ANNEX 30
ACOUSTIC IMPACT STUDY

1. INTRODUCTION

The following document describes the analysis of acoustic emission estimate generated during construction of the Alto Maipo Hydro Power Project.

Construction activities associated with Alto Maipo Hydro Power Project involve generation of noise due to the operation of heavy machinery, traffic flow, and blasting, which potentially constitutes a noise impact on sensitive receptors located within the area of influence of the project.

In order to estimate future expected sound pressure levels in sensitive sectors, a noise modeling of construction sites covered by the project was made using specialized software, whose results will be delivered by noise maps and subsequently compared with criteria both national and international. Finally, mitigation measures will be suggested in those areas so required.

2. OBJECTIVES

- Identify the areas where there are sensitive receptors within the zone of influence due to future noise emissions during construction of the project.
- Carry out measurements of Sound Pressure Level at these points to determine the existing noise environment prior to project implementation (Baseline).
- Get a sound propagation model, from acoustic emission data of noise sources involved in the project and mapping of the area of interest.
- Evaluate the modeled results for stationary and mobile sources with the maximum levels allowed by the standard DS N º 146/97 of MINSEGPRES (Ministry General Secretariat of the Presidency) and the FHWA criteria.
- In case of default, mitigation measures will be proposed at the conceptual level to reverse this situation.

3. MODELING METHODOLOGY

- **Stationary Sources**

- Stationary sources of noise considered in the model are grouped into two types of stationary emission source; working faces and temporary facilities.

  Working faces correspond to in situ facilities where all construction works are carried out, both surface and underground works. In the latter case working faces will be located at the sluice gates exit of each tunnel window.

  The main noise generating activities in working faces correspond to movements of vehicles and machinery, concrete plant and generator operations, earthmoving works, loading and unloading of material and construction works in general. In addition, in the case of working faces, there will be an internal flow of machinery and trucks between working faces and muck disposal sites, for the construction of tunnels.

  Temporary facilities will function as the base of operations of the working faces, where premises for warehouse, parking, comfort of the staff and general administration will be implemented. In this case, the main noise generating activities will be: the internal movement of trucks, generator operation and activities of the workers in the fuel and machinery storage areas, offices, gatehouses, restrooms, cafeterias, etc.

  Considering the above, for each working face and temporary facility, the worst case emission scenario has been included, i.e. the simultaneous operation of the above activities. In this regard, Table 1 shows the power levels of those activities that involve the greater generation of noise emission.

- All sound powers entered in the model correspond to measurements of equipment measured by Control Acústico Ltda and are fully compatible with noise emissions proposed by the British Standard BS 5228: part 1/1984.

- To analyze this impact a modeling was applied based on ISO 9613, parts 1 and 2, which uses the principles of divergence attenuation, with extra attenuation introduced by obstacles and air attenuation.

- The software used corresponds to SoundPLAN ver.6.3.

- Meteorological parameters were set at 10 º C and relative humidity of 80%, constituting an unfavorable scenario for the low attenuation for weather effects. The standard used also considers wind between 3 and 4 (m / s) in favor of propagation. With this combination of values of temperature, humidity and wind, most beneficial results are obtained in the propagation of sound waves because they have the lowest values of sound absorption. This is supported by the provisions of ISO 9613:1993 Acoustics - Attenuation of Sound During Propagation Outdoors and other international standards.

- The expected noise impact is evaluated according to the contrast of the projected noise levels with the limits or considerations established by DS N º 146/97 of MINSEGPRES.

- The activities within the construction phase of the tunnel and hydro power project facilities are:
    - Blasting in access Windows to the tunnel;
    - Truck traffic between working faces and muck disposal sites;
    - Truck and bus traffic between working faces, camps, temporary facilities, and Puente Alto;
    - Heavy equipment (backhoe) for construction of surface works;
    - Loading and unloading of material with truck hoppers in muck disposal sites;
    - Working faces in Windows and water intakes, with 1 concrete plant and 1 soundproof generator.

  The muck disposal transport by conveyor belts and rail cars do not generate significant noise emissions.

- Sound power levels for each source of noise during the construction phase are:

Table 1
Sound power levels of stationary sources for the model. Values are in dB (A) in octave bands

Noise source	Central frequency [Hz]								Total
	63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	
Backhoe	74	82	91	94	99	99	97	92	104
Internal traffic of trucks	38	51	53	58	62	62	57	51	66
Blasting	91	94	97	99	97	91	84	82	104
Loading and unloading of truck	82	90	99	102	107	107	105	100	112
Generator	69	79	86	92	95	96	96	94	102
Concrete plant	87	97	104	110	113	114	114	112	120

- **Mobile Sources**

For flow of trucks and buses on public roads, the emission calculation is based on the methodology recommended by the European Union according to the Guide du bruit de France (see Appendix 1). An average speed of travel for trucks and buses equal to 40 km / h was considered, taking into account windings and road conditions. The calculation of emission of heavy vehicle flow considers only traveling speed and vehicle type (associated power level) and not the flow condition.

The results of the projected noise levels due to flow of heavy vehicles are delivered to receptors located on the side of the road, i.e. about 6 m to the axis of the road, being the most critical case in terms of immission.

For considering a moving truck, it is assumed that the power is distributed according to the route. This calculation is considered similar to a source moving at a speed of, for example, 40 km / h, and running 40,000 m in 1 hour. For this, energy emitted from Lw = 110 dB (A) in 40,000 m for each vehicle must be distributed. The estimate of 110 dB (A) of static sound power Lw was performed by own measurements of trucks and buses in construction sites[1].

Thus, calculation of noise emission by linear meter Lw /meter of flow is obtained for a truck / bus in a period of 1 hour considering flows of Table 2 (total input and personnel flow for a peak month). The following calculations illustrate noise emission.

Puente Alto – Las Lajas Area (it includes flow Las Lajas + Aucayes + Alfalfal): 196 vehicles / month, equivalent to 0.7 trucks / hour (1 truck / hour) over a period of 9 working hours.

Lw/m **=** 110 – 10 Log (length) + 10 Log (Nº of trucks, daytime hours)
= 110 – 10 Log (40,000) + 10 Log (0,7)
= 110 – 46 – 1,5
= 63 dB(A)

Las Lajas Area – Aucayes Area (it includes flow Aucayes + Alfalfal): 123 vehicles/month, equivalent to 0.5 trucks/hour (1 truck/ hour) over a period of 9 working hours.

Lw/m **=** 110 – 10 Log (length) + 10 Log (Nº of trucks, daytime hours)
= 110 – 10 Log (40,000) + 10 Log (0,5)
= 110 – 46 – 3
= 61 dB(A)

[1] Source: Measurements made by Control Acústico Ltda comparable to values included in "Update of Noise database for prediction of noise on construction and open sites (contained in Annex C, Part 1 of BS5228). Department For Environment, Food and Rural Affairs (DEFRA), 2004", part of the British Standard, BS 5228: 1984, "Noise and vibration control on construction and open sites").

Aucayes Area – Alfalfa Area: 21 vehicles/month, equivalent to 0.08 trucks/hour (1truck/tour) over a period of 9 working hours.

Lw/m **=** 110 – 10 Log (length) + 10 Log (Nº of trucks, daytime hours)
= 110 – 10 Log (40,000) + 10 Log (0,08)
= 110 – 46 – 11
= 53 dB(A)

Puente Alto – El Yeso Area (it includes flow El Yeso + El Volcán): 73 vehicles/month, equivalent to 0.3 trucks/hour (1 truck/hour) over a period of 9 working hours.

Lw/m **=** 110 – 10 Log (length) + 10 Log (Nº of trucks, daytime hours)
= 110 – 10 Log (40,000) + 10 Log (0,3)
= 110 – 46 – 5,7
= 58 dB(A)

El Yeso Area – El Volcán Area: 35 vehicles/month equivalent to 0.13 trucks/hour (1 truck/hour) over a period of 9 working hours.

Lw/m **=** 110 – 10 Log (length) + 10 Log (Nº of trucks, daytime hours)
= 110 – 10 Log (40,000) + 10 Log (0,13)
= 110 – 46 – 8,9
= 55 dB(A)

The noise emission calculations exemplified above are identical to the result calculated by GdR or modified French method, and recommended by the EEC.

For example, the calculation for the area: Puente Alto - Las Lajas is:

Lw/m = 110 – 10 Log (length) + 10 Log (Nº of trucks, daytime hours)
= 110 – 10 Log (40,000) + 10 Log (0.7)
= 110 – 46.02 – 1.54
= *62,4dB(A)*

Lw is the sound power of a truck to a respective speed Lw = 110dBA (adjusted to Chile) as the French standard GdB uses a factor of Lw of 109.9dBA.
The value is an average of NPSmax values measured at 7.5 m from the axis of the road, which is NPSmax = 84.5 dBA (this value is measured in octave bands and the total value in dBA is shown).
This calculation is made according to the GdB emission.

The noise emission is defined as follows:

$$E = (L_w - 10 \log V - 50)$$

Where V is the speed of the vehicle in km/h

$$E = (110dBA - 10 \log 40 - 50) = 110 – 16 – 50 = 44$$

Values are in octave bands, and only the total value in dBA is shown.

$$Law /m = 10Log (10^{(Eiv + 10 Log Qiv)/10} + 10^{(Ehv + 10 Log Qhv)/10)} + 20$$

- Eiv is the sound emission of light vehicles Adapted to Chile; 31 dBA
- Ehv is the sound emission of heavy vehicles Adapted to Chile; 44 dBA
- Qiv is the light traffic volume during the reference interval; 0 veh/h
- Qhv is the volume of heavy vehicles during the reference interval, 0,7veh/h
- Ψ is the correction performed to take into account sound level produced by the pavement, 0 dBA
- l, is the length of the tranche of line sources represented by a point source l in meters, = 1 meter (it has no influence on the calculation since it is always a linear meter
- R(j) is the spectral value, in dB(A), by octave band j,

Sum of all bands (Law /m)

$$Lw/m = 10Log (10^{0\ (31v + 10 Log0)/10} + 10^{(44 + 10 Log 0.7)/10)} + 20$$
$$= 10\log (0 + 17.378) + 20 = 42.4 + 20 = 62,4 \text{ dBA}$$

Moreover, the detail of estimated traffic flow and its distribution in each of the areas is described in the Supplementary Road Impact Study, attached in Annex 14 of this EIA.

The linear power level for each area is shown below:

Table 2

Calculation of linear power level, in dB (A), from projected vehicle flow for each area

Area / Tranche	Projected Flow (vehicle/hour)	Lw/m dB(A)
El Volcán	15	64
El Yeso	15	64
Colorado Siphon	15	64
Las Lajas Tunnel	36	68
Maipú River Discharge	20	66
Alfalfal Access	30	67
Main road (road G-25)	3	57
Road G-455 (Alto-El Yeso Bridge)	7	58
Road G-25 (San Gabriel - El Volcán Area)	0.13	55
Road G-25 (Alto-Las Lajas Bridge)	0.7	63
Road G-345 (Las Lajas-Maitenes)	0.5	61
Road G-345 (Maitenes-Alfalfal)	0.08	53

With these values of linear noise emission level, a profile of propagation at various distances is obtained from the following formula:

$$Leq = Lw - 10 \text{ Log } (d) - 5$$

Where:

Leq is the equivalent level in the receptor, in dB (A)
Lw is the linear power level, in dB (A)
d is the distance from the axis of the road used to the identified receptor.

4. RESULTS

- Stationary Sources

The areas considered in the modeling of stationary sources associated with the construction of the project are listed in the following table:

Table 3
Activities associated with the construction phase of the project in the different areas considered

Work or Activity	Area					
	El Volcán	El Yeso	Las Lajas Tunnel	Alfalfal	Colorado River (siphon and windows)	Maipo River discharge
Excavations for construction of tunnels	X	X	X		X	X
Construction of water intakes and minor works	X	X		X		
Construction of flumes	X	X		X	X	
Construction of siphon		X		X	X	
Construction of bridges	X	X		X	X	

Noise maps are given below, where it is possible to determine the exclusive contributions of noise sources in receptors associated to points measured during the Baseline, near the sources of noise, which is the worst case scenario as to immission. It is worth mentioning that El Volcán area does not have nearby receptors that are affected by the project works (the nearest receptor is located to about 3 km). However, the area of works was modeled, discarding the breach of the rules, in consideration of the distance over which the receiver is located.

Construction Scenario

Figure 1
Noise Map of Alto Río Volcán. Construction Scenario

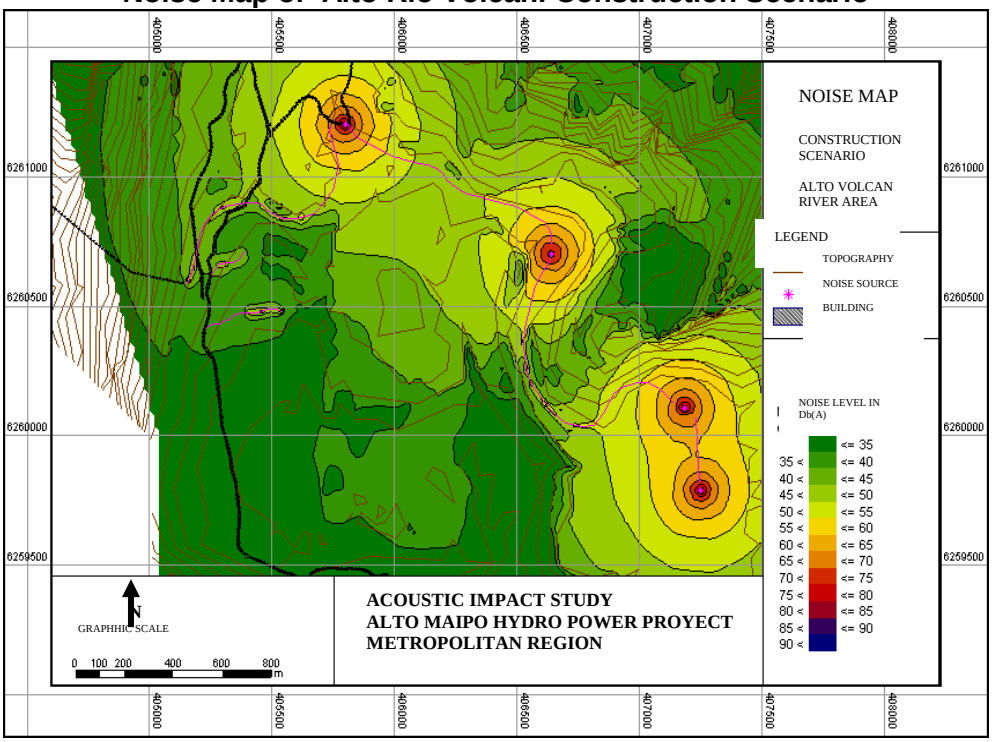


Figure 2
Noise Map of Alfalfal area. Construction Scenario

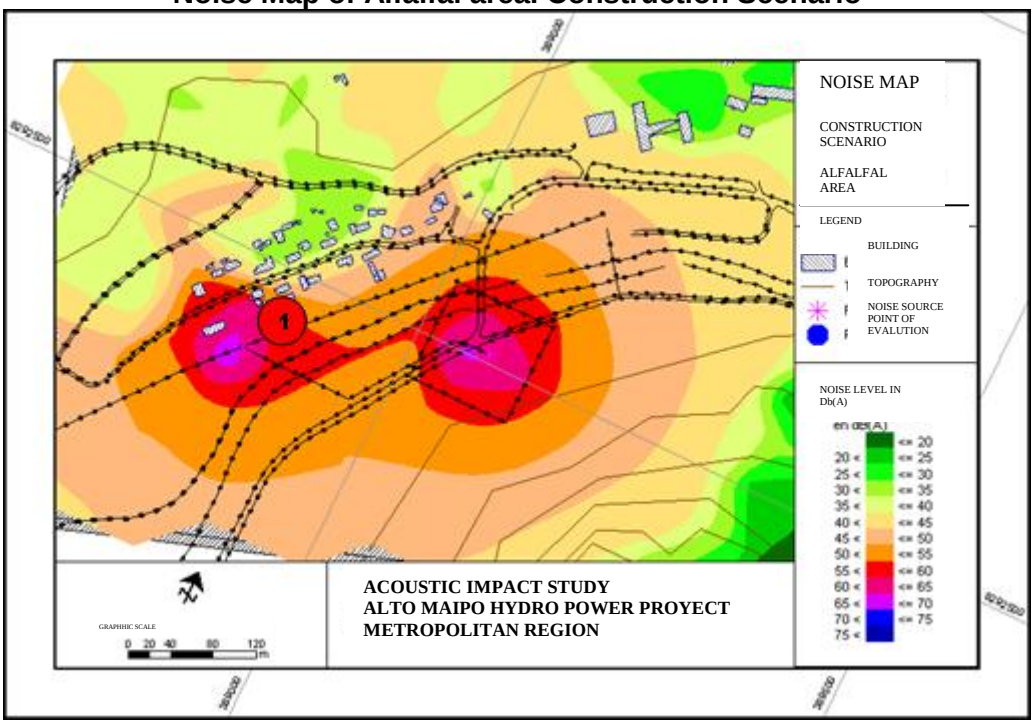


Figure 3
Noise Map Torrejón area. Construction Scenario

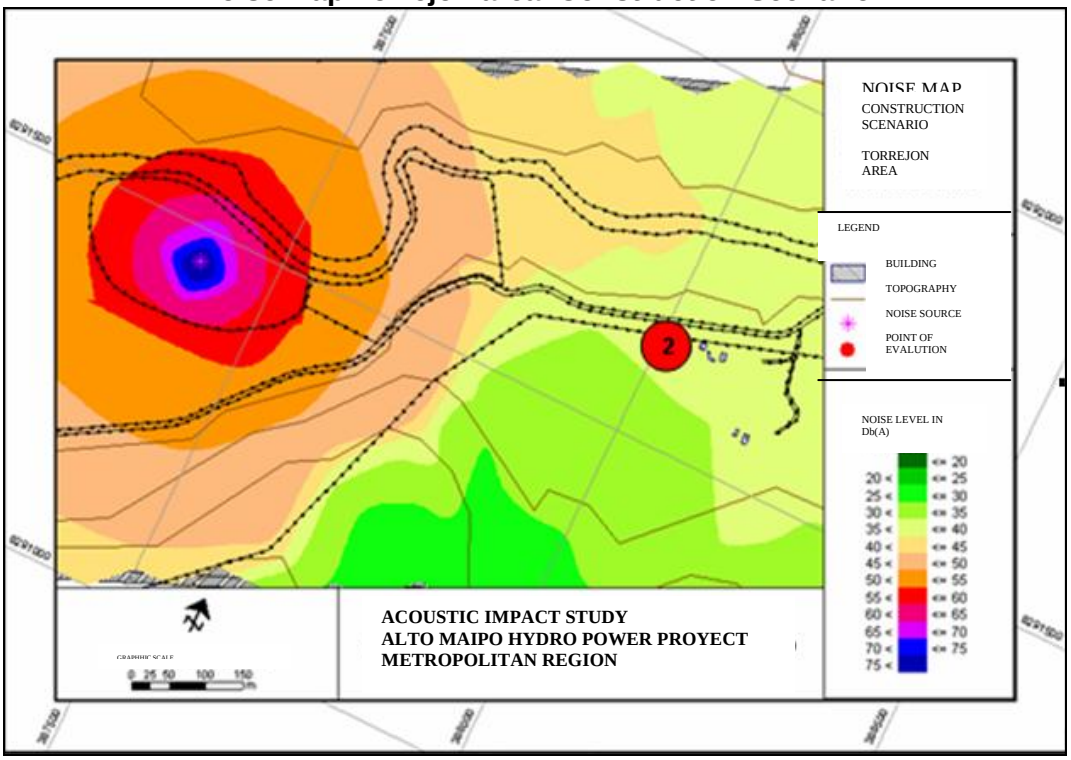


Figure 4
Noise Map Los Trescientos area. Construction Scenario

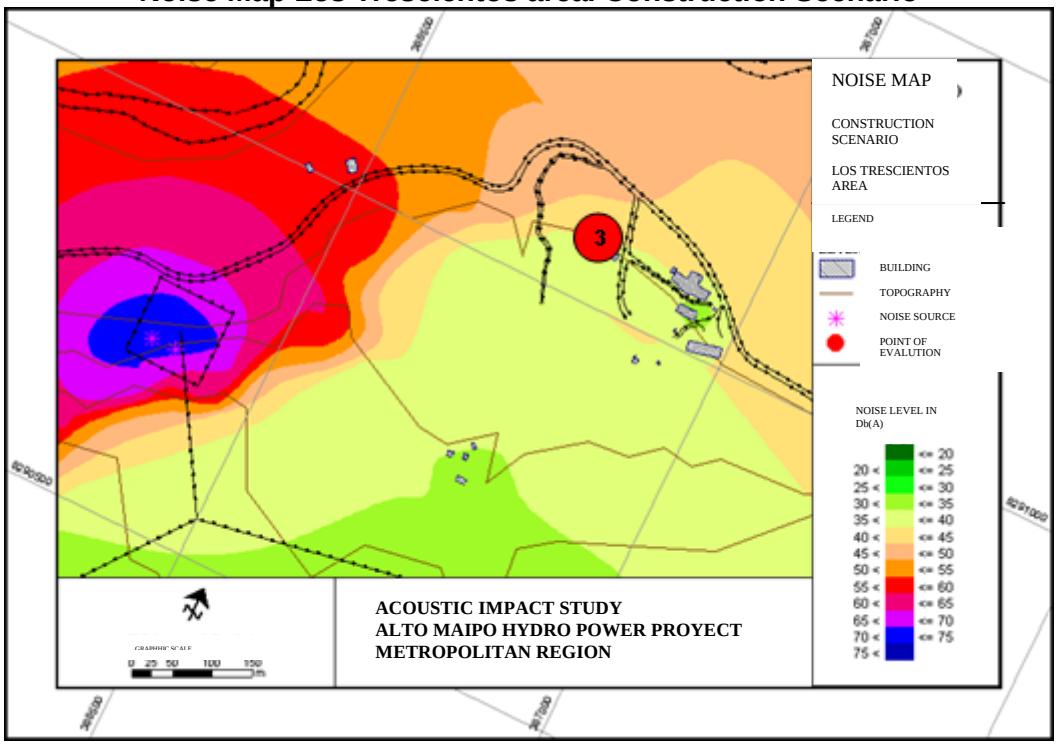


Figure 5
Noise Map Maitenes area. Construction Scenario

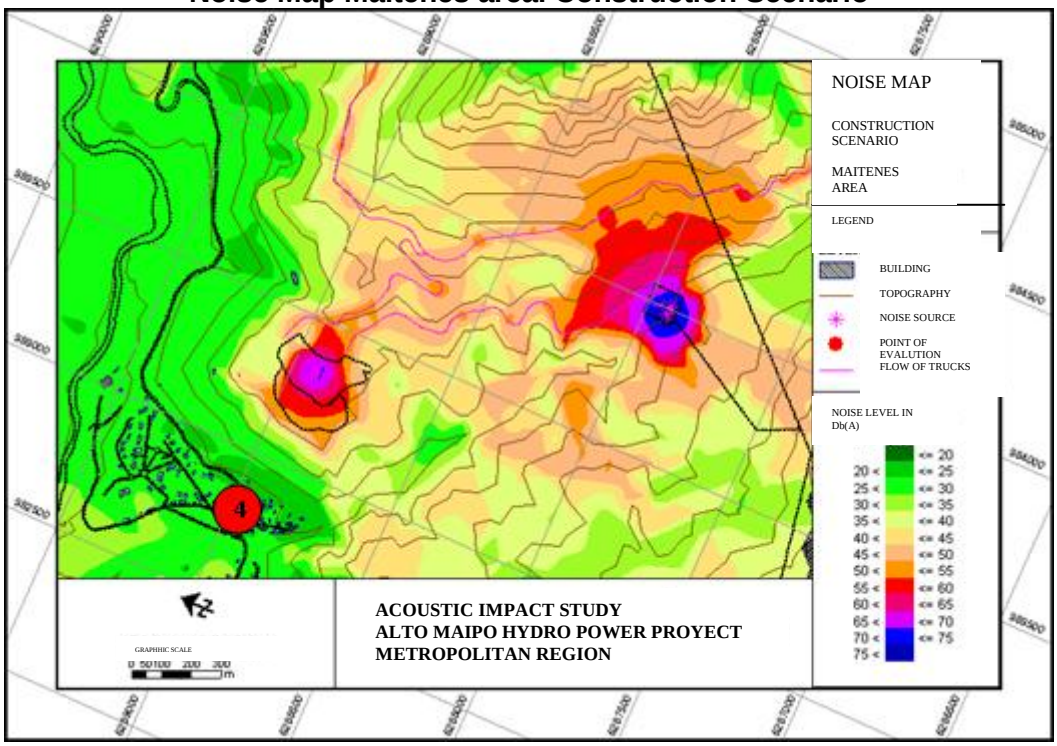


Figure 6
Noise Map of Las Lajas (El Sauce) area. Construction Scenario

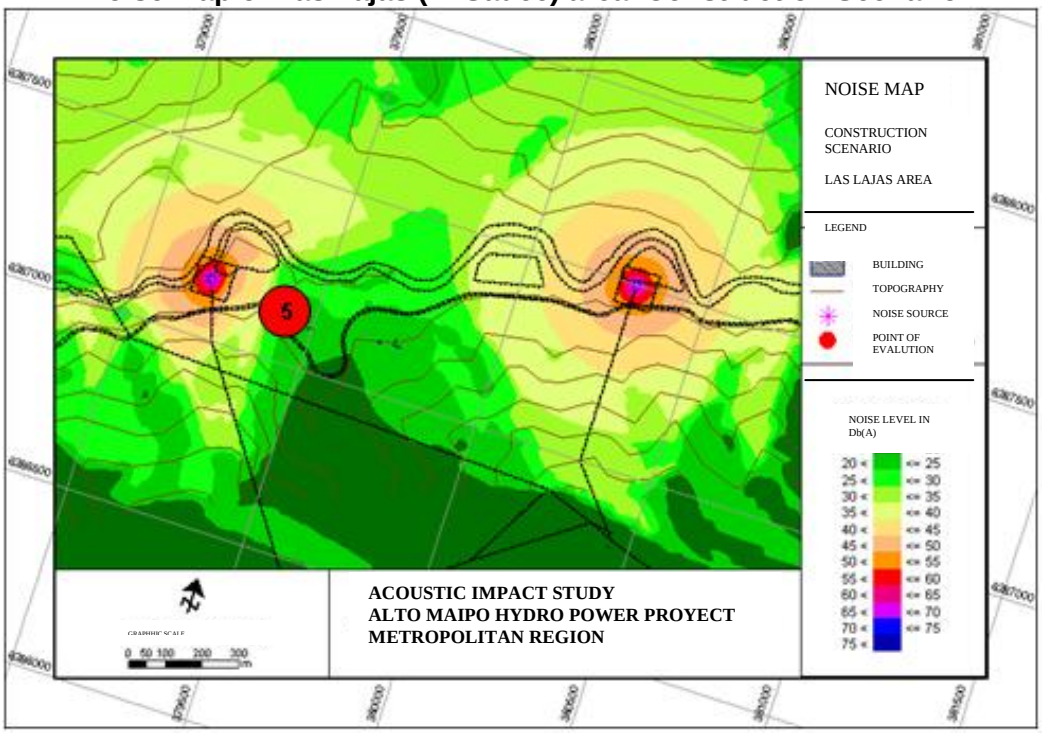


Figure 7
Noise Map of El Yeso Siphon. Construction Scenario

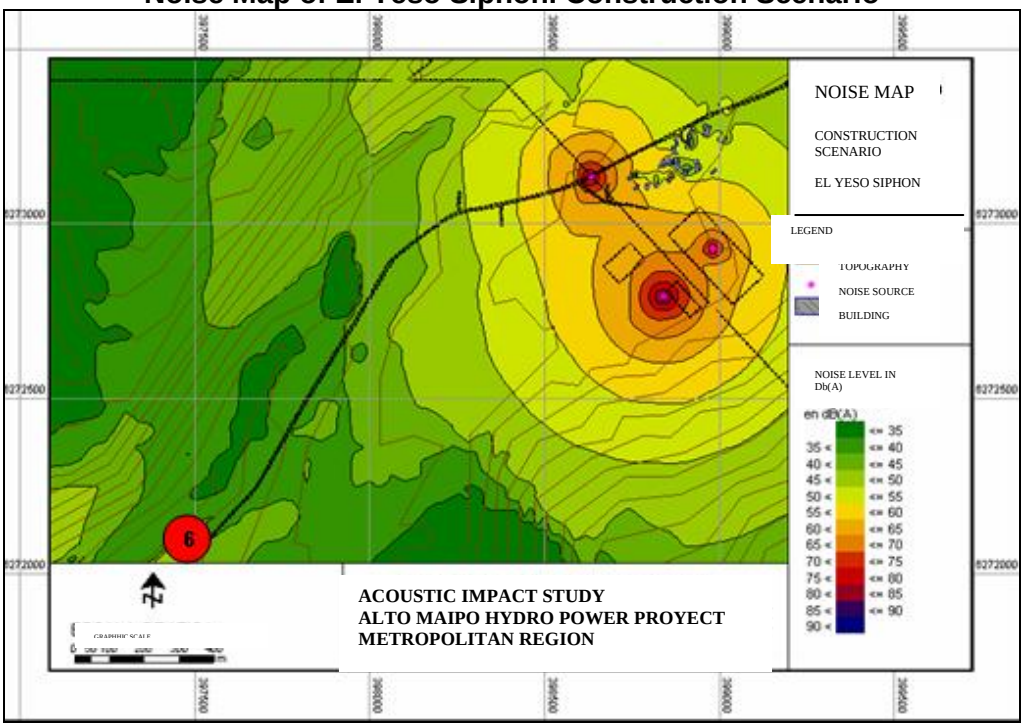


Figure 8
Noise Map of Alfalfal Flume Area. Construction Scenario

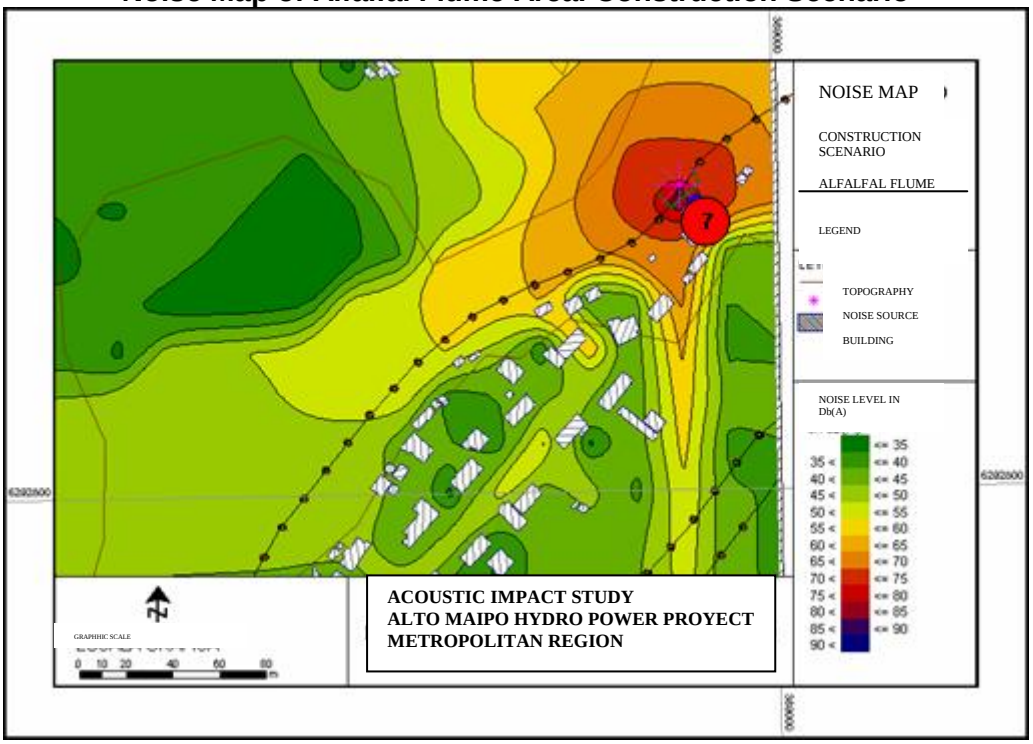
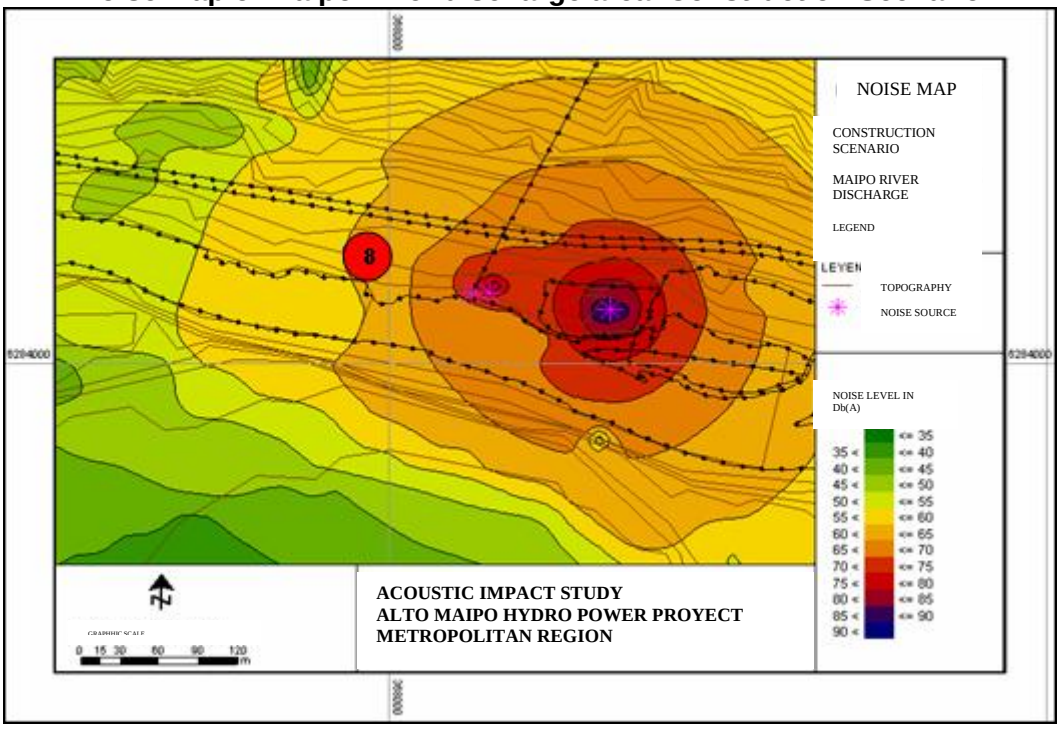


Figure 9
Noise Map of Maipo River discharge area. Construction Scenario



Blasting Scenario

Figure 10
Noise Map of Alto Río Volcán area. Blasting Scenario

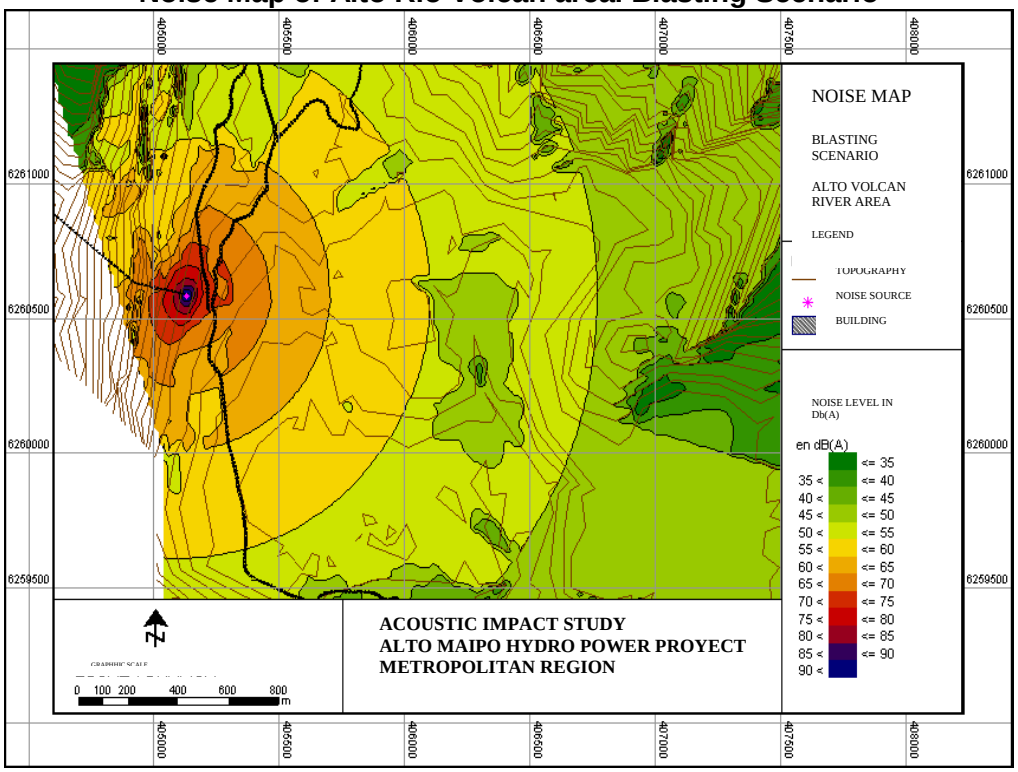


Figure 11
Noise Map of Torrejón area. Blasting Scenario

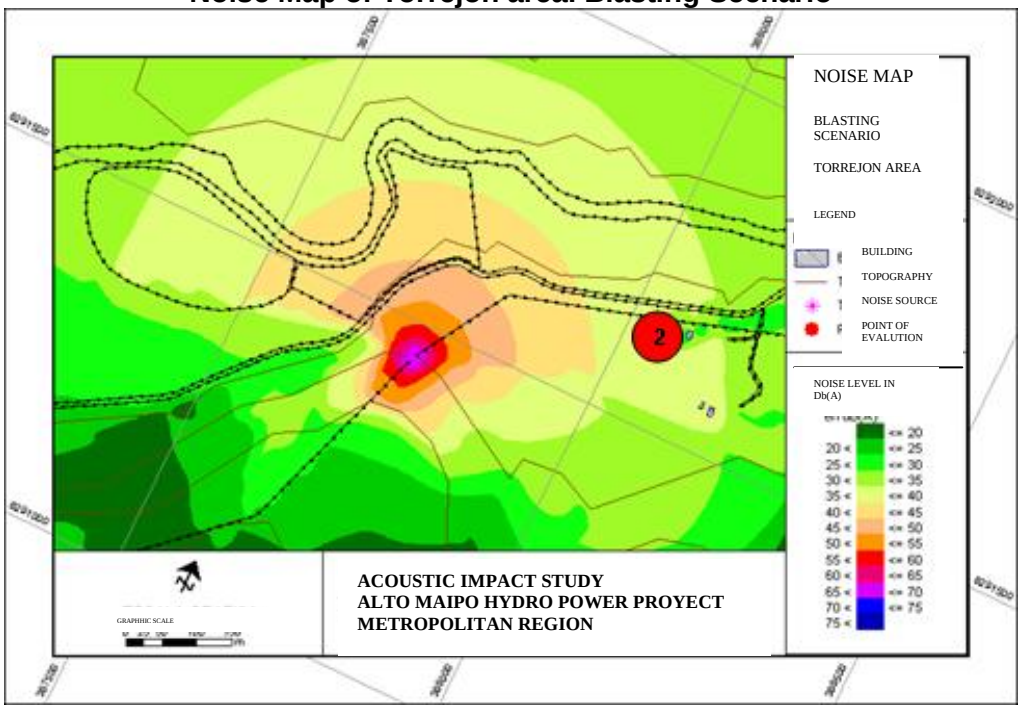


Figure 12
Noise Map of Los Trescientos area. Blasting Scenario

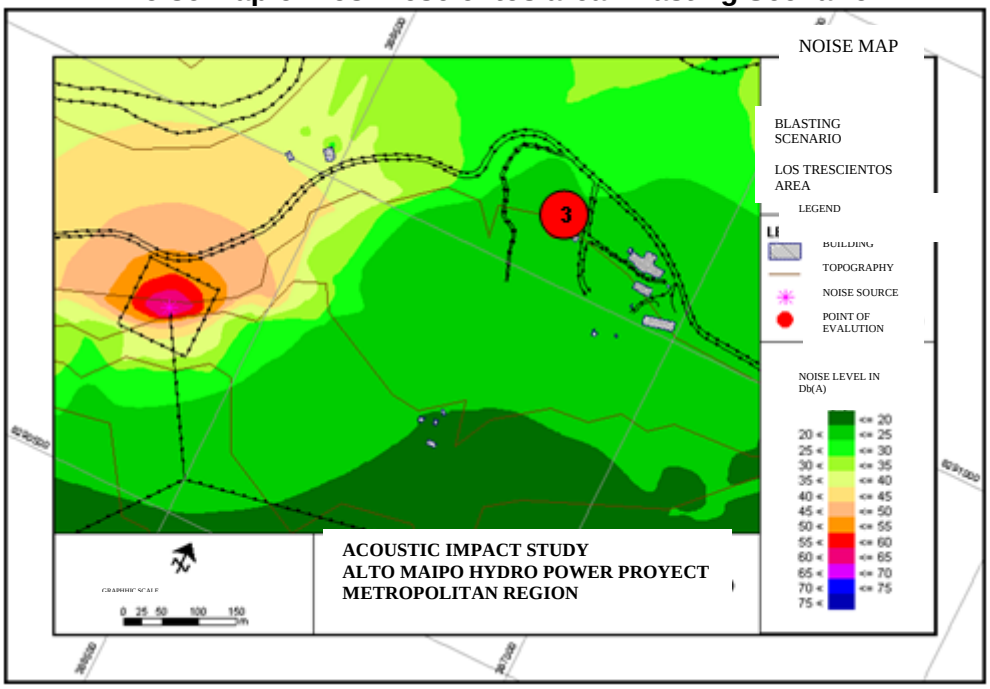


Figure 13
Noise Map of Maitenes area. Blasting Scenario

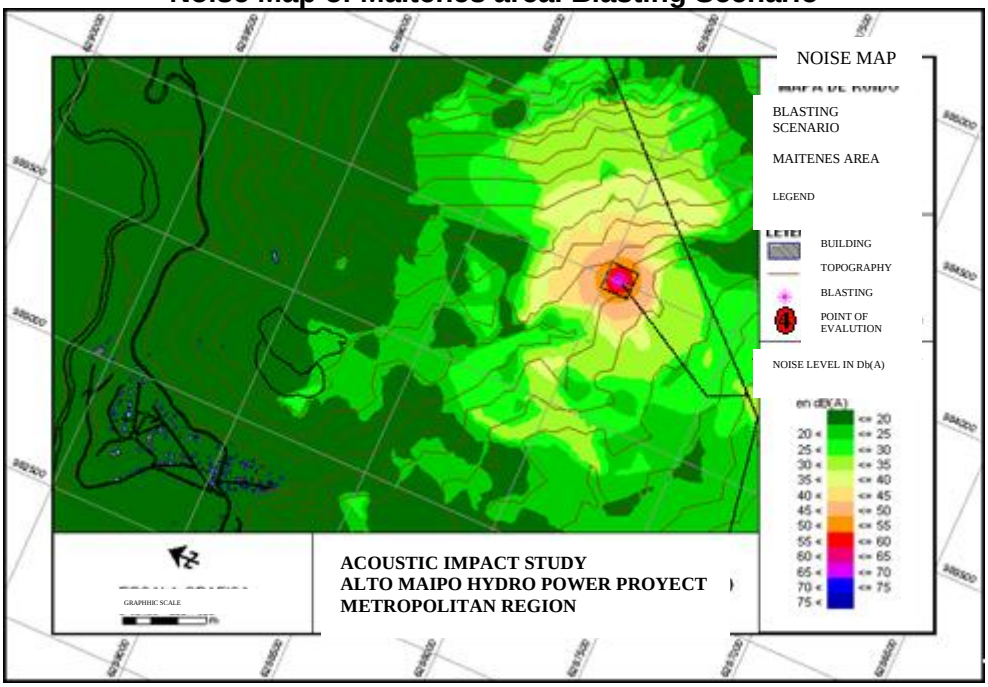


Figure 14
Noise Map of Las Lajas (El Sauce) area. Blasting Scenario

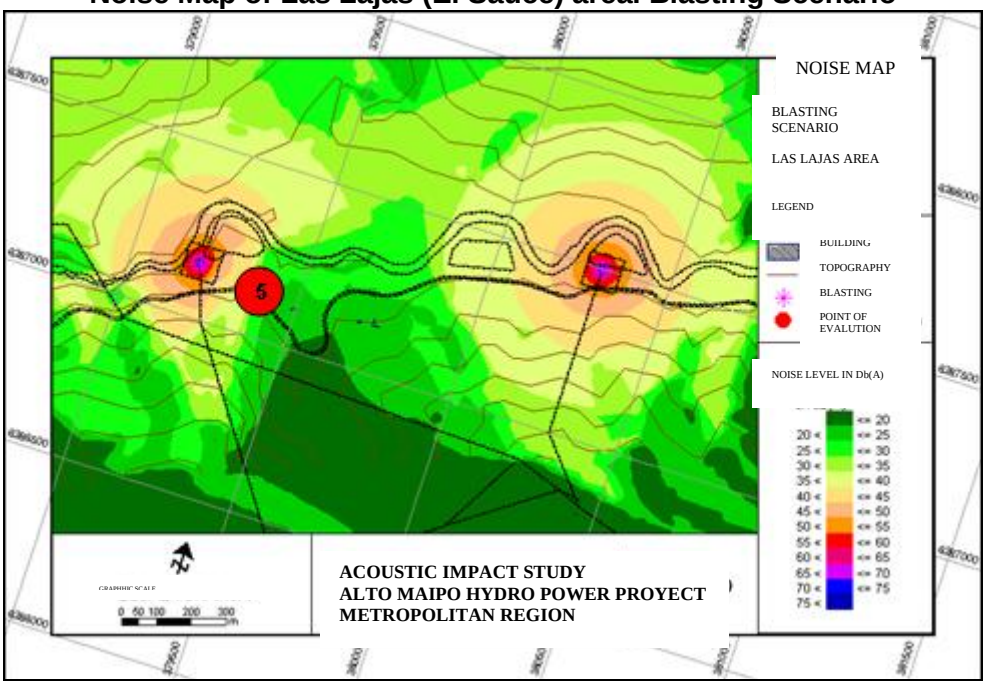


Figure 15
Noise Map of El Yeso Siphon area. Blasting Scenario

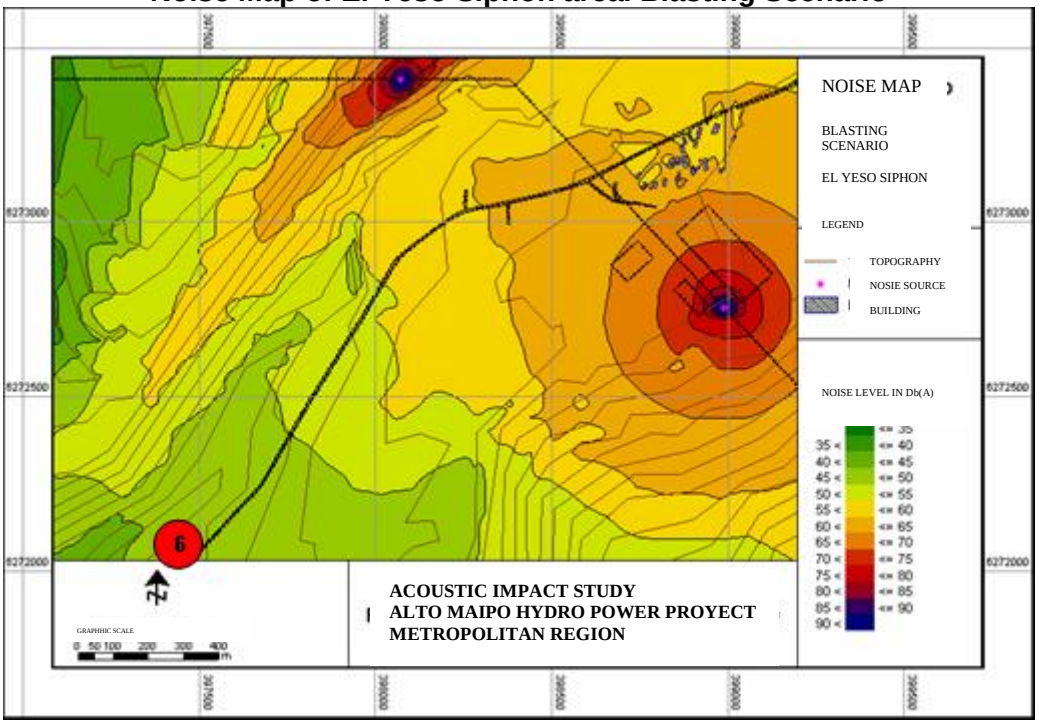
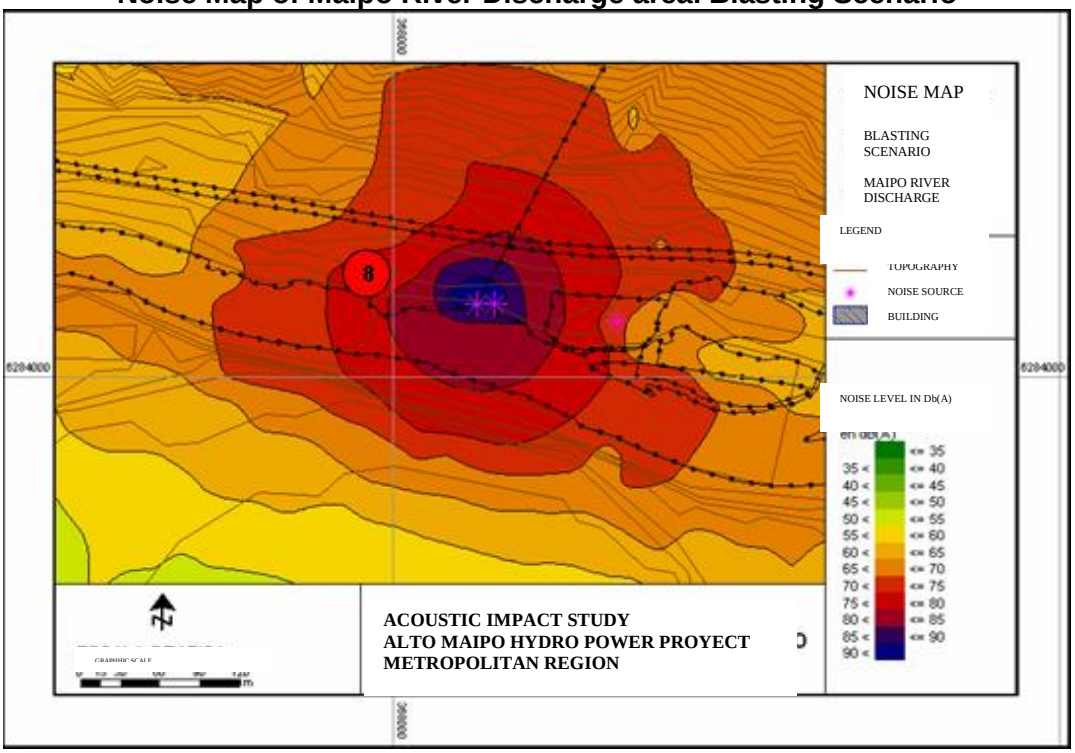


Figure 16
Noise Map of Maipo River Discharge area. Blasting Scenario



The following table relates measurement points presented in the Baseline (see Chapter 5) with contribution projected during works included in the construction phase, distinguishing on the contribution from blasting (considering NPSeq of 9 minutes to unexpected noise).

Table 4
Contribution of sound pressure level in each sector, from the noise maps obtained

Point	Work Areas	Models noise levels dB(A)	
		NPSmax Blasting	NPSeq Construction
1	Forebay Alfalfal area	—	61
2	Connection pipe-tunnel El Torrejón area	37.6	35
3	Window El Trescientos area	18.0	36
4	Aucayes (Maitenes)	7.4	20
5	Las Lajas (El Sauce area)	30.4	48
6	El Yeso	47	45
7	Flume Alfalfal area	—	75
8	Maipo River discharge	76	61

- **Mobile Sources**

Taking into account the projected traffic flow on receptors located in the vicinity of public roads that will be used by PHAM, the following table shows the expected noise on receptors near routes, considering the facade of the house to 6 m of road axis of the route, being the most critical case.

Table 5
Projected values of noise due to vehicular traffic for receptors near route (6 m to road axis)

Tranche	Projected Flow Trucks/hour	NPSeq hour dB(A)
El Volcán	15	52
El Yeso	15	52
Colorado Siphon	15	52
Las Lajas Tunnel	36	55
Maipo River Discharge	20	53
Alfalfal Access	30	55
Main road (road G-25)	3	45
Puente Alto - El Yeso	0.3	45
El Yeso - El Volcán	0.13	42
Puente Alto - Las Lajas	0.7	50
Las Lajas - Maitenes	0.5	48
Maitenes - Alfalfal	0.08	40

5. EVALUATION OF RESULTS

- **Stationary Sources**

The area where the project is located, and its immediate environment (area of influence), corresponds to a type of *Rural Area*[1]. For such areas, the Supreme Decree N º 146/97 MINSEGPRES, Title III provides in Article 5 that:

"In rural areas, the corrected sound pressure levels that are obtained from the emission of a stationary source emitting noise, measured at the place where the receptor is located, shall not exceed the background noise by 10 dB (A) or more. "

In Annex 13 of this EIA the land use certificate is attached, according to Metropolitan Master Plan (PRMS) , in the areas or receptor sites to noise levels according zonings set out in DS 146/97 MINSEGPRES "Standard of Annoying Noises Generated by Stationary Sources ", issued on 03/19/2008 by the Municipality of San José de Maipo.

[1] In accordance with what was talked with personnel of Municipality of San José de Maipo, the only territorial planning instrument in force in the municipality is the Santiago Metropolitan Master Plan PRMS. In this sense, and for purposes of defining the zoning established in DS 146/97 MINSEGPRES "Standard of Annoying Noises Generated by Stationary Sources," consistent with the uses defined by this planning tool, the areas where the project is developed are rural areas.

From the information provided in the Certificate No. 37/2008 of the Director of Municipal Works of San Jose de Maipo, follows the approval of land use that determines the PRMS for 8 noise receptor points, identified as sensitive for the project, according to the zoning established by Supreme Decree No. 146/97 of MINSEGPRES

Table 6
Approval of noise receptor points of the Project and zoning of DS 146/97 and PRMS

Receptor points of the Project	Santiago Metropolitan Master Plan	Approvals DS 146/97
1	1-A	Rural Area
2	2-2	Rural Area
3	3-A	Rural Area
4	4-A	Rural Area
5	5-A	Rural Area
6	2-B	Rural Area
7	7-B	Rural Area
8	9-B	Rural Area

Based on the provisions above, maximum permitted levels are delivered, determined from the present situation of the sound environment. For the case of point 8, the minimum measured level was used because it represents the worst case scenario, that is, without the influence of traffic.

The evaluation of the results of the modeling was performed by comparing the maximum allowed and total levels at each point, the latter are the result of the energy sum between project's exclusive contribution and Background Noise.

The exclusive contributions for each stage correspond to NPSeq obtained according to measurement periods set forth in the standard, in this way, for the construction phase NPSeq modeled values are used, based on a time window of 15 minutes (fluctuating noise), while in the blasting scenario the NPSeq based on a time window of 9 minutes (impulsive noise) from the maximum value modeled is used.

During the construction phase of the project works, two work modalities will be used; the first referring to the surface works, such as flumes, forebay, water intakes, bridges, etc., that will be performed at daytime, and the second corresponds to the construction of tunnels and their activities in the working faces, which will run continuously for 24-hour rotating shifts. In this sense, the internal construction of the tunnels and associated works will be imperceptible from the surface, while the activities in these faces during night time will be limited to the discharge of material from inside.

In the case of the Colorado River sector works and because night work will take place in temporary facilities nearby towns, the level of noise emissions was determined considering a day and night scenario. Below are the results of such evaluation.

Table 7
Assessment of levels modeled for construction phase (day period), according to Supreme Decree No. 146/97. Values are in dB (A)

Point	Modeled Level dB(A)	Background Noise dB(A)	Maximum Level Allowed dB(A)	Assessment
1	61	54	64	*Complies*
2	35	53	63	*Complies*
3	36	47	57	*Complies*
4	20	49	59	*Complies*
5	48	51	61	*Complies*
6	51	44	54	*Complies*
7	75	52	62	*Exceeds in 13 dB(A)*
8	66	72	82	*Complies*

Table 8
Assessment of levels modeled for construction phase (night period), according to Supreme Decree DS N° 146/97. Values are in dB(A)

Point	Modeled Level dB(A)	Background Noise dB(A)	Maximum Level Allowed dB(A)	Assessment
1	61	55	65	*Complies*
2	35	49	59	*Complies*
3	36	39	49	*Complies*
4	20	40	50	*Complies*
5	48	51	61	*Complies*
7	75	53	63	*Exceeds in 12 dB(A)*

From the results of the assessment of the levels modeled for construction scenario, noise impact is expected in point 7 (housing in Alfalfal area), due to its proximity to the temporary facilities and that these levels will exceed Background Noise by 13 dB (A) for daytime and 12 dB (A) for the night period, according to the maximum allowed by Supreme Decree No. 146/97 of MINSEGPRES. To mitigate these values, mitigation measures will be recommended in section of that name.

Table 9
Assessment of levels modeled for blasting event (day period), according to Supreme Decree DS N° 146/97. Values are in dB(A)

Point	Modeled Level dB(A)	Background Noise dB(A)	Maximum Level Allowed dB(A)	Assessment
2	38	53	63	*Complies*
3	18	47	57	*Complies*
4	7	49	59	*Complies*
5	30	51	61	*Complies*
6	47	44	54	*Complies*
8	76	72	82	*Complies*

While blasting noise emission is considerably higher than that of construction machinery, it must be considered that it corresponds to the sound power of a shot, that is, the sound energy of a particular event in time equivalent to sound exposure level (SEL); on the other hand, the sound power of the machinery corresponds to the sound energy from a moving sound source during a specific time operation (in this case 15 minutes).

In this regard, the results of the noise maps (which in turn are obtained from sound energy initially considered) are weighted temporarily based on measurement periods of the standard, which is equivalent to weight SEL (blasting event) in a time of 9 minutes (impulsive noise). Meanwhile, levels modeled for machinery are already weighted from the outset in the power levels used.

For the scenario of blasting noise, impact is not expected, because these levels, together with the Background Noise of each sector, do not exceed the maximum allowed by Supreme Decree No. 146/97 of MINSEGPRES. Without prejudice to the foregoing, and in particular for the construction of surface works of area that are within 35 m of a nearby house (between 35 m and 7 m), and in order to comply with the DS N º 146/97, the implementation of mobile noise barriers is recommended, whose specifications are given in Section 6 of this report.

- **Mobile Sources**

To assess the level of noise emitted by mobile sources, FHWA[2] standards were used as benchmark, which consider that an impact will occur when expected future levels approach or exceed the limit values presented in the table below:

Table 10
Criterion of noise reduction (Noise Abatement Criteria, NAC) of the FHWA. Values are Sound Pressure Level Hour in dB (A)

Category of activity	Leq (h)	L_{10} (h)	Description of the category of activity
A	57 (Outdoors)	60 (Outdoors)	Land on which serenity and quiet are of extraordinary importance and are used for important public need and where the preservation of those qualities is essential if the area is to continue serving for this purpose.
B	67 (Outdoors)	70 (Outdoors)	Camping area, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries and hospitals.
C	72 (Outdoors)	75 (Outdoors)	Developed land, properties or activities not included in Categories A or B above.
D	—	—	Undeveloped areas.
E	52 (Indoors)	55 (Indoors)	Residences, motels, hotels, public gathering centers, schools, churches, libraries, hospitals and auditoriums.

Leq_{hora} projected values for receptors near the route where trucks circulate on the route Puente Alto - Construction sites are compared with the maximum recommended by FHWA, considering these receptors as Category B, for homes or residences, parks and hospitals according to the table above.

[21] Federal Highway Administration, "Procedures for Abatement of Highway Traffic Noise and Construction Noise", 23 C.F.R., Part 772, Federal Register, vol. 47, pp. 29653-29657, 8 July 1982.

Table 11
Assessment of projected levels with the FHWA criterion

Tranche	Leq_{hora} Projected dB(A)	FHWA criterion dB(A)	Assessment
El Volcán	52	67	*No impact*
El Yeso	52	67	*No impact*
Colorado Siphon	52	67	*No impact*
Las Lajas Tunnel	55	67	*No impact*
Maipú River Discharge	53	67	*No impact*
Alfalfal Access	55	67	*No impact*
Main Road (road G-25)	45	67	*No impact*
Puente Alto-El Yeso	45	67	*No impact*
El Yeso - El Volcán	42	67	*No impact*
Puente Alto - Las Lajas	50	67	*No impact*
Las Lajas - Maitenes	48	67	*No impact*
Maitenes - Alfalfal	40	67	*No impact*

It is expected that the truck flow does not generate noise impact on receptors closest to the route.

FHWA considers a noise level LEQ (Leq3600) of an hour (Leq_{3600}), which is fully consistent with the descriptor used by the French Method GdB (emission model). At the same time, the traffic noise models are composed of calculation standards of noise emission, propagation and evaluation, which may be combined if descriptors are spatially and temporally consistent. FHWA rating values are values Leq3600.

- **Modeling and Evaluation of Vibration**

For the case of sectors near blasting events, there will be a modeling of expected VVP values (Vertical Particle Velocity in mm / s) of vibration in the nearest receptor. Subsequently, the modeled values will be evaluated with respect to the limits set in the standard "Title 30: Mineral Resources, Part 816-Permanent Program Performance Standards-Surface Mining Activities; § 816.67 Use of explosives: Control of adverse effects", of the United States of America, one of the countries mentioned in Article 7 of the DS No. 95/2001 of MINSEGPRES "Regulation of Environmental Impact Assessment System" (see Appendix 2).

To predict vibrations produced by blasting the need emerges for a mathematical model that predicts vibration at a certain point, for which a review of the formulas available in the related literature was done. Within formulas studied, the most used in the mining area corresponds to Devine, where the Vertical Velocity of Particle (VVP) is expressed as follows:

$$VVP = K\left(\frac{d}{\sqrt{P}}\right)^{-\alpha} \text{ [mm/s]}$$

Where:

d is the distance from source to receiver [m]

P is the explosive load [kg]

K and α are statistically dependent variables of geological conditions of the soil. The respective constants used in each model are shown in Table 14.

Table 12
Values of constants K and α soil according to Devine

Formula	K	α
Devine	357	2.07

The values of the constants of the model are given by the author, from field measurements and theoretical calculations according to soil type studied.

VVP values modeled by Devine formula correlate well with values measured in the field[2] with similar soil characteristics to that of the present project, being an average error equal to 0.005 [mm / s] in the case studied, which is an acceptable margin of error for modeling purposes. The estimated value of explosive charge to be considered for this case is 30 kg per delay.

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[2] Measurement of vibration generated by blasting conducted in the central area between January 2005 and March 2006.

Table 13
VVP projected value at the nearest receptor to the blasting of points in evaluation

Point	Distance Blasting-receptor, in meters	VVP, in mm/s
1 y 7	1472	0.18
2	331	1.98
3	367	1.68
4	1633	0.15
5	154	6.73

Points 6 and 8 (El Yeso and Maipo River discharge area) are not near population centers, major effects of vibrations caused by blasting are not expected, so the VVP was not projected for the nearest receptor.

The standard "Title 30: Mineral Resources; Part 816-Permanent Program Performance Standard-Surface Mining Activities; § 816.67 Use of explosives: Control of adverse effects"[3], now effective throughout the territory of the U.S., sets the values of maximum peak speed allowable of particles for different distances, and a formula for determining the maximum load considering the distance to the nearest receptors.

The following table shows the maximum permitted by this regulation.

Table 14
Maximum values allowed by the Standard "Title 30, part 816, paragraph 816.67 of the Code of Federal Regulations"

Distance (D), from the blasting site, in feet (m)	Peak particle velocity maximum allowed (V max) for ground vibration, in inches / second	Scaled distance factor to be applied without seismic monitoring (Ds)
0 - 300	1.25	50
301 - 5000	1	55
5001 and more	0.75	65

This rule states that the peak values weighted with curve C given the slow detector response shall not exceed 105 dB (C) in the assessment points. The following table shows the peak values in dB (C) for each of the evaluation points considered.

Table 15
Peak levels in dB (C) associated with each of the noise sensitive points located in the environment of the Project

Point of Assessment	Description	Limit of the Standard dB (C)	Peak Level dB(C)
1 and 7	Forebay and flume Alfalfal area	105	—
2	Connection pipe-tunnel El Torrejón area	105	78.6
3	Window El Trescientos area	105	59
4	Aucayes (Maitenes)	105	48.4
5	Las Lajas	105	71.4

[3] "Title 30, part 816, paragraph 816.67 of Code of Federal Regulations.

From the above table it is shown that all values remain well below the maximum value allowed by the reference standard used for evaluation. Moreover, since points 6 and 8 (El Yeso and Maipo River discharge area) are not near population centers major effects of vibrations caused by blasting are not expected.

Below is the assessment of compliance with the standard in accordance with sensible points detected by the project.

Table 16
Assessment of compliance with the standard according to sensible points identified by the Project

Point	Distance (m)	Distance (ft)	VVP LJ (mm/s)	VVP LJ (inch/s)	Peak particle velocity maximum allowed (V max) for ground vibration, in inches / second
1 and 7	1472	4829	***0.18***	***0.007***	***1***
2	331	1086	***1.98***	***0.078***	***1***
3	367	1204	***1.68***	***0.066***	***1***
4	1633	5358	***0.15***	***0.006***	***0.75***
5	154	505	***6.73***	***0.265***	***1***

From the above table it is shown that all the values remain below the limits imposed by the regulation.

Furthermore, using the formula for calculating the maximum load of explosives to be detonated in 8 milliseconds, which is: W = (D / Ds) ^{2}, it is determined for the case of the Project that the nearest receptor would be at 505 feet away, falling into the category of DS = 55, whereby the estimated maximum load would be 84.3 pounds equivalent to 38 kg, according to the calculations set out below.

$$W = \left(\frac{D}{Ds}\right)^2 = \left(\frac{505}{55}\right)^2 = 84.3 \text{ libras}$$

Evaluation effects on El Morado Natural Monument and San Francisco de Lagunillas Nature Sanctuary

El Morado Natural Monument and San Francisco de Lagunillas Nature Sanctuary will be crossed by El Volcán tunnel and Alfalfal tunnel, respectively, so any blasting in these areas will have a surface level of vibration that will depend on the depth of both tunnels.

In the tranche below the El Morado Monument tunnel depth will vary between 550 and 1,500 m. While in the tranche below San Francisco Nature Sanctuary the depth will vary between 400 and 450 m. In both cases there will be no access windows to the tunnel, roads, or other surface work.

In this regard, it is important to note that depths less than 300 m would have the maximum vertical velocities (mm / s) indicated in the following table, which also indicates the maximum load of explosive per delay:

Table 17
Ratio Depth v/s Estimated Vibration

Depth m	Maximum vibration VVP LJ mm/s	Maximum Load Kg
50	*2.24*	0.8
100	*2.13*	3
150	*2.19*	7
200	*2.27*	13
300	*2.31*	30

Consequently, and considering the minimum vertical distances between the two tunnels and areas of protected areas, it is not expected any effect on surface due to vibrations that may cause excavation works below the El Morado Natural Monument and San Francisco Nature Sanctuary, according to the standards taken as reference.

6. MITIGATION MEASURES

In order to minimize the effects of noise emissions on dwellings located on the outskirts of the area where works of Alfalfal flume will be developed and receptors located within 35 m from the working face where works of construction with heavy machinery will be developed, implementation of noise barriers at work sites is recommended, with which an attenuation of between 11 and 15 dB (A) is expected. The expected attenuations by implementation of barrier and the evaluation of final levels as established in the D. S. N º 146/97 of MINSEGPRES in the construction phase for works of Alfalfal flume is shown (Point 7).

Figure 17
Noise Map Alfalfal Flume Area. Scenario with implementation of mitigation measures

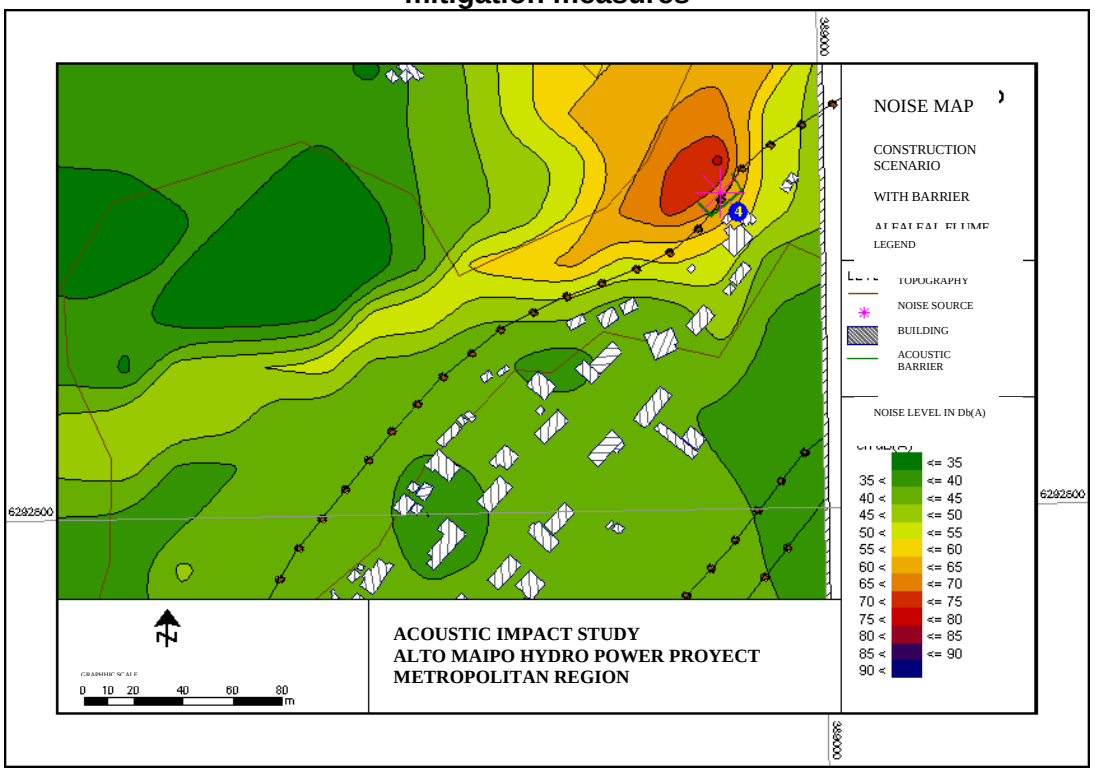

Table 18
Attenuations expected in daytime with implementation of barrier and evaluation of final levels as established in D. S. N º 146/97 of MINSEGPRES. Construction Phase

Point	NPSeq without barrier dB(A)	NPSeq with barrier dB(A)	Maximum allowed dB(A)	Expected attenuation dB(A)	Assessment
7	75	60	62	15	*Complies*

Table 19
Attenuations expected in night time with implementation of barrier and evaluation of final levels as established in D. S. N º 146/97 of MINSEGPRES. Construction Phase

Point	NPSeq without barrier dB(A)	NPSeq with barrier dB(A)	Maximum allowed dB(A)	Expected attenuation dB(A)	Assessment
7	75	60	63	15	*Complies*

The acoustic screen can be an opaque panel without acoustic leaks, with a density of 15 kg/m^2, of OSB wood, Plywood or Steel, and a minimum height of 3 m.

Suggested Configuration: OSB or Plywood (minimum thickness: 10 mm) / rock or mineral wool (minimum density 60 kg/m^3, thickness: 50 mm) / Raschel Mesh.

Figure 18
Panel of mobile acoustic screen – Plywood or OSB

Details of the Panel

Assembly

It is noteworthy that, once implemented the necessary acoustic barriers in receptors located within 35 m (not less than 7 m) of construction machinery and considering the acoustic powers referred to in the modeling of this report, compliance with in force regulations is ensured. Finally, the following general recommendations are given to construction sites.

7. APPARATUS AND REFERENCES USED

- *Rion* NL-22 Sound level meter, type 2.
- *Rion* NC-73 Sound Level Calibrator
- Digital Camera Canon A30 model.
- *Garmin* eTrex Venture Personal Navigator.
- Noise modeling software *SoundPLAN* 6.3.
- **IEC 61672-1:2002**, "*Electroacoustics – Sound Level Meters – Part 1: Specifications*".
- **BS 5228 : Part 1 : 1984 (2004)** - *Noise control on construction and open sites*.
- **ISO 9613-2:1996**, *Attenuation of sound during propagation outdoors*.
- **Supreme Drecree Nº 146**: *Standard of annoying noises generated by stationary sources,* April 17 de1998, of Ministry General Secretariat of the Presidency,

APPENDIX 1
FRENCH STANDARD SPANISH EXCERPT
GUIDE DU BRUIT

An attachment of the main excerpt of the "Guide de Bruit 1980" from France is presented next, which is used for the calculation of emissions per lineal meter Lw/m:

For its use with XPS 31-133 and according to the specifications of the Guide du Bruit 1980, the sound power level Lw and the sound emission E, are calculated from the pressure level Lp, and the speed of the vehicle V with the following formula:

$$L_w = L_p + 25{,}5 \text{ y } E = (L_w - 10 \log V - 50)$$

The noise emission is defined as presented next:

$$E = (L_w - 10 \log V - 50)$$

Where V is the speed of the vehicle

Thus, emission E is a sound level that can be described in terms of dB (A) as the sound level Leq where the reference isophone for just one vehicle per hour in traffic conditions according to:

- Type of vehicle,
- Speed,
- Traffic flow,
- Longitudinal Profile.

The "Guide du Bruit" provides nomograms which give the sound level Leq (1 hour) in dB (A), (also known as sound emission E, described in point 3.1.2.1). The sound level is separately given for just one light weight vehicle (sound emission Eiv) and for a heavy weight vehicle (sound emission "Ehv" per hour). For these different types of vehicles, E is according to the speed (see point 3.1.2.3), the traffic flow (see point 3.1.2.4) and the longitudinal profile (see point 3.1.2.5). Although the sound level presented in the nomograms do not foresee pavement corrections, the current directions incorporate a corrective system of this type (see point 3.1.4).

The level of acoustic power that depends on the Lawi frequency, in dB (A), from a complex specific source i at a determined octave band j, is calculated out of the individual sound emission levels corresponding to the light and heavy weight vehicles pointed out in nomogram 2 of the "Guide du Bruit 1980" (called "nomogram 2" in the current Directions) through the equation:

$$L_{awi} = L_{aw/m} + 10\lg(li) + R(j) + \psi$$

Where:

- Law is the total acoustic power level per meter of road in dB (A) attributed to the line of the specific sources, and it is obtained with the following formula:

$$Lawi/m = 10Log\left(^{(10\,(Eiv + 10\,Log\,Qiv)/10} + 10^{(Ehv + 10\,Log\,Qhv)/10}\right) + 20$$

- Eiv is the sound emission of the light weight vehicles according to the definition of nomogram 2;
- Ehv is the sound emission of the heavy weight vehicles according to the definition of nomogram 2;
- Qiv is the volume of light weight vehicles traffic during the interval of reference;
- Qhv is the volume of heavy weight vehicles traffic during the interval of reference;
- Ψ is the correction done to take in consideration the sound level produced by the pavement, defined in point 3.1.4,
- l, is the length of the tranche of the line of sources represented by a point source components l in meters,
- R(j) is the spectral value, in dB (A) per octave band j, pointed out in chart 2.

APÉNDICE 1
EXTRACTO ESPAÑOL NORMATIVA FRANCESA
GUIDE DU BRUIT

A continuación se adjunta un extracto principal de la "Guide de Bruit 1980" de Francia, utilizada para el cálculo de emisión por metro lineal Lw/m:

Para su uso con XPS 31-133 y conforme a las especificaciones de la Guide du Bruit 1980, el nivel de potencia sonora Lw y la emisión sonora E se calculan a partir del nivel de presión Lp, y la velocidad del vehículo V mediante la formula siguiente:

$$L_w = L_p + 25{,}5 \text{ y } E = (L_w - 10 \log V - 50)$$

La emisión de ruidos se define del modo siguiente:

$$E = (L_w - 10 \log V - 50)$$

Donde V es la velocidad del vehículo

Así pues, la emisión E es un nivel sonoro que puede describirse en términos de dB (A) como el nivel sonoro Leq en la isófona de referencia debido a un solo vehículo por hora en condiciones de tráfico que son función de :

- El tipo de vehículo,
- La velocidad,
- El flujo de tráfico,
- El perfil longitudinal.

La "Guide du bruit" proporciona nomogramas que dan el valor del nivel sonoro Leq (1 hora) en dB(A), (conocido también como emisión sonora E, descrita en el punto 3.1.2.1). El nivel sonoro se da separadamente para un solo vehiculo ligero (emisión sonora Eiv) y para un vehiculo pesado (emisión sonora "Ehv" por hora). Para estos distintos tipos de vehiculo, E es función de la velocidad (véase el punto 3.1.2.3), el flujo de tráfico (véase el punto 3.1.2.4) y el perfil longitudinal (véase el punto 3.1.2.5). Aunque el nivel sonoro mostrado en los nomogramas no prevé correcciones de pavimento, las presentes orientaciones incorporan un sistema de corrección de ese tipo (véase el punto 3.1.4).

El nivel de potencia acústica dependiente de la frecuencia Lawi, en dB(A), de una fuente puntual compleja i en una determinada banda de octava j se calcula a partir de los niveles de emisión sonora individuales correspondientes a los vehículos ligeros y pesados indicados en el nomograma 2 de la "Guide du Bruit 1980" (denominado "nomograma 2" en las presentes Orientaciones) mediante la ecuación:

$$L_{awi} = L_{aw/m} + 10\lg(li) + R(j) + \psi$$

Donde:

- Law es el nivel total de potencia acústica por metro de vía en dB(A) atribuido a la línea de fuentes especificada, y se obtiene con la fórmula siguiente

$$Lawi/m = 10Log\left(^{(10\,(Eiv + 10\,Log\,Qiv)/10} + 10^{(Ehv + 10\,Log\,Qhv)/10}\right) + 20$$

- Eiv es la emisión sonora del vehículos ligeros según se define en el nomograma 2;
- Ehv es la emisión sonora del vehículos pesados según se define en el nomograma 2;
- Qiv es el volumen de tráfico ligero durante el intervalo de referencia;
- Qhv es el volumen de vehículos pesados durante el intervalo de referencia,
- Ψ es la corrección realizada para tener en cuenta el nivel sonoro producido por el pavimento, definida el punto 3.1.4,
- l, es la longitud del tramo de la línea de fuentes representada por una fuente de puntos componentes l en metros,
- R(j) es el valor espectral, en dB(A), por banda de octava j, indicado en el cuadro 2.

APPENDIX 2
SPANISH STANDARD EXCERPT
"Title 30: Mineral Resources; Part 816—Permanent Program Performance Standards—Surface Mining Activities; § 816.67 Use of explosives: Control of adverse effects"[1]

§ 816.67 Use of explosives: Control of adverse effects.

(a) *General requirements.* The blast must be guided in order to prevent injuries to the people, damage to public or private property out of the permitted area, adverse impacts in any underground mine and changes of courses, flow or disposition of superfluous or underground waters out of the permitted area.

(b) *Shock wave: (1) Limits.* (i) The shock wave cannot exceed the maximum limits listed down in the carry out of any house, public building, school, church or communal or institutional building out of the permitted area by exception of those described in paragraph (e) of this section.

Low frequency limit of the measuring system, in Hz (±3 dB)	**Maximum level, in dB**
0.1 Hz or lower: flat response[1]	Maximum 134.
2 Hz or lower: flat response	Maximum 133.
6 Hz or lower: flat response	Maximum129.
Weighting C: slow response[1]	Maximum 105 dBC.

[1] Only once after it has been approved by the regulatory authority.

(ii) If necessary to prevent damage, the regulatory authority must specify the shock wave maximum levels permitted that are lower to those specified in paragraph (b)

(1) (i) out of this section, for use in the vicinity of a specific blast.

(2) Control. (i) The operator must perform periodic controls to ensure conformity with compliance of the standards for shock waves. The regulatory authority can request the measurement of the shock wave of any blast or out of the total amount of blasts and can specify the location where these measurements will take place.

(ii) The measurement systems must have a final superior flat frequency response of at least 200 Hz.

(c) *Projected rock.* The trajectory of a projected rock on the air or along the land should not be projected from the area of the blast.

[1] Electronic Code of Federal Regulations e-CFR [En línea] <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr;sid=49c84a7bae221cbf191ba4e14aff592d;rgn=div5;view=text;node=30%3A3.0.1.11.47;idno=30;cc=ecfr> [consulta: mayo 2008]

(1) More than half the distance of a house or other nearer structure in use;

(2) Beyond the area of control required in paragraph (c) of section §816.66; or

(3) Beyond the permitted limit.

(d)(d) Vibration of the land: (1) General. All the blasts operations, by exception of those authorized in paragraph (e) of this section, the vibration of the land cannot exceed the values approved in the blast plan required under section §780.13 of this chapter. The maximum vibration of the land for the structures protected, numbered in paragraph (d)(2)(i) of this section, must be established according to the maximum limits of the highest particle speed of paragraph (d)(2), the equation of distance escalated of paragraph (d)(3), the chart of the blast level paragraph (d)(4) of this section, or by the regulatory authority under paragraph (d)(5) of this section. All the structures in the vicinity of the blast area, that do not appear in paragraph (d)(2)(i) of this section, such as water towers, distribution pipes, tunnels, dams, ponds and underground mines must be protected from damage, establishing a maximum limit permitted for vibration of the land, provided by the blast plan operator and approved by the regulatory authority.

(2) *Maximum particle speed*. (i) Vibration of the land cannot exceed the following limits in the carry out of any house, public building, school, church or communal building or institutional building out of the permitted area.

Distance (D) of the site of the blast, in feet	**Maximum particle speed permitted (V max.) for land vibration, in inches/seconds[1]**	**Factor of escalated distance to be applied without seismic monitoring[2](*Ds*)**
0 to 300	1,25	50
301 to 5.000	1,00	55
5.001 onwards	0,75	65

[1]Vibration of the land must be measured as the particle speed. The particle speed must be registered in three directions reciprocally perpendicular. The maximum particle speed permitted must be applied to each one of the three measures.
[2]Applicable to the equation of escalated distance of paragraph (d)(3)(i) of this section.

(ii) A seismographic record must be provided for each blast.

(3) *Equation of escalated distance*. (i) An operator can use the equation of escalated distance, W=(D/Ds)2, to determine the explosives weight permitted of the load that will be detonated in a period of 8 milliseconds, without seismic monitoring; where W is equal to the maximum explosives weight, in pounds; D is equal to the distance, in feet, of the site of the blast to the closest protected structure; and Ds is equal to the factor of escalated distance, which initially can be approved by the regulatory authority using the values for the factor of escalated distance described in paragraph (d)(2)(i) of this section.

(ii) The development of a modified factor of escalated distance can be authorized by the regulatory authority through a written request to the operator, supported by the seismographic records of the blast in the site of the mine. The modified factor of the escalated distance must be determined so the forecast speed of the land vibrating particle should not exceed the maximum speed permitted prescribed in paragraph (d)(2)(i) of this section, at 95% of reliability.

(4) Shock wave level chart. (i) An operator can use the limits of land vibration in Figure 1 to determine the maximum and vibration permitted.

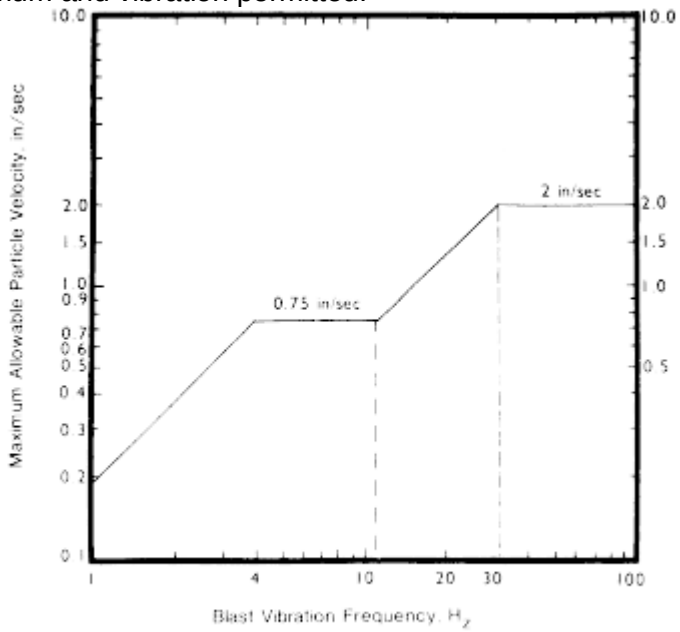

Figure 1. Alternative blasting level criteria
(Source: Modified from figure 8-1, Bureau of Mines, RI8507)

(ii) If the limits of Figure 1 are used, a seismographic record including both the particle speed and the frequency levels of vibration for each blast must be provided. The method for predominant frequency analysis contained in the blast records must be approved by the regulatory authority before the application of this criterion of alternative blast.

(5) The maximum land vibration permitted must be reduced by the regulatory authority if exceeding the limits presented in this section, if it is determine to provide protection of damage.

(6) The regulatory authority can request an operator to carry out a seismic monitoring of any blast or all of them, or it can specify the location where the measures should be taken and the degree of details necessary in them.

(e) The maximum compliance standards for land vibration and shock wave of paragraphs (b) and (d) of this section should not be applied to the following locations:

(1) In structures which are owned by the permit applicant and not leased to another person.

(2) In structures which are owned by the permit applicant and leased to another person, if a resignation in written by the leaseholder to the regulatory authority before the blast.

[48 FR 9807, March 8th 1983, as amendment to 48 FR 44780, September 30th 1983]

§ 816.68 Use of explosives: Blast operation records

The operator must keep a record of all the blasts for at least three years. If needed it, copies of these records must be made in order to have them available for inspection of the regulatory authority and the public. These records must have the following information:

(a) Name of operator carrying out the blast.

(b) Location, date and time of the blast.

(c) Name, signature and certification number of the operator in charge of the blast.

(d) Identification, direction and distance, in feet, from the closest hole of entrance of the explosives to the houses, public building, school, church, communal or institutional building closer to the permitted area, by exception of those described in paragraph (e) of section §816.67.

(e) Meteorological conditions, including those that might cause possible adverse effects in the blast.

(f) Type of material used in the blast.

(g) Draft of the pattern of blast, including the number of holes, load, space, supports and time delay pattern.

(h) Diameter and depth of the holes.

(i) Type of explosives used.

(j) Total weight of the explosives per hole.

(k) Maximum weight of the explosives detonated at a period of 8 milliseconds.

(l) Initiation system.

(m) Type and length of the peg.

(n) Covers and other types of protections used.

(o) Seismographic records and shock wave, if required, must include:

(1) Type of instrument, sensitivity and signal of calibration or certification of annual calibration;

(2) Exact location of the instrument and date, time and distance of the blast;

(3) Name of the person and company taking the registration;

(4) Name of the person and company analyzing the seismograph record; and

(5) Level of the shock wave and/or vibration registered.

(p) Reasons and conditions of each unplanned blast.

[[48 FR 9809, March 8th 1983, as amendment to 52 FR 29181, August 6th, 1987]

APÉNDICE 2
EXTRACTO EN ESPAÑOL NORMA
"Title 30: Mineral Resources; Part 816—Permanent Program Performance Standars—Surface Mining Activities; § 816.67 Use of explosives: Control of adverse effects"[1]

§ 816.67 Uso de explosivos: Control de efectos adversos.

(a) *Requisitos generales.* La explosión debe ser guiada para prevenir lesiones en las personas, daño a la propiedad pública o privada fuera del área permitida, impactos adversos en cualquier mina subterránea y cambios de curso, cauce o disposición de aguas superfluas o subterráneas fuera del área permitida.

(b) *Onda expansiva:* (1) *Límites.* (i) La onda expansiva no debe sobrepasar los límites máximos enumerados abajo en el emplazamiento de cualquier vivienda, edificio público, escuela, iglesia o edificio comunal o institucional fuera del área permitida excepto las que se describen en el párrafo (e) de esta sección.

Límite de frecuencia inferior del sistema de medición, en Hz (±3 dB)	**Nivel máximo, en dB**
0,1 Hz o inferior: respuesta plana[1]	Máximo 134.
2 Hz o inferior: respuesta plana	Máximo 133.
6 Hz o inferior: respuesta plana	Máximo129.
Ponderación C: respuesta lenta[1]	Máximo 105 dBC.

[1] Solamente una vez aprobado por la autoridad regulatoria.

(ii) Si es necesario para prevenir daños, la autoridad regulatoria debe especificar niveles de onda expansiva máximos permitidos que sean inferiores a los especificados en el párrafo (b)

(1) (i) de esta sección para uso en las inmediaciones de una explosión específica.

(2) *Control.* (i) El operador debe realizar controles periódicos para asegurar conformidad con las normas de cumplimiento para las ondas expansivas. La autoridad regulatoria puede requerir la medición de la onda expansiva de cualquiera de las explosiones o de la totalidad de ellas y puede especificar el lugar en donde estas mediciones deben tomarse.

(ii) Los sistemas de medición deben tener una respuesta de frecuencia plana final superior de al menos 200 Hz.

(c) *Roca en vuelo.* La trayectoria de la roca en vuelo por el aire o a lo largo del terreno no debe ser proyectada desde el lugar de la explosión:

[1] Electronic Code of Federal Regulations e-CFR [En línea] <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr;sid=49c84a7bae221cbf191ba4e14aff592d;rgn=div5;view=text;node=30%3A3.0.1.11.47;idno=30;cc=ecfr> [consulta: mayo 2008]

(1) Más de la mitad de la distancia a la vivienda u otra estructura ocupada más cercana;

(2) Más allá del área de control requerida bajo el párrafo (c) de la sección §816.66; o

(3) Más allá del límite permitido.

(d) *Vibración del terreno:* (1) *General.* En todas las operaciones de explosiones, excepto las autorizadas en el párrafo (e) de esta sección, la vibración del terreno máxima no debe sobrepasar los valores aprobados en el plan de explosión requerido bajo la sección §780.13 de este capítulo. La vibración del terreno máxima para las estructuras protegidas enumeradas en el párrafo (d)(2)(i) de esta sección se debe establecer de acuerdo a los límites máximos de la velocidad de partículas más alta del párrafo (d)(2), la ecuación de distancia escalada del párrafo (d)(3), el gráfico del nivel de explosión del párrafo (d)(4) de esta sección, o por la autoridad regulatoria bajo el párrafo (d)(5) de esta sección. Todas las estructuras en las inmediaciones del área de la explosión, que no aparecen en el párrafo (d)(2)(i) de esta sección, como torres de agua, ductos de distribución, túneles, represas, estanques y minas subterráneas deben ser protegidas de daño al establecer un límite máximo permitido para la vibración del terreno, proporcionado por el operador del plan de explosión y aprobado por la autoridad regulatoria.

(2) *Velocidad de partícula máxima.* (i) La vibración del terreno máxima no debe sobrepasar los siguientes límites en el emplazamiento de cualquier vivienda, edificio público, escuela, iglesia o edificio comunal o institucional fuera del área permitida.

Distancia (D) del sitio de la explosión, en pies	**Velocidad de partícula máxima permitida (*V* máx.) para la vibración del terreno, en pulgadas/segundos[1]**	**Factor de distancia escalada para ser aplicada sin monitoreo sísmico[2](*Ds*)**
0 a 300	1,25	50
301 a 5.000	1,00	55
5.001 en adelante	0,75	65

[1]La vibración del terreno debe ser medida como la velocidad de partícula. La velocidad de partícula debe ser registrada en tres direcciones mutuamente perpendiculares. La velocidad de partícula máxima permitida se debe aplicar a cada una de las tres medidas.
[2]Aplicable a la ecuación de distancia escalada del párrafo (d)(3)(i) de esta sección.

(ii) Se debe proporcionar un registro sismográfico para cada explosión.

(3) *Ecuación de distancia escalada.* (i) Un operador puede usar la ecuación de distancia escalada, $W = (D/Ds)^2$, para determinar el peso de explosivos permitido de la carga que será detonada en un período de 8 milisegundos, sin monitoreo sísmico; donde *W* es igual a el peso de explosivos máximo, en libras; *D* es igual a la distancia, en pies, del sitio de la explosión a la estructura protegida más cercana; y *Ds* es igual a el factor de distancia escalada, que inicialmente puede ser aprobado por la autoridad regulatoria usando los valores para el factor de distancia escalada descritos en el párrafo (d)(2)(i) de esta sección.

(ii) El desarrollo de un factor de distancia escalada modificado puede ser autorizado por la autoridad regulatoria mediante una solicitud por escrito del operador, respaldada por registros sismográficos de la explosión en el sitio de la mina. El factor de distancia escalada modificado debe determinarse de modo que la velocidad de partícula de la vibración del terreno pronosticada no deberá exceder la velocidad de partícula máxima permitida prescrita en el párrafo (d)(2)(i) de esta sección, a un 95% de confiabilidad.

(4) *Gráfico del nivel de onda expansiva.* (i) Un operador puede usar los límites de la vibración del terreno en la Figura 1 para determinar la vibración del terreno máxima permitida.

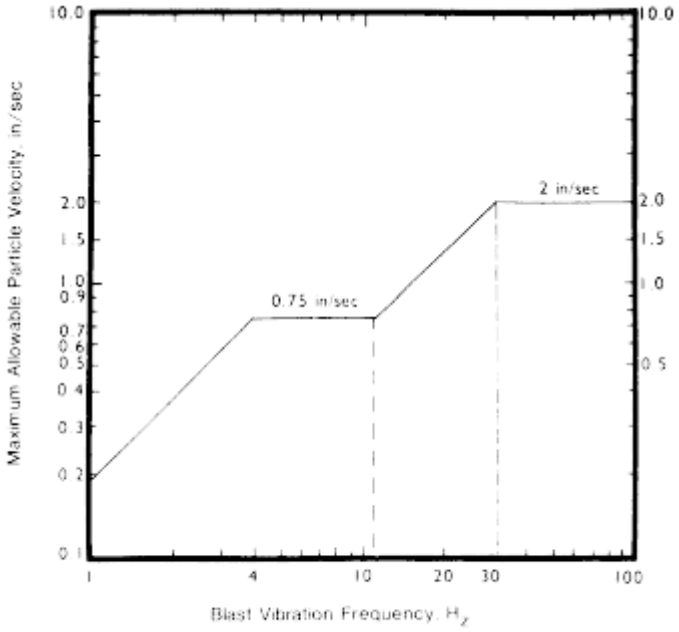

Figure 1. Alternative blasting level criteria
(Source: Modified from figure B-1, Bureau of Mines, RI8507)

(ii) Si se usan los límites de la Figura 1, se debe proporcionar un registro sismográfico que incluya tanto la velocidad de partícula y los niveles de frecuencia de la vibración para cada explosión. El método para el análisis de la frecuencia predominante contenida en los registros de explosión debe ser aprobado por la autoridad regulatoria antes de la aplicación de este criterio de explosión alternativo.

(5) La vibración del terreno máxima permitida debe ser reducida por la autoridad regulatoria si sobrepasa los límites proporcionados por esta sección, si se determina necesario para entregar protección de daño.

(6) La autoridad regulatoria puede requerir un operador para que lleve a cabo un monitoreo sísmico de cualquier explosión o de la totalidad de ellas, o puede especificar la ubicación donde deben tomarse las mediciones y el grado de detalle necesario en ellas.

(e) Las normas de cumplimiento máximas para la vibración del terreno y para la onda expansiva de los párrafos (b) y (d) de esta sección no deben aplicarse en los siguientes lugares:

(1) En las estructuras que son propiedad de quién solicitó el permiso y no arrendadas a otra persona.

(2) En las estructuras que son propiedad de quién solicitó el permiso y arrendadas a otra persona, si se presenta una renuncia por escrito del arrendatario a la autoridad regulatoria antes de la explosión.
[48 FR 9807, 8 de marzo de 1983, como enmienda a 48 FR 44780, 30 de septiembre de 1983]

§ 816.68 Uso de explosivos: Registros de operaciones de explosiones

El operador debe conservar un registro de todas las explosiones de por lo menos tres años. Si se requiere, deben hacerse copias de estos registros para que estén disponibles para la inspección de la autoridad regulatoria y el público. Estos registros deben contener la siguiente información:

(a) Nombre del operador que lleva a cabo la explosión.

(b) Ubicación, fecha y hora de la explosión.

(c) Nombre, firma y número de certificación del operador a cargo de la explosión.

(d) Identificación, dirección y distancia, en pies, desde el agujero de entrada de explosivos más cercano hasta la vivienda, edificio público, escuela, iglesia, edificio comunal o institucional más cercanos fuera del área permitida, excepto aquellos descritos en el párrafo (e) de la sección §816.67.

(e) Condiciones meteorológicas, incluidas aquellas que pudieran causar posibles efectos adversos en la explosión.

(f) Tipo de material usado en la explosión.

(g) Bosquejo del patrón de la explosión, incluido el número de agujeros, carga, espaciado, soportes y patrón de retardo.

(h) Diámetro y profundidad de los agujeros.

(i) Tipos de explosivos usados.

(j) Peso total de los explosivos usados por agujero.

(k) Peso máximo de los explosivos detonados en un período de 8 milisegundos.

(l) Sistema de iniciación.

(m) Tipo y longitud del taco.

(n) Cubiertas u otras protecciones usadas.

(o) Registros de sismografía y onda expansiva, si se requiere, debe incluir:

(1) Tipo de instrumento, sensibilidad y señal de calibración o certificación de calibración anual;

(2) Ubicación exacta del instrumento y la fecha, hora y distancia de la explosión;

(3) Nombre de la persona y de la empresa que toma el registro;
(4) Nombre de la persona y de la empresa que analiza el registro sismográfico; y

(5) El nivel de onda expansiva y/o vibración registrado.

(p) Razones y condiciones de cada explosión no planificada.

[48 FR 9809, 8 de marzo de 1983 como enmienda a 52 FR 29181, 6 de agosto de 1987]