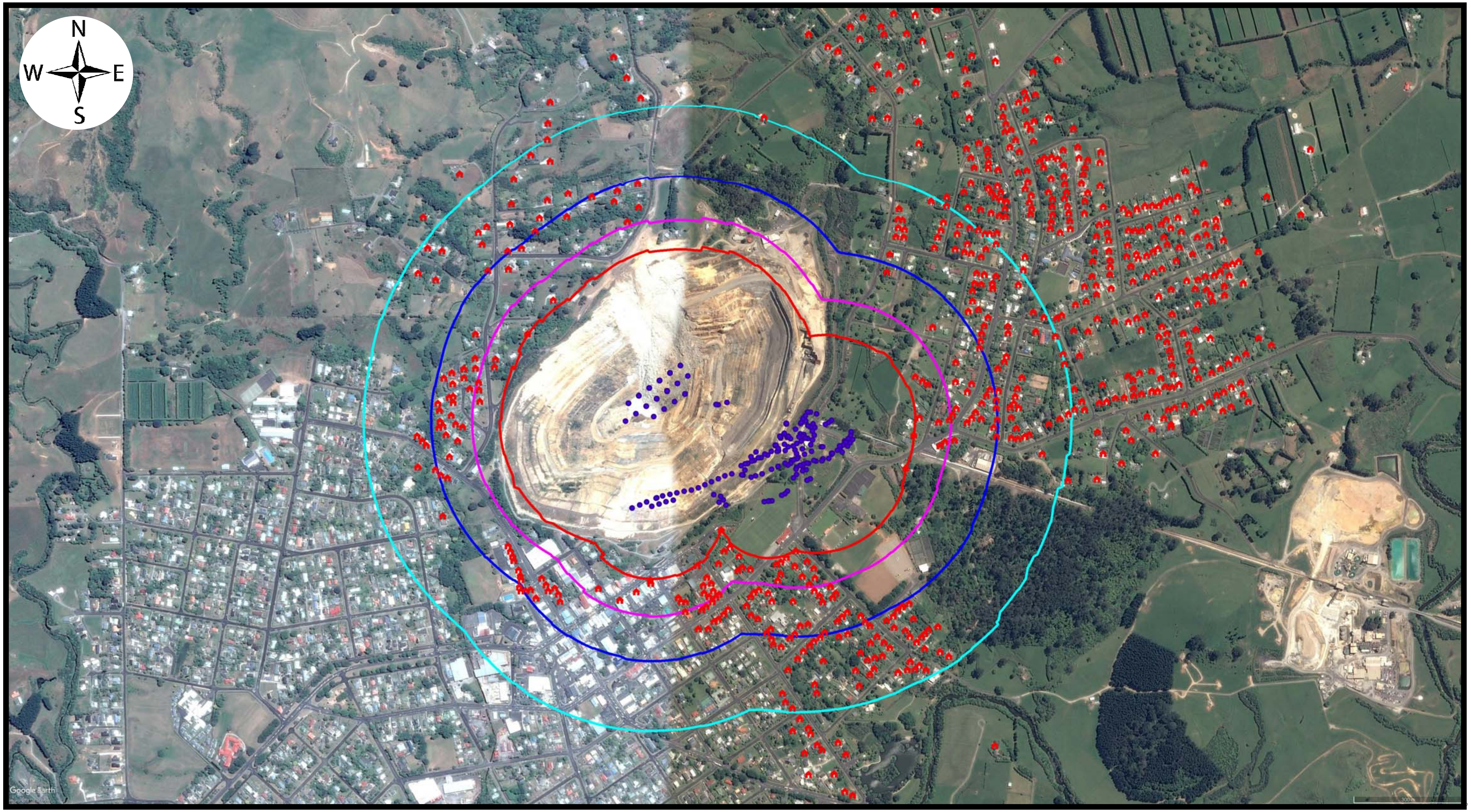
Plate No. I

Revision History
R1: Original

Date Drawn: **9 January 2018**

Ref No: Martha Project

Job No: HP1712-6



Created using TunnelTRAP Software

Compliance Properties

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Blasting Areas

Project Description: MARTHA PROJECT - Mining in 2029 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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Plate No. J	Date Drawn: **9 January 2018**
Revision History R1: Original	**Ref No: Martha Project**
	Job No: HP1712-6

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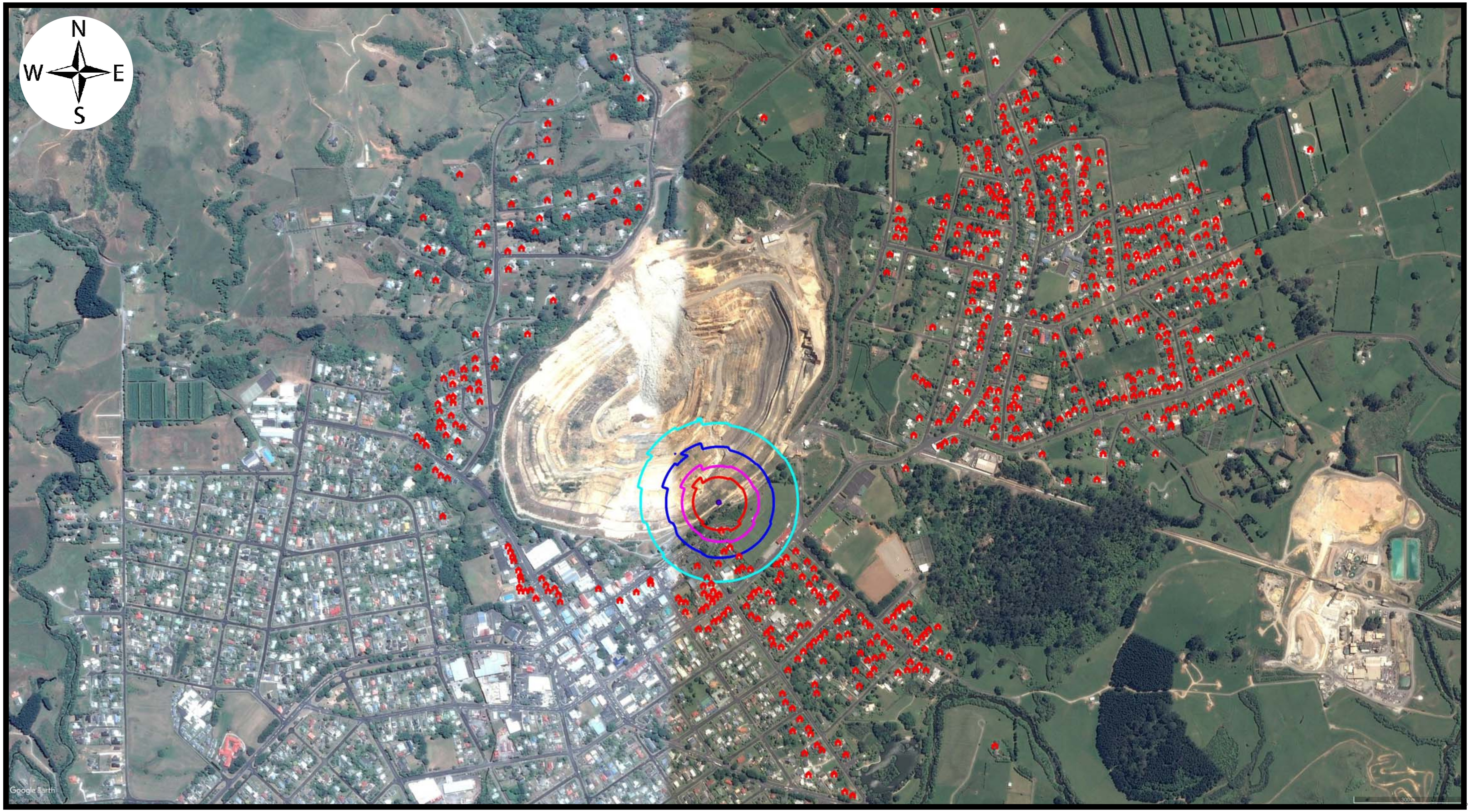

Created using TunnelTRAP Software

Compliance Properties

SCALE

0 150 300 450 600 750m

Surface Vibration Levels

- 5 mm/s Vibration Contour
- 4 mm/s Vibration Contour
- 3 mm/s Vibration Contour
- 2 mm/s Vibration Contour

Blasting Areas

Project Description: MARTHA PROJECT - Mining in 2030 - Vibration contours based upon explosive weights calculated for compliance with 5mm/s at sensitive residential receivers

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OCEANAGOLD
WAIHI OPERATION

Plate No. K

Revision History

R1: Original

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In preparing this drawing, HP have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request were complete, accurate and up to date. Where we have obtained information from a Government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware why any of the assumptions are incorrect.