

APPENDIX F

Noise Appendix

APPENDIX F-1

Assessment of Rock Blasting Impacts –
Revey Associates, Inc.

REVEY Associates, Inc.
PO Box 261219
Highlands Ranch, CO 80163-1219
Phone: (303) 470-0416
Fax: (303) 791-0140

**ASSESSMENT OF ROCK BLASTING IMPACTS AND
RECOMMENDED PRACTICES FOR PROPOSED
ROBLAR ROAD QUARRY
SONOMA COUNTY, CALIFORNIA**

November 2006

Prepared for:
ENVIRONMENTAL SCIENCE ASSOCIATES

Prepared by:
Gordon F. Revey, Principal, REVEY Associates, Inc.
Highlands Ranch, CO

REVEY Associates, Inc.

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ATTACHMENT 1 – ISEE INDUSTRY BLAST MONITORING STANDARDS

1.0 INTRODUCTION AND SCOPE

North Bay Construction, Inc. (Applicant) is proposing to develop and operate a rock quarry on a 198.76-acre parcel of land at 7601 Roblar Road in Southern Sonoma County, located approximately five miles west of the City of Cotati (see Figure 1: Site Location Map). A preliminary investigation of rock at this site (J.H. Dailey, 2002) indicates it contains a substantial source of moderate to hard Franciscan Sandstone and other hard volcanic basalt and andesite rock. High-quality aggregates produced from these formations could service area construction markets for many years. For identification purposes, the proposed operation would be called the Roblar Road Quarry.

On October 9, 2005, Gordon F. Revey (author) inspected the proposed site of the Roblar Road quarry. A representative from Environmental Science Associates (ESA) accompanied the author and pointed out where planned excavations would be located at the site. Locations of adjacent agricultural structures, residences, roadways, the closed Sonoma County Landfill site, utilities and other facilities in the area, along with the topography of the site, were also studied during this site visit. Other materials that were reviewed in the course of this evaluation include: plans submitted by the Applicant, various County documents related to the application, Geological studies of the site, and Comments regarding Submitted Plans. Project related references and other general technical references referred to in the text of this report are listed in the References Section (6.0) of this report.

In order to acquaint the reader with the physical science of blast effects, including ground vibration and air-overpressure (noise), short technical summaries about physical blast effects are included in the body of this report. A review of proposed blasting operations and specific evaluations of their potential impacts is also included and in some instances additional mitigation controls are proposed.

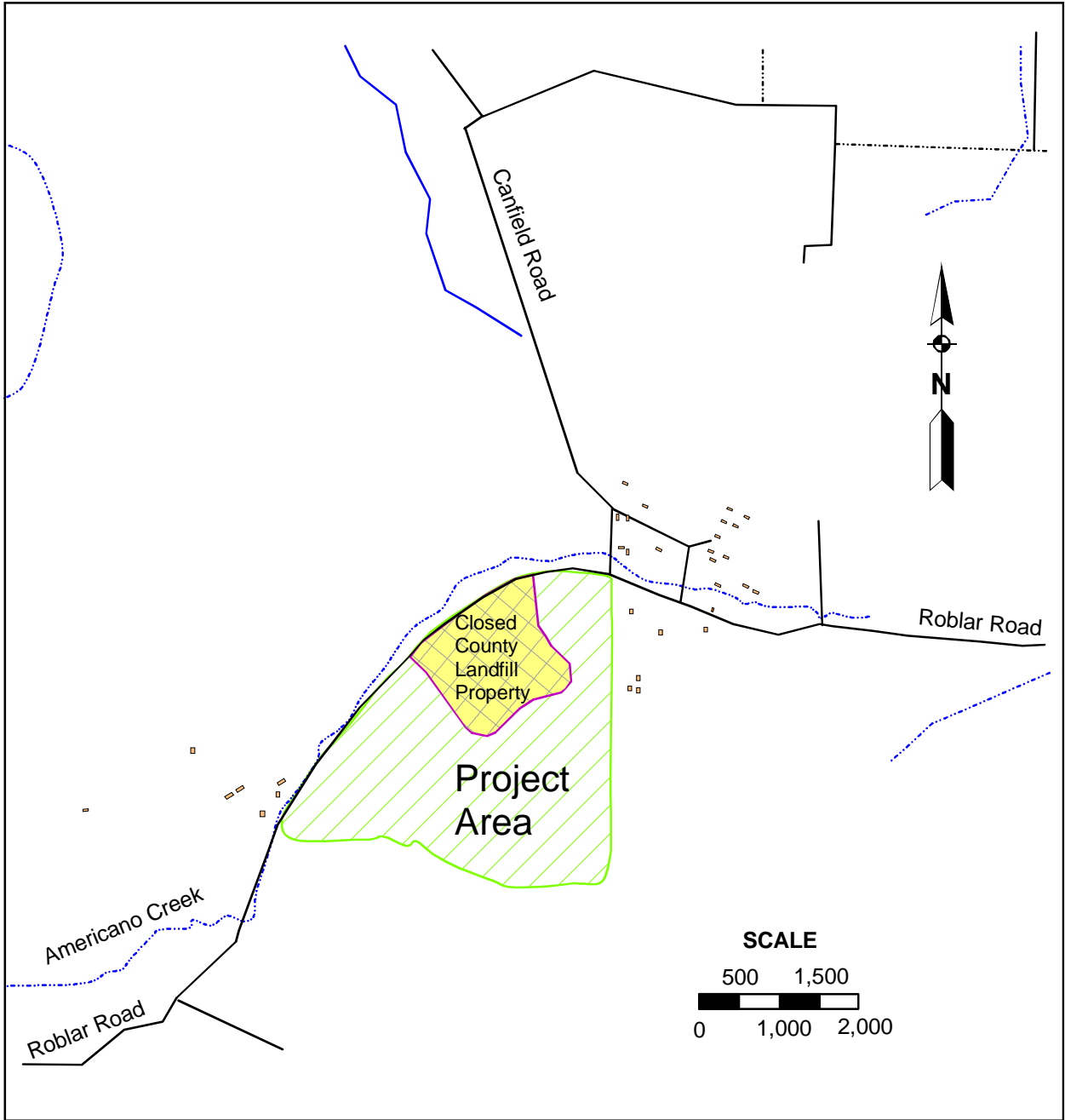


Figure 1.0 – Roblar Road Quarry Site Location Map

2.0 BLASTING CONCERNS AND IMPACTS

Following is a listing of identified blasting concerns and issues. They are not listed in any particular order based on importance or other criteria.

1. Impacts on water resources including surface water, ground water and neighboring wells and aquifers.
2. Security of explosive materials.
3. Damage to neighboring structures including but not limited to residential property, agricultural structures, and buried utilities.
4. Impacts on domestic and wild animals.
5. Disturbances caused by blast-induced vibration and noise.
6. Control of blast dust and fumes.
7. Nitrate and ammonia contamination of soil and water resources by blasting chemicals.
8. Stability of adjacent rock and soil slopes.
9. Concern about blast-induced flying rock and debris.
10. Impacts of blasting of adjacent landfill cells.

All identified concerns are evaluated in Section 4.0 of this report.

3.0 BLAST EFFECTS, DAMAGE CRITERIA AND HUMAN RESPONSE

Before analyzing potential impacts of the specific blasting operations proposed at the Roblar Road site, the following pages and subsections 3.1 through 3.6 provide a general technical review of the physical effects of blasting, prediction methods, damage criteria, and human response.

When explosive charges detonate in rock, they are designed so that most of the energy is used in breaking and displacing the rock mass. However, some of the energy can also be released in the form of transient stress waves, which in turn cause temporary ground vibration. Detonating charges also create rock movement and release of high-pressure gas, which in turn induce air-overpressure (noise), airborne dust and audible blast noise.

In the very-near zone, crushing usually occurs in the rock around the charge. The extent of this compressive and shear failure zone is usually limited to one or two charge radii (half the diameter of the charge). Beyond the plastic crushing zone, the rock or ground is temporarily deformed by elastic strain waves. For some distance, tangential strain intensity exceeds the rock's strength and new fractures are created. The magnitude of dynamic strain and particle motion decreases as distance from the charge increases. Radial cracks are created in rock around detonating charges as a result of induced strain that exceeds the rock's tensile strength. These cracks generally do not extend farther than 26 charge radii. For instance, if the diameter of the charge is 5 inches, radial cracks might extend 65 ($5/2 \times 26$) inches into adjacent rock.

3.1 Vibration Ground Waves

Within and beyond the cracking zone, stress waves spread through the rock mass and along the ground surface. Some waves pass through the "body" of the rock mass. Primary compression waves and shear waves are examples of body waves. Other surface vibration waves travel along the ground surface similar to the way waves travel along the surface of water. In an ideal isotropic and homogenous rock mass, wave energy would travel evenly in all directions. However, most rock masses are far from ideal, so wave energy is reflected, refracted and attenuated by various geological and topographical conditions. The elastic properties of rock greatly influence vibration magnitude and attenuation rate. When seismic waves pass through the ground, ground particles oscillate within three-dimensional space. Soon after blasting has stopped, vibration energy dissipates and the ground particles become still.

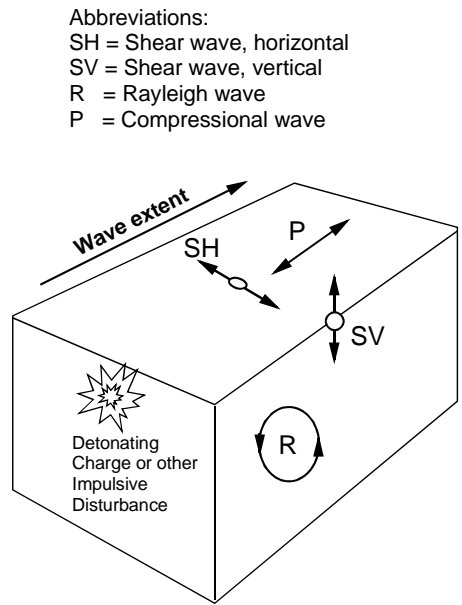


Figure 3.1 – Typical Vibration Waves

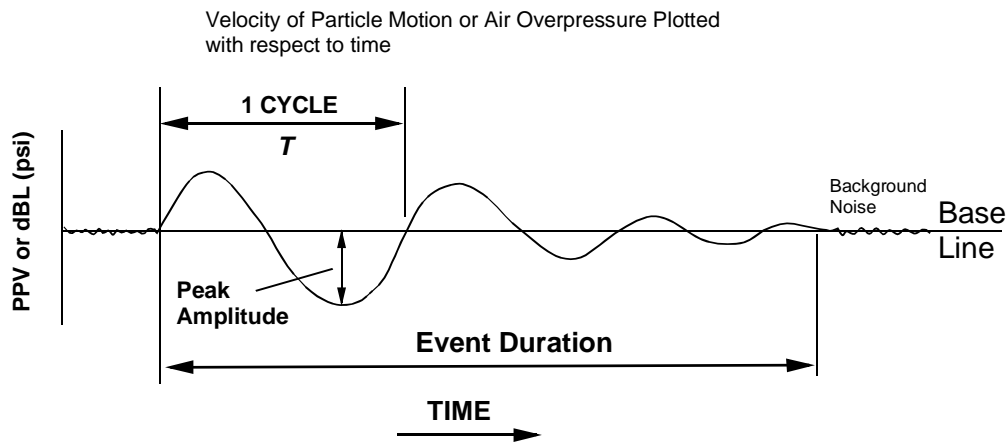


Figure 3.2 – Idealized Vibration or Air Overpressure Time—Intensity History Plot

The intensity of ground motion can be measured in several ways. These measures include:

- Particle displacement
- Particle velocity
- Particle acceleration
- Vibration frequency

Displacement is a measure of ground particle travel distance or location with respect to time. Particle velocity measures the speed of movement and acceleration is the rate of velocity changes. Vibration frequency is a measure of how many oscillations a ground particle makes per second of time. Frequency is reported in units of Hertz (Hz), which is equivalent to cycles per second.

3.2 Vibration Perception and Damage Criteria

The average person is quite sensitive to ground motion, and levels as low as 0.50 mm/s (0.02 in/s) can be detected by the human body when background noise and vibration levels are low. A curve plotting intensities of ground motion and motion frequencies that would not cause cosmetic cracking in drywall and plaster-lath walls is shown in Figure 3.3. Vibration intensity is expressed as Peak Particle Velocity (PPV), which is simply the maximum speed that the ground moves while it temporarily shakes. Since ground-shaking speeds are very small, it is measured in inches per second (in/s). Frequency of motion or cycles per second is a measure of how many times a particle of ground moves back and forth (or up and down) in one second of time. Frequency is expressed in units of Hertz (Hz).

The “Safe PPV Limits” for various frequencies of ground recommended by the US Bureau of Mines (Siskind et al, 1980), are shown by the curves in Figure 3.3. These limits, usually applied in most California jurisdictions, are specifically intended to protect typical wood frame homes. Significantly higher PPV limits, ranging from 5.0 to 20 in/s, are used to protect buried pipes and other heavy civil structures.

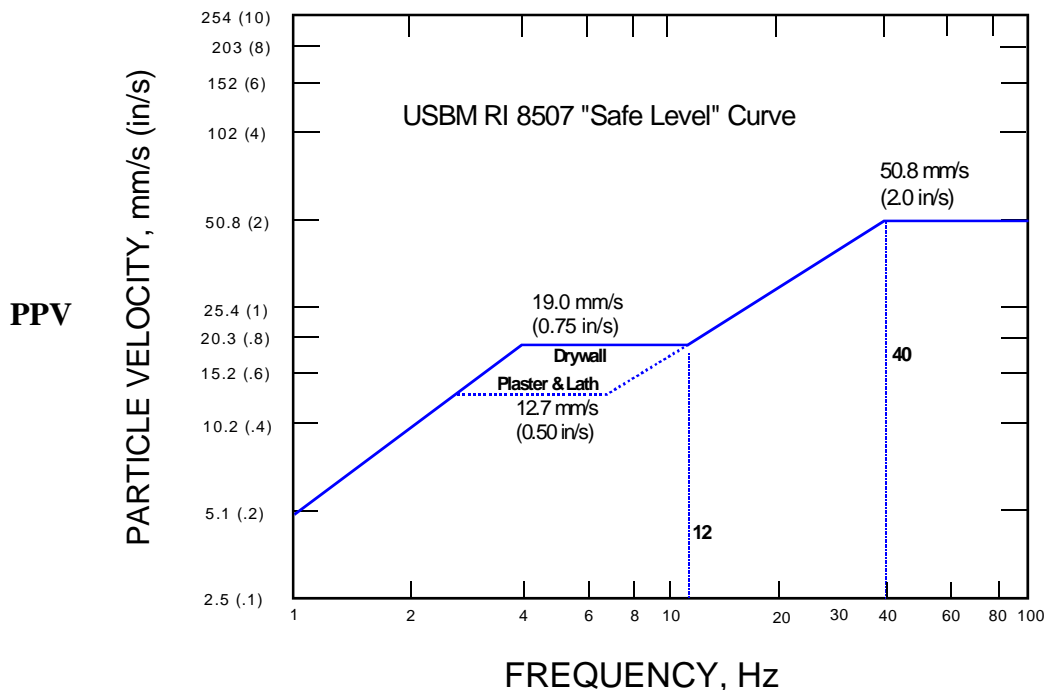


Figure 3.3 -- USBM “Safe Level” vibration curve from RI 8507

3.3 Blast Noise (Air-Overpressure)

The term “Blast noise” is a misleading because the largest component of blast-induced noise occurs at frequencies below the threshold-of-hearing for humans (16 to 20 Hz). Hence, the common industry term for blast-induced noise is “air-overpressure”. As its name implies, air-overpressure is a measure of the transient pressure changes. These low-intensity pulsating pressure changes, above and below ambient atmospheric pressure, are manifested in the form of acoustical waves traveling through the air. The speed of sound varies in different materials, depending on the density of the medium. For instance, pressure waves travel at the speed of 4,920 ft/s (1,500 m/s) in water, whereas, in air they travel at only 1,100 ft/s (335 m/s) because air has a lower density.

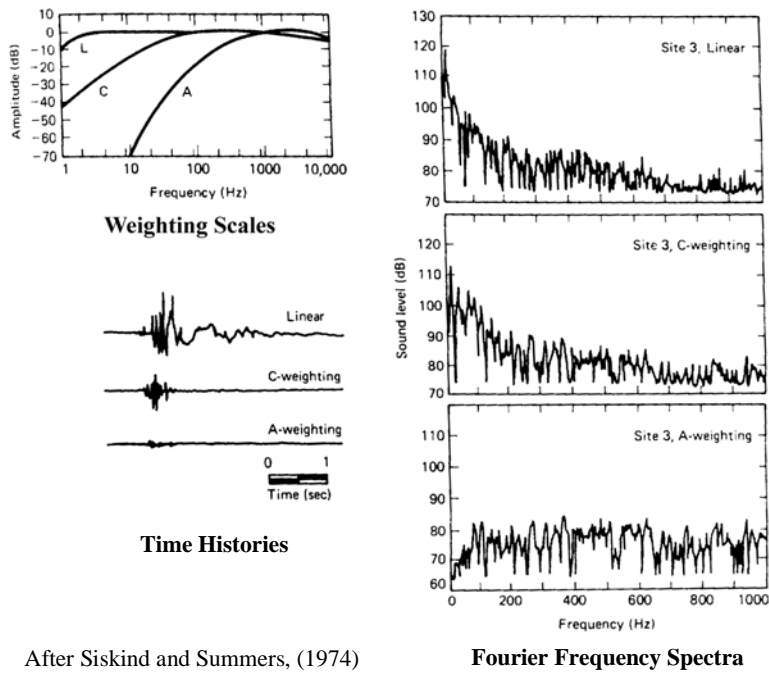
When calculating maximum overpressure values, the absolute value of the greatest pressure change is used — regardless of whether it is a positive or negative change. The frequency of the overpressure (noise) is determined by measuring how many up-and-down pressure changes occur in one second of time. Blast noise occurs at a broad range of frequencies and the highest-energy blast noise usually occurs at frequencies below that of human hearing (<20 Hz).

3.4 Air-Overpressure Measurement Scales

When measurements include low frequency noise (2 Hz and higher) with a flat response, they are called "linear scale" measurements. Air-overpressure measurements are typically expressed in decibels (dB) units and when the scale is linear, the unit designation is “dBL.” Regular acoustical noise measurements taken for the purpose of monitoring compliance with local noise ordinances almost always use weighted scales that discriminate against low frequency noise. Thus for a similar noise source, A-weighted and C-weighted scales will usually record significantly lower levels of noise. Differences between decibel scale measurements for individual blasts will vary depending on their unique frequency-intensity spectrums. Since full-range recording of blast-induced noise can only be done with linear (2-Hz response) instruments, it is imperative that all compliance specifications for blast-induced noise be expressed in “Linear” scale decibels (dBL).

In a study by USBM, researchers measured blast-induced noise a common location using A-weighted, C-weighted and Linear Microphones. The comparable measurements taken about 800 feet from a blast, shown in Figure 3.4, show that a linear peak noise of 120 dBL equates to only 112 dBC and 85 dBA. For blasts at the Roblar Road site, where closest neighboring structures are 600 feet away, the peak linear-scale noise would be around 122.5 dBL. $[120-20 \text{ Log } (600/800)]$ ($OP_x = OP_1 - 20 \text{ log}_{10} (R_x / R_1)$).

Note that differences for individual blasts will vary depending on their unique frequency-intensity spectrums. Since full-range recording of blast-induced noise can only be done with linear scale instruments, it is imperative that all compliance specifications be expressed in linear scale (dBL).



After Siskind and Summers, (1974) Fourier Frequency Spectra

Figure 3.4 -- Effects of Weighted Filtering on Air-overpressure Records

The regulatory limit defined by USBM, in State of California regulations, for air-overpressure measured with 2-Hz response seismographs is 133-dBL (0.014 psi). Damage to old or poorly glazed windows does not occur until air-overpressure reaches about 150 dBL. More importantly, since the decibel scale is a logarithmic ratio, the actual overpressure at 150 dBL is 0.092 psi, versus 0.013 psi at 133 dBL. Therefore, the actual pressure at the 133 dBL limit, is over seven times (0.0917/0.0129) lower than the threshold damage level at 150 dBL. The relationships between actual overpressure expressed in psi and decibel scale measurements are shown in the following Equations. NOTE: Due to the logarithmic ratios used to decibel values, seemingly small changes in decibel readings can equate to large changes in absolute overpressure (psi).

$$dB = 20 \text{Log}_{10} \left(\frac{P}{P_o} \right) \quad \text{or} \quad P = P_o 10^{\left(\frac{dB}{20} \right)} \quad \text{Equation 3.1}$$

Where: dB = decibels, P = overpressure (psi), P_o = Threshold of Human Hearing Pressure (20 microPascals or 2.9 x 10⁻⁹ psi).

3.5 Blast Vibration Intensity Predictions

It is standard practice to use scaling relationships to predict vibration intensities at various distances. These relationships, based on similitude theory, are used to develop empirical relationships between ground vibration particle velocity, charge weight, and distance. Distance is scaled by dividing it by the square root of the maximum charge weight firing at any time within a blast. This single scaled distance variable can then be used to predict vibration intensity (PPV). The scaling relationship between peak-particle-velocity (PPV) and scaled distance (D_s) is shown below in Equation 3.2.

$$PPV = K \left(\frac{D}{\sqrt{W}} \right)^m \quad \text{or} \quad PPV = K (D_s)^m \quad \text{Equation 3.2}$$

- Where:
- PPV = Peak Particle Velocity (in/s)
 - D = Distance (ft)
 - W = Maximum Charge-weight-per-delay (lb)
 - K = Rock Energy Transfer Constant (K-Factor)
 - m = Decay Constant
 - D_s = Scaled Distance (m-kg^{-0.5})

Site-specific constants, **K** and **m**, can be determined by performing a regression analysis of multiple peak particle velocity (PPV) and D_s data pairs. In simple terms, for any given site, **K** is a measure of how much vibration energy is transferred to the ground near the explosive charge and **m** defines how fast the energy attenuates with distance.

A sample regression curve that was recently prepared by the author to support blasting controls for an upcoming subway project in New York City is shown in Figure 3.4. When plotted in log-log scale, the exponential relationship between scaled distance and PPV generally follows a straight line with a negative slope (**m**) -- usually around -1.6, and Y-intercept (**K**) values varying between 960 and 26, as defined by Oriard (1972). The **K** value (amount of energy at the source) is higher when charges are more confined and/or rock has a high stiffness ratio (Young's modulus of elasticity).

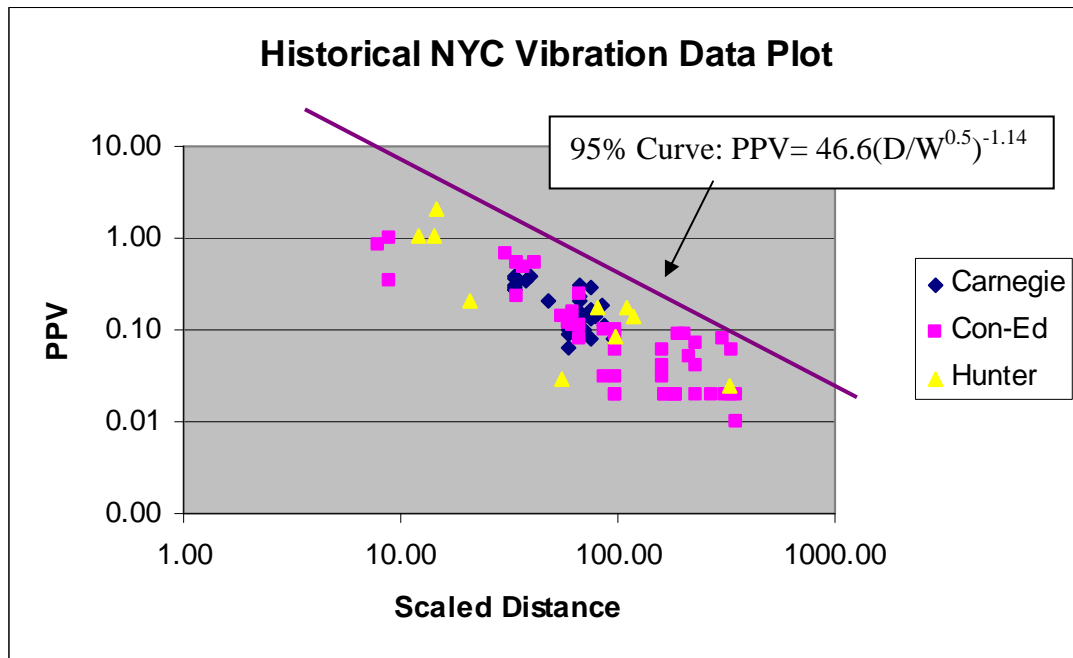


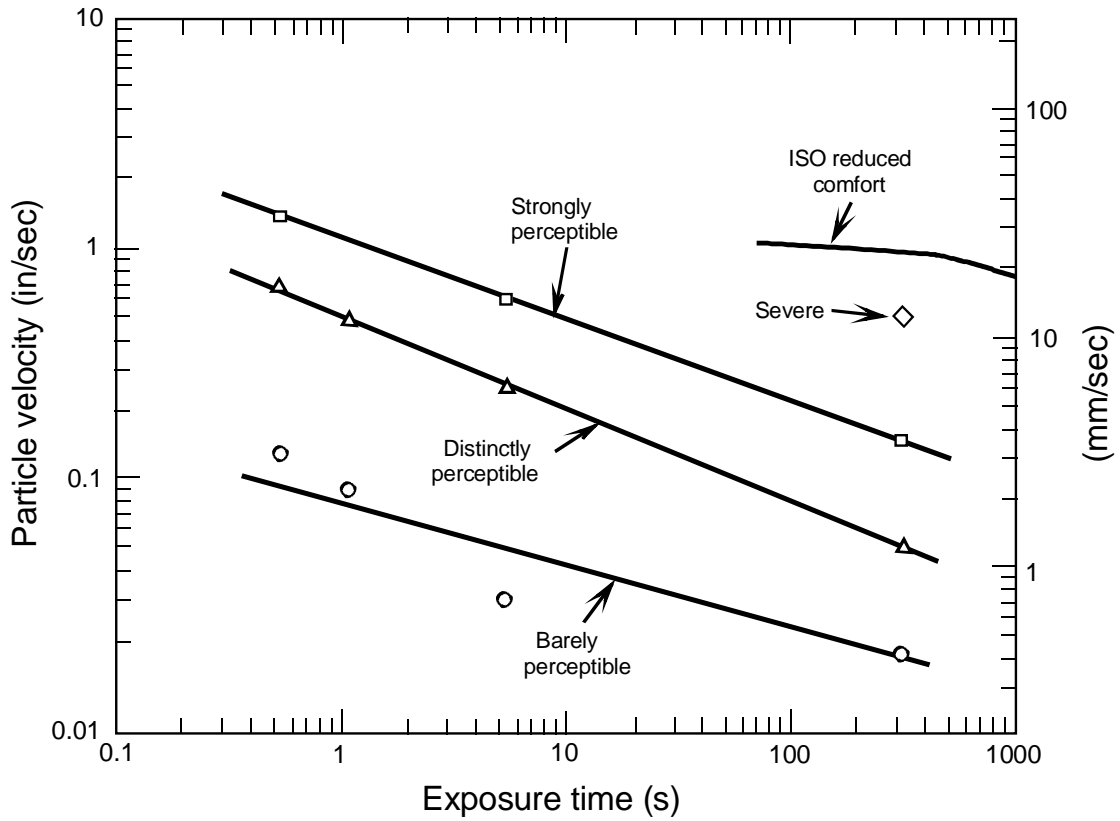
Figure 3.4 – Historical NYC Scaled Distance—PPV Data from Blasting at Carnegie Hall, the Con-Edison Shaft at 36th Street and 1st Avenue and foundation blasting at Hunter College at between 38th and 39th Streets (NOTE: the 95% curve means that 95 percent of the time, predicted values will be lower than the value calculated).

When site-specific historical data is not available, the *K* factor value can be estimated based on physical rock properties and degree of blast confinement. From the author’s past experience, for blasts in the hard Franciscan Sandstone and other igneous rock formations at the Roblar Road site, a prediction equation with a *K* factor of 240 can be used to predict vibration intensities (PPV) at various locations of concern. With this cautiously high *K*-factor, predicted levels of vibration will likely be higher than actual values measured at similar scaled distances. The resulting prediction equation, which is used in the site-specific evaluations in Section 4 of this report, is shown Equation 3.3 below.

$$PPV = 240 \left(D / \sqrt{W} \right)^{-1.6} \quad \text{Equation 3.3}$$

3.6 Human Response to Transient Vibrations

In addition to concerns about vibration damage, under certain conditions, humans and animals can be startled or annoyed by blast-induced ground vibration. Research has also shown that the human response to transient vibration--like those caused by blasting--varies depending on exposure time and the intensity of the motion. Response curves defining how humans respond to transient vibrations based on these variables are shown in Figure 3.5.



Human response to transient pulses of varying duration after Wiss and Parmalee (1974)

Figure 3.5 – Human Response to Transient Vibration

4.0 IMPACTS OF BLASTING AT THE PROPOSED ROBLAR ROAD QUARRY SITE

In the following sections, potential effects of blasting are analyzed and where appropriate, practical and proven mitigation measures are recommended.

The preliminary blast plan details described by the Applicant's representative (Hummer, 2004) indicates explosive charges would be stemmed by at least 8 feet of clean crushed stone stemming. Blasting information in the Applicant's Surface Mining and Reclamation Plan indicates that one or two blasts, typically having 20 to 25 holes, would occur monthly. Holes would be spaced on 10-foot centers and drilled to a maximum depth of 30 feet. Since it is generally recommended to confine charges with stemming of height equal to or greater than 20 charge-diameters, an appropriate maximum diameter of blastholes for this proposed quarry would be around 5 inches (8 x 12 / 20).

Assuming four feet of extra drilling is done below the 30-foot bench floors (sub-drilling) the maximum explosive column in a 34-foot-deep hole, stemmed with 8 feet of crushed stone would be 26 feet. The use of an Ammonium Nitrate and Fuel Oil blend (ANFO) is described in the mining plan for use in dry holes. For wet holes, packaged or pumped emulsion explosives having appropriate water resistance can be used in place of bulk ANFO. Pumped emulsion explosives carry a higher weight of charge compared to use of bulk explosives. As a worst-case scenario, it is assumed for this study that pumped emulsion explosives are used. Using this assumption, the maximum weight of a single 26-foot charge would be around 275 pounds ($5^2 \times 1.24 \times 0.34 \times 26$). It should be noted that charge weights at the eastern edge of the mining area would likely need to be reduced to 100 or so pounds to ensure peak ground motions do not exceed 0.5 in/s. For practical blasting purposes, the single charge in a 34-foot hole could be separated into two or three individually delayed charges, separated by stemming, to ensure the maximum charge weight-per-delay in 5-inch holes is appropriate for vibration control.

For the purposes of the evaluations done in this report, it is also assumed that the applicant would not drill blastholes with diameter greater than 5-inches and the maximum-charge-per-delay would not exceed amounts necessary to ensure vibration levels (PPV) do not exceed safe levels shown in Figure 3.3. Note that for vibration and air-overpressure prediction purposes, the impact of various delay-timed charges is not considered cumulative unless the delay time between sequentially fired charges is less than 8 milliseconds.

4.1 Impacts on Water Resources

From the author's experience at many other blasting operations throughout the United States, concerns about blasting impacts on water resources have involved physical damage to existing water wells, reservoirs, springs and aquifers or chemical contamination of ground water. A discussion of these potential physical and chemical impacts at the Roblar Road site follows.

Physical Damage to Water Resources

In a study (RI 7901, 1983) conducted by the US Bureau of Mines (USBM), researchers set up tests designed to determine the maximum zone of physical rock damage zone that can occur

around blastholes. In this study, core logs, borehole periscopes, permeability tests and various other measures were used to determine the extent of blast damage to adjacent rock not fragmented and removed by blasting.

Data from the study indicated that the extent of localized blasthole damage in the form of radial cracking is generally a function of radial charge diameter, explosive type, and rock characteristics. In one test, the fracturing produced around 6½ -inch-diameter blastholes, loaded with bulk ammonium nitrate /fuel oil (ANFO) was measured and it was found that the maximum cracking extended 26 charge radii.

At the Roblar Road site, the maximum fracture radius for the assumed 5-inch blastholes, at 26 charge radii, would likely not exceed 65 inches or 7.3 feet. Since all off site water wells and other utility lines are located much farther than the limits of ground rupturing, it is not physically possible that they could be damaged by blast-induced ground fracturing.

Using a conservative assumption that a potential private well would be located at the nearest residence (600 feet northeast of the edge of the mining area), the resultant intensity of ground motion for blasting with charge-per-delay not exceeding 100 pounds would be around 0.34 in/s ($240 (600/100^{0.5})^{-1.6}$). Vibratory motion of this intensity in the ground near wells would have no impact on the condition of the aquifers that feed them or on the quality or quantity of the water produced by the well. For perspective, a ten-foot increase in the height of water in the well would create a greater more pressure than the transient pressure caused by vibration waves of this intensity.

Chemical Contamination of Ground Water and Surface Water

Most commercial explosives contain 70 to 94% ammonium nitrate, by weight. If substantial amounts of explosives were spilled or incompletely detonated, rainwater would cause some amount of ammonia and nitrate to leach out and go onto into the ground. Over time, leached ammonia and nitrates would penetrate into ground water and can possibly be washed by rainwater over the ground surface and into surface and ground water resources. The U.S. EPA ambient water quality criterion is 0.02-mg/L free-ammonia and the drinking water criterion for nitrate as nitrogen ($\text{NO}_3^- \text{N}$) is 10-mg/L.

At the Roblar Road site, if best industry standards of care concerning clean-up procedures are used to recover any spilled explosives materials like ANFO or emulsion slurry explosives, and charges are adequately primed with cast-booster primers, losses of ammonia and nitrates to ground water or flowing surface water would not even be measurable. The author has visited many existing quarries with operating conditions similar to that of the proposed Roblar Road quarry, and knows of no substantial water contamination incidents at these operations, many of which have operated for over 20 years.

4.2 Security of Explosive Materials

In this day and age, it is quite normal and expected for residents to express concerns about the security of explosive materials. To ensure that explosive materials are indeed properly secured during transport and use, industry groups and government agencies have cooperatively developed laws and standard practices used in all operations throughout the United States. In March, 2003 the Safe Explosives Act was enacted, which hereby requires background checks for all persons that handle, use, or have access to explosive materials. The act also requires all explosive users to obtain a federal blasting license issued by the Bureau of Alcohol Tobacco and Firearms (ATF).

The Applicant has indicated that no explosives would be stored on the site, so on-site storage permits would not be required and issues regarding overnight explosives storage would not apply.

Since most quarry blasting in the State of California is now done by sub-contractors, it is presumed that in this case a blasting contractor would deliver adequate quantities of explosives to the site on days when blasting is planned. All unused explosives and detonators would be returned to the blasting contractor's secure offsite magazines at the end of each day that a blast occurs.

As required by Department of Transportation (DOT) rules, explosive materials would be delivered in specially built vehicles marked with United Nations (UN) hazardous materials placards. Explosives and detonators are delivered in separate vehicles or they are separated in compartments meeting DOT rules within the same vehicle. Vehicles contain at least two 10-pound Class-A fire extinguishers and all sides of the vehicles display placards displaying the UN Standard hazard code for the onboard explosive materials. Drivers must have commercial drivers licenses (CDL) with Hazmat endorsements, and drivers must carry bill-of-lading papers detailing the exact quantities and code dates of transported explosives or detonators. Once explosives are delivered to the blasting site, the licensed blaster-in-charge is responsible for directly overseeing their security. The blaster-in-charge must have adequate experience and successfully pass a licensing test verifying their knowledge of blasting methods, rules and safety procedures.

In the State of California, CalOSHA administers the testing and licensing of blasters and the California Highway Patrol establishes safe explosive transport routes and oversees all DOT rules enforcement.

If all these rules and procedures are rigorously followed, similar to the thousands of similar deliveries made daily to other quarry sites throughout the US, explosive materials could be safely transported to and from this site without incident.

4.3 Impacts to Neighboring Homes, Pipes, other Structures and Earthen Slopes

In response to a question from the County Permits and Resource Management Department (PRMD) concerning vibration limits, the Applicant’s representative (Hummer, 2004) responded that blast-induced ground motion shall not exceed 2.0 in/s near any private off site structure. While this limit might be appropriate to protect well-constructed buildings with brick or concrete walls, it is not an appropriate limit for older off-site wood-frame dwellings. Most city and state regulations, in accordance with the low-frequency PPV limits suggested by the US Bureau of Mines (RI8507), limit ground motion to 0.5 in/s at wood-frame structures. Moreover, from the author’s experience, occupants of homes could vigorously object to ground motion exceeding 0.5 in/s at any frequency.

As shown in Figure 4.1, at the nearest residence would be located about 600 feet northeast of the proposed mining area where rock-blasting operations might occur. At this distance, to ensure that that the intensity of ground motion does not exceed the reasonable 0.5 in/s limit, the author recommends all blasting should be designed to assure that charges are sized to maintain a scaled distance (D_s) of 65 or greater. With this limitation, maximum cumulative weight of any charges firing within any 8-milliseconds time period should not exceed 85.2 pounds $[(600/65)^2]$. This limitation could be achieved if the applicant used delay-decked charges in 5 inch holes or reduced hole-size or the height of benches.

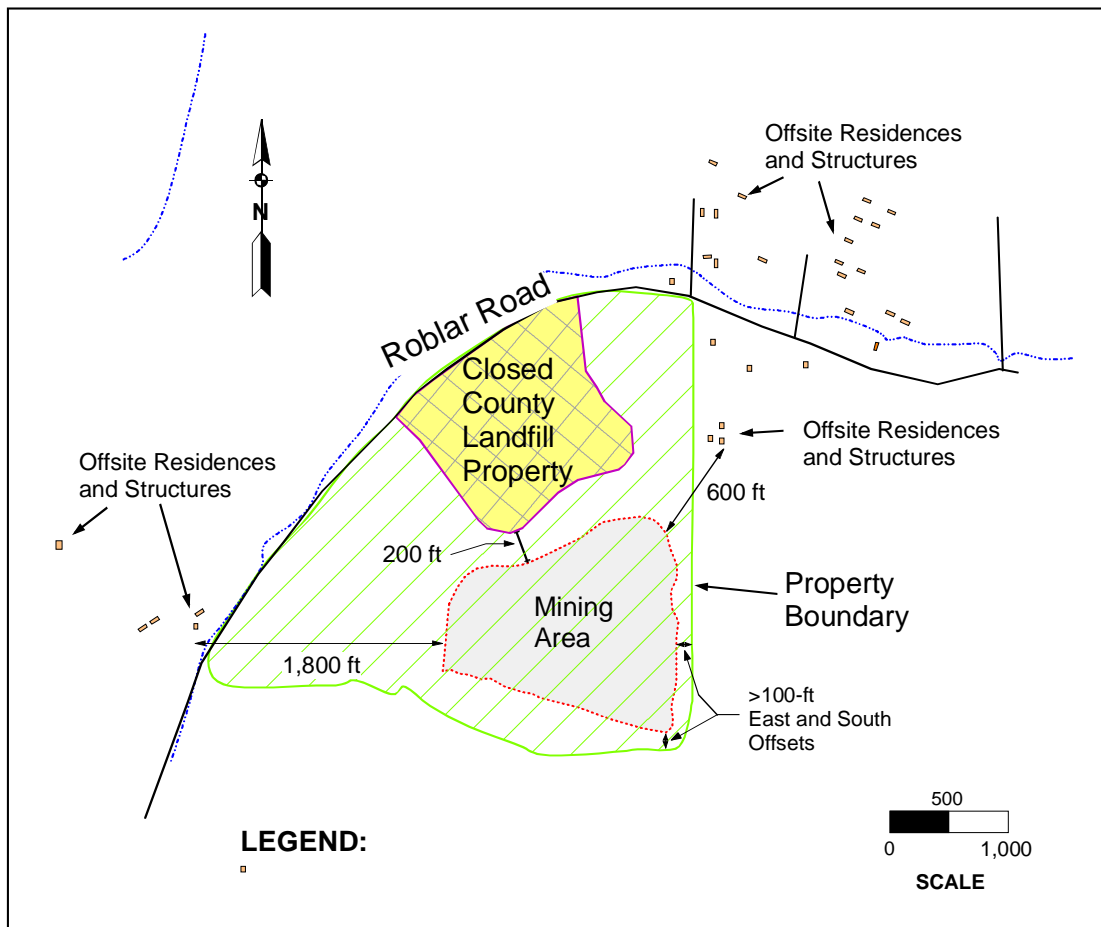


Figure 4.1 – Roblar Road Mining Area and Nearby Structures of Concern

Impact to Earthen or Rock Slopes adjacent to Roblar Road

Concern may be expressed that blast-induced vibration may cause liquefaction of soils in slopes adjacent to Roblar Road. This occurrence would be extremely unlikely because at the closest distance of 1,100 feet between blast areas and Roblar Road soil slopes, and an assumed maximum charge-per-delay of 275 pounds, the scaled distance would be $66.3\text{-ft}\cdot\text{lb}^{-0.5}$ ($1,100 / 275^{0.5}$), which would exceed the liquefaction threshold level of $10\text{-ft}\cdot\text{lb}^{-0.5}$ by more than a factor of six times.

With no need for further analysis, it can be concluded that blasting, conforming to the described limits, would not damage any structures, utilities, and earthen or rock slopes near the proposed Roblar Road mining area.

Impact to Buried Pipes or Utilities at Nearby Residences

Presuming that pipes and other utility lines are located at or near the closest residence located 600 feet northeast of the proposed mining area, peak ground motion in ground near utilities for blasts where charges would be sized to meet a minimum scaled distance of 65, would likely not exceed 0.30 in/s [$240(65)^{-1.6}$]. Motion of this intensity is far below the cautious 5.0-in/s -limit recommended by the US Bureau of Mines (RI 9523) to expressly protect buried pipes of any construction and condition. Therefore, blasting vibrations would likely have no impact on buried pipes or utilities at nearby residences.

Air-overpressure and Flyrock Control

In the submitted Mining Plan the Applicant has proposed limiting Air-overpressure to 130 dBL, which is less than the 133-dBL limit recommended by the US Bureau of Mines. In this case, intensities of air-overpressure (blast noise) for 5-inch charges, stemmed with at least 8 feet of crushed stone stemming, would likely not exceed 122.5 dBL at distances of 600 feet and greater (See calculation in Section 3.4, p. 7). Using 8-feet of crushed stone stemming to confine 5-inch charges would also assure that excessive rock movement (flyrock) does not occur and the improved charge confinement would limit gas-pressure losses, which would certainly improve overall rock fragmentation.

The onset of potential air-overpressure damage (broken or loosened glass window panes) does not occur until air-overpressure exceeds 145 dBL. In real pressure terms, expected air-overpressure level of 122.5 dBL generates a pressure of 0.00387 psi, which is 13.4 times lower than the 0.052-psi pressure at 145 dBL. If The Applicant applies the recommended stemming controls, and consistently measures air-overpressure with intensities less than the proposed 130-dBL limit at nearby structures, it is extremely unlikely that any damage or annoyance would result from blast-induced air-overpressure.

4.4 Human and Animal Impacts

As established in the prior section, respective vibration and air-overpressure intensities at the nearest off-site properties are not expected to exceed 0.30 in/s and 122.5 dBL.

Human Response to Blasting

Since the duration of quarry blasts rarely exceed two seconds, the Wiss-Curves (see Figure 3.5) indicate that ground vibration, at the nearest offsite dwelling, with levels around 0.09 in/s would be in the barely perceptible range. Since Cal-OSHA Rules limit blasting to daytime hours when ambient levels of background noise and vibration are high, neighbors to the blasting would most often not even know it has occurred.

Impacts on Animals

While visiting the site, the author observed pastureland, where domestic animals may feed or range, on adjacent properties. Accordingly, some neighbors might express concerns about potential blasting impacts on domestic and wild animals. Several years ago the author participated in a controlled study regarding the impacts of blasting on a variety of animal species conducted by animal biologists at the Washington Park Zoo in Portland, Oregon. In this study, researchers evaluated the effects of nearby (as close as 500 ft) blasting noise and vibration on black rhinos, naked mole rats, elephants, spotted owls, snow leopards, red pandas and several other species (Hall et al, 1998). Elephants were specifically chosen for this study because they are known to communicate at infrasonic noise frequencies below human hearing range. The black rhinos were studied because zookeepers were concerned that blasting might aggravate the problems with a pair that was unsuccessful at breeding during the year prior to the construction work. The physiological effects of blasting were evaluated by measuring the level of the stress hormone (cortisol) found in animal scat, before and after blasting. In addition, for the first six blasts, the physical reactions of the tested animals were observed when blasting occurred. The intensity of blast-induced ground motion in this study was as high as 0.68 in/s, which is more than six times higher than the 0.11-in/s level expected at nearest off-site range areas.

Maximum air overpressure for this blasting was about 130 dBL (Linear scale) and ground motion reached about 0.25 in/sec, which are both much higher than levels expected for the blasting at the Roblar Road Quarry. The researchers noted that the tested animals noticed the first blast or two; however, they quickly acclimated to the noise and vibration. Additionally, the black rhinos mated successfully for the first time while construction was occurring on the tunnels. In their final conclusions, the researchers found that the tested animals experienced no long-term negative effects from the levels of noise and vibration produced by the construction blasting.

From the authors' personal experience, white-tailed deer were observed, on many occasions, within several hundred feet of an open-air explosive testing range at the Reynolds Plant of the former Atlas Powder Company in Tamaqua, Pennsylvania. The peak air overpressures, during unconfined explosive tests, at that distance often exceeded 145 dBL. When blasts were detonated

the deer might casually lift their heads and look toward the test site. However, they never ran away or appeared otherwise bothered by the loud noise. It was obvious that, like the animals at the Metro Washington Park Zoo in Portland, the deer had become acclimatized to the blasting noise.

For the past five or so years, the author was involved in several expansion projects at the County of Sonoma California Central Disposal Site in Petaluma, CA, where blasting regularly occurred within 1,000 feet of dairy cows. Measurements in the cow pastures indicated that respective blast noise and vibration levels were as high as 0.08 in/s and 128 dBL, which are similar in scale to levels anticipated for the proposed Roblar Road Quarry. Despite initial concerns by the dairy operators, all involved parties have now concurred that blasting did not disturb the cows.

Based on the referenced studies and observations of the author at many other projects, blasting at the Roblar Road Project would have little or no impact on domestic or wild animals near the site or on neighboring properties.

4.5 Control of Dust

MSHA rules require the use water injection when drilling to control drilling dust. Standard blasting practices using sequential delay timing schemes to generate effective rock fragmentation and vibration control would also minimize blasting dust. Quarry operators usually remove loose overburden to prevent dilution of mined rock, which also lessens the amount of fine material that can become airborne by blasting. If needed, during dry summer periods, water can also be sprayed onto blast areas to further mitigate dust. If these standard practices are committed to by the applicant and rigorously applied, it is unlikely that airborne dust from blasting would be a cause of concern.

4.6 Impacts on Soil Resources

Some small amounts of blasting agents, which in quarries is typically ammonium nitrate pellets mixed with fuel oil (ANFO), is lost to the ground by spillage or wind blowing it during loading. The amount of nitrates released to the ground by these losses is typically not toxic to any flora or fauna in an agricultural environment like that near the Roblar Road site. Wind-blown ANFO dust that lands on the ground surface effectively becomes fertilizer for plants that convert it to other natural matter through photosynthesis. If The Applicant applies good practices for minimizing spillage, concentrations of nitrates or ammonia in soils would not be harmful or even noticeable.

4.7 Impacts on the Closed Sonoma County Landfill

The County and others have expressed concern that blast-induced vibrations could influence the ground beneath and adjacent to the closed landfill cells (the landfill cell closest to the proposed quarry is located approximately 400 feet north of the edge of the quarry).. Concern has also been

expressed that methane gas generated from decomposing waste might be transmitted through rock crevices and create a threat of potential gas-explosions.

In the responses to PRMD question regarding blasting impacts on the landfill site, the Applicant's representative (Hummer, 2004) has indicated that drill holes would be monitored with a methane gas detection device in the area of the old landfill cells. No distance or minimum methane limits are defined. Several years ago the author developed controls for quarrying and construction blasting conducted very close to landfill cells at the current Sonoma County Waste Management Facility in Petaluma, CA. For that blasting, at times done within 50 feet of waste fill locations, methane monitoring was required for all blastholes within 1,000 feet of waste filled areas.

Standard testing devices, like those commonly used in underground coal mines or gassy mines, can be used to perform this testing. If blastholes intersect methane gas pockets or formations that produce methane, these test instruments can accurately detect its presence. Since concentrations of methane in air that are combustible range from 4 to 15%, it would certainly be safe and reasonable to allow blasting when measured levels of methane do not exceed the 0.1 percent minimum trace level allowed to escape to the air by the Bay Area Air Quality Management District. Moreover, since natural concentrations of methane are not expected in the Franciscan sandstone formations, methane monitoring could be done at the collars of blastholes closest to the existing buried waste areas. For this site, it is extremely unlikely that methane above the proposed 0.1 percent limit would be detected in any drilled holes. However, for caution it would be reasonable to test methane at hole-collars of six holes drilled closest to the landfill site for all blasts located within 1,500 feet of the existing waste storage cells.

Blast induced ground motion in ground above, below, and surrounding the waste cells, at a distance of 400 feet would be around 1.5 in/s. It is important to note that at closer distances, the frequency of ground vibration would be relatively high, which is important because elastic ground displacement is inversely proportional to frequency. In perspective, this site has been earthquake proofed by the 1989 Loma Prieta quake that created motions and displacements many times greater than those that would be caused by blasting. For comparison, peak motions exceeding 13 in/s at frequency of 1 Hz were caused by the Loma Prieta Quake at nearby monitoring locations. Assuming motions at this site were only 5.0 in/s at 1 Hz, the peak ground displacement would have been around 0.8 inches [$5 / (2 \times 3.14 \times 1) = PPV / (2 \times \pi \times f)$]. Blast motions caused by point-source charges, at a distance of 400 feet would occur at a frequency of 30 Hz and probably much higher. At a peak particle velocity of 1.5 in/s, the peak elastic ground displacement would be around 0.012 inches, which is over 60 times less than the movement the fill-site has already survived during the Loma Prieta Quake. Hence, if charge weight-per-delay does not exceed 275 pounds, it is extremely unlikely that blast-induced ground motion would have any impact whatsoever on the four existing buried waste cells or on the ground around them.

Leachate pipes and/or water quality monitoring wells are on the closed landfill property are located within 350 to 400 feet of the proposed mining area. If charge-per-delay is limited to ensure peak particle velocities do not exceed 5.0 in/s at these pipes and wells, it is unlikely that any damage would occur. At the closest distance of 350 feet, the maximum charge allowed to ensure ground motion of 5.0 in/s would not be exceeded would be over 900 pounds. However, this would not occur because much smaller charges would be needed to ensure with the much smaller PPV limits that would apply to the residential homes. Hence, due to the residential vibration requirements, ground motions at the wells and leachate pipes would be far below levels of concern.

5.0 CONCLUSIONS

If the Applicant adopts the practices and limitations already planned and accepts the additional limitations proposed in this report, the author finds no issues that could prevent the execution of safe and environmentally compliant blasting operations at the Roblar Road Quarry.

If mining does occur, to ensure compliance with regulated and proposed blasting limitations the Applicant should monitor ground vibration and air-overpressure at a minimum of two locations for each blast. One location should be at or close to the nearest residential property. Second monitoring points should include the landfill area and other structures of concern. All monitoring equipment and practices should conform to standards developed by the Vibration Section of the International Society of Explosive Engineers (ISEE), as shown in Attachment I.

6.0 REFERENCES

Hall, S, Fraser, J., Mellen, J. and Shephardson, D.J. (1998). "Response of Zoo Animals to Airblast and Ground Vibration Resulting from Light Rail Train Construction," Metro Washington Park Zoo, Portland, Oregon, 1998.

Hummer, J., (March 2004), Letter with subject: Response to PRMD Letter Dated February 2, 2004 on the proposed Roblar Road Quarry; 7601 and 7175 Roblar Road, Petaluma; PRMD File No. PLP03-0094.

Oriard, L.L., (1970). "Blasting Operations in the Urban Environment," Association of Engineering Geologists Annual Meeting, Washington, DC, October 1970, published in Bulletin of AEG, Vol. IX. No. 1, October, 1972.

Revey, G.F., (1995). "Close-in Blasting at the TRI-MET Light Rail Tunnels in Portland, Oregon," ISEE Proceedings.

Davis, G., (January 8, 2004), Memo to Mike Sotak, File/Subject: PLP03-0094 7601 & 7175 Roblar Rd. Petaluma.

Seppeler, C., (August, 2004), Sonoma County PRMD Report, “Project Description and Probable Environmental Effects of the Roblar Road Quarry Project.”

Siskind, D.E., 1997, SAFE BLAST VIBRATION CRITERIA FOR HOMES, Journal of the International Society of Explosive Engineers, July/August, 1997.

Siskind, D. E. et al, R.I. 9523, (1993), SURFACE MINE BLASTING NEAR PRESSURIZED TRANSMISSION PIPELINES, Siskind, David E., Stagg, Mark S., Wiegand, John E. and Schultz, David L., 1993.

Siskind, D.E. and Fumanti, R.R., RI 7001, (1983). BLAST-PRODUCED FRACTURES IN LITHONIA GRANITE, United States Bureau of Mines, Report of Investigations 7901.

Siskind, D. E., Stagg, M. S., Kopp, J.W. and Dowding, C.H. (1980). Structure Response and Damage Produced by Ground Vibration From Surface Mine Blasting. RI 8507, U. S. Bureau of Mines.

Siskind, D.E., Stachura, V.J., Stagg, M.S., and Kopp, J.W., (1980). US Bureau of Mines Report of Investigations 8485.

Wiss, J.F. and Parmalee, R.A. (1974), “Human Perception of Transient Vibrations,” Journal of the Structural Division, ASCE, Vol. 4, pp. 349-377.

ATTACHMENT 1

ISEE BLAST MONITORING STANDARDS

INDUSTRY BLAST MONITORING STANDARDS

The following standards should be applied when measuring blast-induced vibration and air-overpressure (noise). These standards are based on the best practices recommended by The Vibration Section of the International Society of Explosives Engineers – 1999.

Part 1. General Guidelines

1. Operators: Only personnel who have successfully completed a proper training course should operate monitoring equipment.
2. Calibration: The instrument manufacturer should annually calibrate recording units and sensors. Documenting certificates should be kept on file and copies should be provided to appropriate persons upon request.
3. Event Record Keeping: Hard copy reports and electronic file-copies of all event-monitoring records should be maintained for all blasts. Operating notes should be programmed into the instruments, which should be printed monitoring records. These notes at a minimum should include the operator's name, date, time, place and other pertinent data specific to the monitoring location.
4. Trigger Levels: When employing instruments to operate in auto-trigger-mode, trigger levels should be set low enough to record blast effects. If expected levels of blast noise or vibration do not exceed minimum trigger levels, the instrument should be attended by an operator and turned on manually.
5. Documenting Monitor Location: In addition to event reports, an accurate method should be used to determine the monitoring location for later reference. Acceptable methods are 1) plotting numbered locations on scaled maps; 2) defining location with GPS northing, easting and elevation values; and 3) noting the name of the structure and the measured distance (+/- 1 ft) where the seismograph was placed relative to at least two identifiable reference points. Any person should be able to locate and identify the exact monitoring location at a future date.
6. Distance to Blast: The horizontal distance from the seismograph to the blast should be known to at least two significant digits. For example, a blast within 1000 feet would be nearest tens of feet and a blast within 10,000 feet would be measured to the nearest hundreds of feet. Where the vertical-to-horizontal ground slope ratio exceeds 2.5 to1, slant distances or true distance should be used and recorded in the monitoring records.
7. Processing Time: When instruments are used in auto-trigger and continuous-recording mode to record the effects of multiple blasts, the time between successive blasts shall be at least one (1) minute and seismographs shall be set to NOT automatically print out event records. These procedures should ensure that instruments have adequate time to save event data for each blast and reset to monitoring mode before subsequent blasts occur.

8. Memory Management: The instrument operator should know the memory or record capacity of the seismograph and ensure that adequate memory is available to store the event data from the blast(s) planned during that operating day.
9. Waveform Data: Instruments shall be set to save full waveform data for all monitored blast and digitally saved event files shall contain this data for use in further analyses if needed.
10. Instrument Setup Time: Equipment operators should allow ample time for proper setup of the seismograph, transducers and microphones. At least 15 minutes of time should be allotted for each setup location.
11. Securing cables: In order to prevent false triggering caused by wind-blown cables, the operator should secure suspended or freely moving cables from the wind or other extraneous sources.

Part II. Ground Vibration Monitoring

A. Sensor Placement

The sensor should be placed on or in the ground on the side of the structure towards the blast. A structure can be a house, pipeline, telephone pole, etc. Measurements on driveways, walkways, and slabs are to be avoided where possible.

1. Location relative to the structure: The sensor should be placed within 10 feet of the structure or less than 10% of the distance from the blast, whichever is less.
2. Soil density evaluation: The operator should avoid placing velocity transducers in loose or low-density soils. The density of the ground should be greater than or equal to the sensor density.
3. Sensor Level: Transducers should be placed so they are level or nearly level.
4. Sensor Orientation: Sensor blocks should be oriented so the arrow indicating the longitudinal direction is aimed at the blast location.
5. Monitoring when Access to Nearest Structure is not Accessible: Where access to a structure is not available, the transducers should be placed at the accessible location closest to the structure of concern and in line with the blast.

B. Sensor coupling

1. Sensor Coupling Methods: Based on expected acceleration determined from Chart 1, to avoid decoupling errors, the operator shall use the following methods to couple vibration transducers to the ground or structure.
 - a. Less than 0.2 g: No burial or attachment is necessary.

- b. Between 0.2 and 1.0 g: Transducer should be attached to the ground with a spike or covered with a sand bag.
- c. Greater than 1.0 g: Transducer should be buried, bonded to the ground or structure with stiff clay or putty, or some other method that should achieve firm attachment.

TABLE 1 – Acceleration intensity (g's) based on estimated particle velocities and frequencies

	Maximum Frequency (Hz or cycles-per-second)										
	4	10	15	20	25	30	40	50	100	150	200
PPV (in/s) at Acc. (g) ≥ 0.2	3.08	1.23	0.82	0.62	0.49	0.41	0.31	0.25	0.12	0.08	0.06
PPV (in/s) at Acc. (g) ≥ 1.0	15.38	6.15	4.10	3.08	2.46	2.05	1.54	1.23	0.62	0.41	0.31

- 2. Sensor Burial: When velocity transducers are buried the operator should employ the following methods.
 - a. Excavate a hole that is no less than three times the height of the sensor (ANSI S2.47-1990, R1997).
 - b. If possible, spike the sensor to the bottom of the hole.
 - c. Firmly compact soil around and over the sensor.
- 3. Attaching Sensors to bedrock or hard Structural Surfaces:
 - a. Bolt, clamp or use epoxy or putty to firmly couple the sensor to the hard surface.
 - b. The sensor may be attached to the foundation of the structure if it is located within +/- 1-foot of ground level (USBM RI 8969). This should only be used if burial, spiking or and bagging is not practical.
- 4. Other sensor placement methods: Use other methods as described below if disturbance of the ground is not possible.
 - a. Cover transducers with sand bags loosely filled with about 10 pounds of sand. When placed over the sensor the sandbag profile should be as low and wide as possible with a maximum amount of firm contact with the ground.
 - b. A combination of both spiking and sandbagging gives even greater assurance that good coupling is obtained.

C. Programming considerations

Site conditions dictate certain actions when programming the seismograph.

- 1. Ground motion trigger level: The PPV-trigger-level should be programmed low enough to trigger the unit from blast vibrations and high enough to minimize the occurrence of false events. The level should be slightly above the expected background vibrations for the area. A good starting level is 0.05 in/s.

2. Dynamic range and resolution: If PPV is expected to exceed 10 in/s or frequency is expected to exceed 250 Hz, special sensors approved by the Vibration Specialist should be used to measure blast effects. In these cases, the Vibration Specialist should also determine a digital sampling rate that should provide accurate recordings.
3. Recording duration: Set the record time for 2 seconds longer than the blast duration plus 1 second for each 1100 feet from the blast.

Part III Air-overpressure Monitoring

The following procedures should be used as possible when setting up instruments to measure blast-induced noise.

A. Microphone placement

The microphone should be placed along the side of the structure nearest the blast.

1. The microphone should be covered with a windscreen and mounted near the velocity transducers.
2. The preferred microphone height is 3 feet above the ground or within 1.2 inches of the ground. Other heights may be acceptable for practical reasons. (ANSI S12.18-1994, ANSI S12.9-1992/Part2) (USBM RI 8508)
3. If practical, the microphone should not be shielded from the blast by nearby buildings, vehicles or other large barriers. If such shielding cannot be avoided, the horizontal distance between the microphone and shielding object should be greater than the height of the shielding object above the microphone.
4. If placed too close to a structure, the airblast may reflect from the house surface and record higher amplitudes. Structure response noise may also be recorded. Placing the microphone near a corner of the structure can minimize reflection of over-pressure energy. (RI 8508)

B. Programming considerations

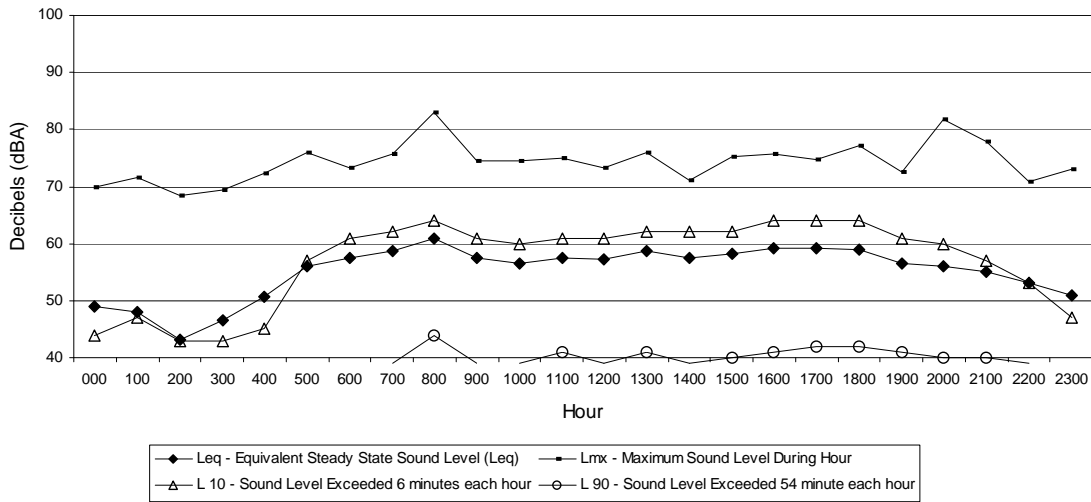
Site conditions dictate certain actions when programming the seismograph to record air-overpressure.

1. Trigger level: When only an airblast measurement is desired, the trigger level should be low enough to trigger the unit from the airblast and high enough to minimize the occurrence of false events. The level should be slightly above the expected background noise for the area. A good starting level is 120 dB.
2. Recording duration: When only recording airblast, set the recording time for at least 2 seconds more than the blast duration. When ground vibrations and air-overpressure measurements are desired on the same record, follow the guidelines for ground vibration programming (Part II C.3).

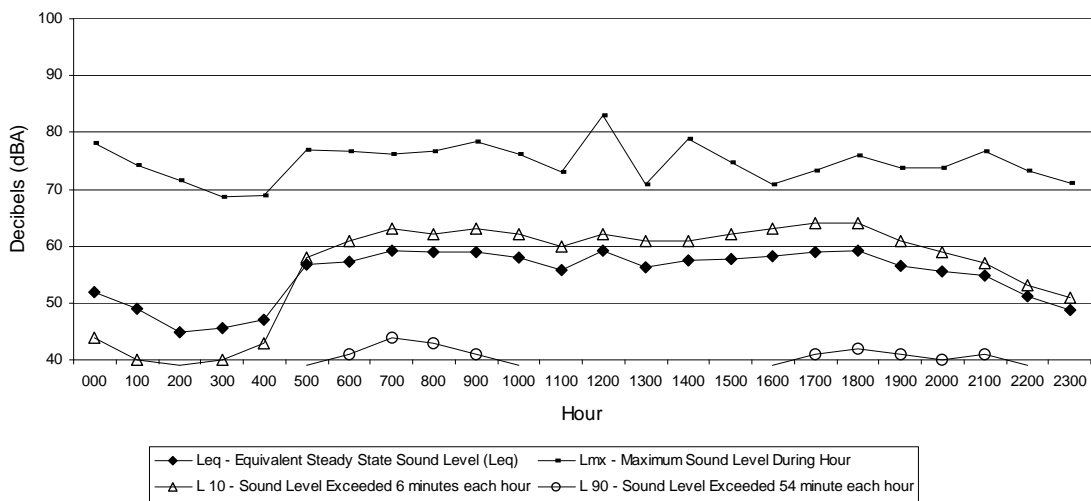
APPENDIX F-2

24-Hour Noise Measurement Data

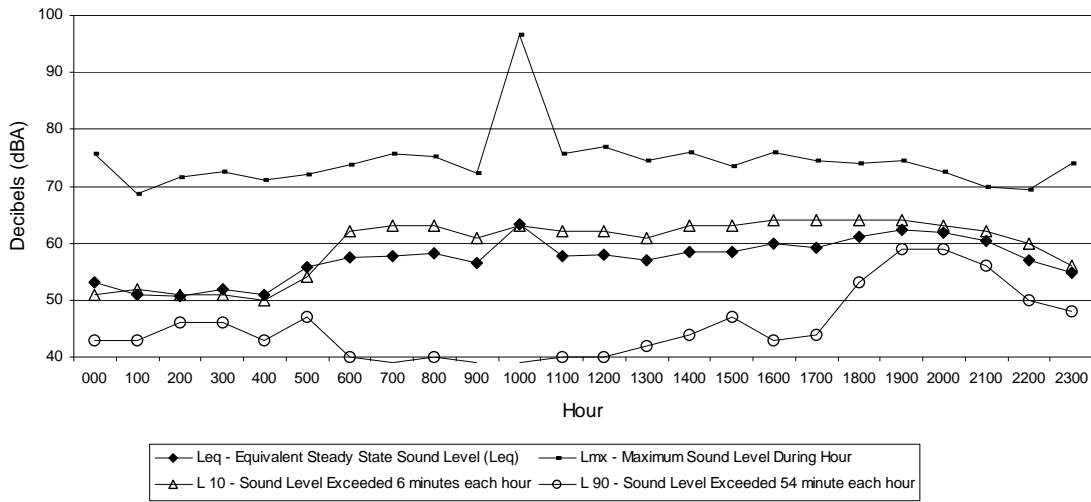
**FIGURE F-1
24-HOUR NOISE MEASUREMENT:
ROBLAR ROAD – DUNHAM SCHOOL (70 FEET FROM ROAD CENTER)
WEDNESDAY, JANUARY 11, 2006**



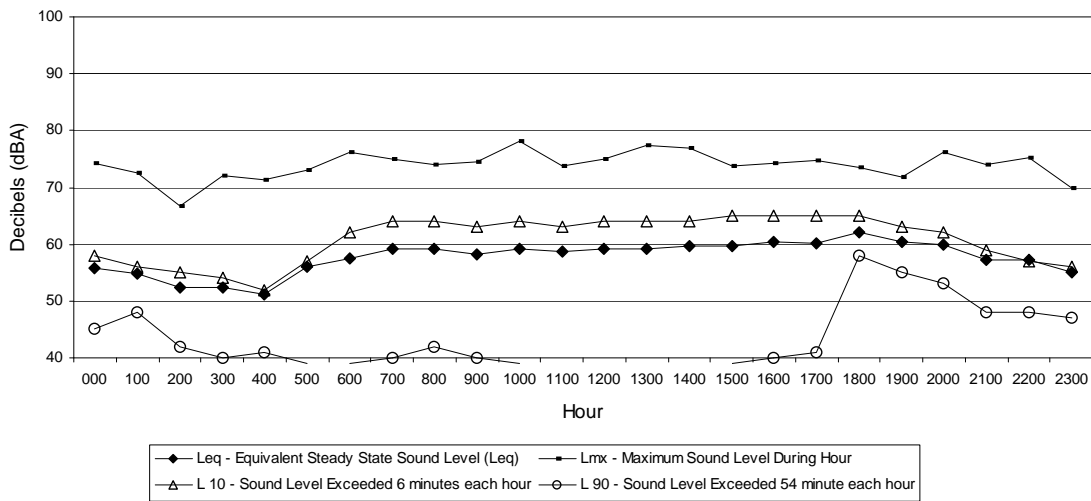
**FIGURE F-2
24-HOUR NOISE MEASUREMENT:
ROBLAR ROAD – DUNHAM SCHOOL (70 FEET FROM ROAD CENTER)
THURSDAY, JANUARY 12, 2006**



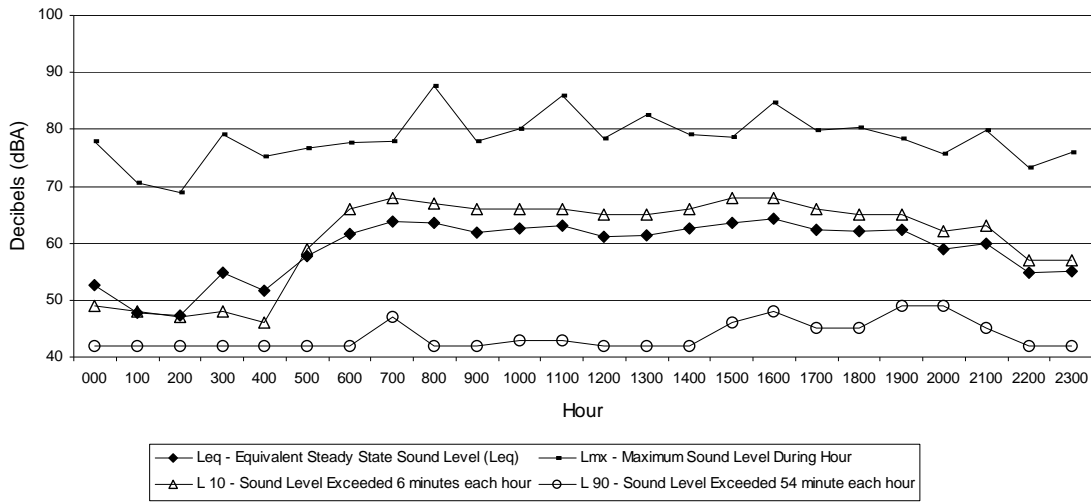
**FIGURE F-3
24-HOUR NOISE MEASUREMENT:
8425 VALLEY FORD ROAD (115 FEET FROM ROAD CENTER)
WEDNESDAY, JANUARY 11, 2006**



**FIGURE F-4
24-HOUR NOISE MEASUREMENT:
8425 VALLEY FORD ROAD (115 FEET FROM ROAD CENTER)
THURSDAY, JANUARY 12, 2006**



**FIGURE F-5
24-HOUR NOISE MEASUREMENT:
1798 PEPPER ROAD (85 FEET FROM ROAD CENTER)
WEDNESDAY, JANUARY 11, 2006**



**FIGURE F-6
24-HOUR NOISE MEASUREMENT:
1798 PEPPER ROAD (85 FEET FROM ROAD CENTER)
THURSDAY, JANUARY 12, 2006**

