Effectiveness of Tire/Road Noise Abatement through Surface Retexturing by Diamond Grinding for Project SUM-76-15.40

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16. Abstract

A portion of I-76, near Akron, OH, had been reconstructed by the Ohio Department of Transportation (ODOT) using concrete to replace the previous surface, which was constructed of asphalt. In the process of reconstruction, the concrete surface was textured with random transverse grooves to comply with the current ODOT specification. Subsequent to construction, residents living in the project area as far as 2600 ft (800 m) from the roadway, perceived an unfavorable difference in their noise environment, which they attributed to the new concrete pavement used on the reconstruction project. Therefore, a project was initiated to re-texture the pavement surface by diamond grinding. The transverse grooves were replaced with longitudinal grooves. Traffic noise measurements were made before and after grinding at five sites in the project area, at distances from 7.5 m to 120 m from the center of the near travel lane. The average reduction in broadband noise at 7.5 m was 3.5 dB, and the average reduction at15m was 3.1 dB. Spectrum analysis showed the greatest reduction in noise occurred at frequencies above 1 kHz and that the retexturing had little to no effect on frequencies less than 200 Hz.

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NOTATIONS

A-weighting network: An electronic filter in a sound level meter that approximates under defined conditions the frequency response of the human ear. The A-weighting network is most commonly used.

Calibration: Adjustment of a sound measurement system so that it agrees with a reference sound source.

Decibels (dB): A unit of logarithmic measure based on ratios of power-related quantities, thereby compressing a wide range of amplitude values into a small set of numbers.

Exponential time-averaging: A method of stabilizing instrumentation response to signals with changing amplitudes over time using a low-pass filter with a known, electrical time constant. The time constant is defined as the time required for the output level to reach 67 percent of the input, assuming a step-function.

Fast time weighting: The response speed of the detector in sound measurement system using a time constant is 1/8 second (125 ms) to detect changes in sound level more rapidly.

Free field: A sound field whose boundaries exert a negligible influence on the sound waves. In a free-field environment, sound spreads spherically from a source and decreases in level at a rate of 6 dB per doubling of distance from a point source, and at a rate of 3 dB per doubling distance from a line source.

Frequency: The number of cyclical variations (periods) unit of time. Expressed in cycles per second (cps) also denoted as Hertz (Hz).

Hertz (Hz): The unit of frequency measurement, representing cycles per second.

Octave: Two frequencies are an octave apart if the ratio of the higher frequency to the lower frequency is two.

Octave (frequency) bands: Frequency ranges in which the upper limit of each band is twice the lower limit. An octave band is often subdivided into 1/3 octaves (3 bands per octave) for finer frequency resolution.

Receiver: One or more observation points at which sound is measured or evaluated. The effect of sound on an individual receiver is usually evaluated by measurements near the ear or close to the body.

Source: An object (ex. traffic) which radiates sound energy.

Spectral, spectrum: Description, for a function of time, of the resolution of a signal into components, each of different frequency and usually different amplitude and phase.

NOTE : Unless indicated otherwise, all sound pressure levels referenced in this report are the maximum A-frequency weighted sound pressure levels.

1. INTRODUCTION

1.1 Background

A portion of I-76, near Akron, OH, had been reconstructed by the Ohio Department of Transportation (ODOT) using Portland cement concrete (PCC) to replace the previous surface, which was constructed of bituminous asphaltic concrete (BAC). In the process of reconstruction, the concrete surface was textured with random transverse grooves to comply with the current ODOT specification (451.09).

Subsequent to construction, residents living in the project area as far as 2600 ft (800 m) from the roadway, perceived an unfavorable difference in their noise environment, which they attributed to the new concrete pavement used on the reconstruction project. Highway engineers in District 4, being aware that pavement materials and especially pavement surface textures have a significant effect on tire/road noise, established a plan to change the surface texture from transverse grooves to longitudinal grooves as a means to alleviate the objectionable differences perceived by residents.

The Ohio Department of Transportation initiated this research project to quantify noise differences due to the pavement re-texturing in order to have an objective basis for: judging the effectiveness of the re-texturing project, correlating any feedback from residents, and establishing the merits of the strategy for consideration in similar situations in the future.

1.2 Literature Review

The literature review on the noise impacts of longitudinal versus transverse concrete grooving showed that there has been limited work done in this area. A short background on the many mechanisms that make up highway noise has been included, as well as some characteristics pertaining to concrete in general.

1.2.1 Vehicle Noise Sources

Efforts to reduce vehicle noise have been concentrated on tire/road noise and drive train noise. Vehicle manufactures have made significant progress in reducing power and drive train noise. If a vehicle is in a good operating condition and has a reasonably good exhaust system, then the effect that power and drive train noise has on the overall noise level will be negligible at moderate to high speeds. There is a “cross-over speed” where tire/road noise begins to dominate the overall noise level of a vehicle. This speed lies in the range of 18.6-31 mi/h (30-50 km/h) for automobiles and 24.9-43.5 mi/h (40-70 km/h) for trucks [Sandberg 1992].

1.2.2 Road Surface Influence on Tire/Road Noise

There are several parameters that affect the amount that the road surface contributes to the generation of tire/road noise. These parameters include the texture, age, thickness, and binder material of the pavement.

The overall texture of the pavement has a significant impact on tire/road noise levels. The texture of a pavement surface can be divided into two subcategories, microtexture and macrotexture. Microtexture can be defined as the small scale roughness or harshness of a road surface, within the individual aggregate, and extends down to molecular sizes [Sandberg 1979]. The function of the microtexture is to provide high dry friction on the pavement surface.

Macrotexture is the roughness or texture that encompasses the tire tread elements and road aggregate up to the size of the tire/road interface area. The function of the macrotexture is to provide a dry pavement surface creating channels where water can escape to create high friction even on wet roads and at high speeds [Sandberg 1987].

Studies have been performed by the Washington State Department of Transportation to evaluate how tire/road noise changes with pavement age. These studies have shown that asphalt pavements start out quieter than Portland cement concrete pavements, but the asphalt pavements exhibit an increase in noise levels over time [Chalupnik and Anderson 1992]. The reason that the noise levels for asphalt pavements increase over time can be attributed to the pores in the pavement becoming clogged causing the pavement to loose some of its absorptive properties. Another reason for the increase in noise levels is due to an increase in stiffness from traffic loading. Finally, as the asphalt surface wears over time, the coarse aggregate becomes exposed which causes an increase in noise.

The same study by the Washington Department of Transportation has shown that noise levels from Portland cement concrete pavement decrease with age for approximately the first eight years of service for the pavements tested. Traffic volume differences for other roadways could change this time period. After eight years have passed, the noise levels generated by the Portland cement concrete pavement increase. Treatments, such as grooving and tining, are applied to the Portland cement concrete surfaces during the finishing process to enhance surface traction. Over time, the irregularities in this treatment are worn down and smoothed causing a reduction in noise levels. Around the eighth year, the aggregate begins to emerge causing an increase in surface texture and in turn an increase in noise levels.

The effect of pavement thickness has been evaluated for open graded asphalt surfaces and shown to have an influence on tire/road noise. In general, as the thickness of a pavement is increased, the frequency at which the maximum sound level occurs is lowered [Sandberg 1992]. In another study, the use of a double layer open graded asphalt surface instead of a single layer (3.2 in (80 mm) instead of 2 in (50 mm)) reduced traffic noise by 1 dB [Storeheier and Arnevik 1990]. This reduction was accomplished by increasing the voids content in the top layer, while maintaining the same maximum aggregate size in both layers.

Super-thick open graded asphalt pavements with thicknesses up to 27.6 in (700 mm) have been tested in comparison to conventional dense graded asphalt pavements. The results indicated that a total noise reduction of approximately 8 dB was achieved with the thick pavements versus a 4 dB reduction for thin layers [Pipien and Bar 1991].

A number of strategies have been developed to reduce tire/road noise by altering the typical design of a pavement based on an understanding of the mechanisms discussed above. Noise reduction methods have been developed for both asphalt and Portland cement concrete pavements. However, only Portland cement concrete will be considered for this study.

In the literature, Portland cement concrete pavements are generally shown to have higher noise levels than asphalt pavements. Efforts to reduce tire/pavement noise levels for Portland cement concrete have focused mainly on strategies involving surface texture. These strategies have included, exposed aggregate, thin overlays or surface dressings, and variations in transverse grooving and longitudinal grooving.

One method to reduce tire/road noise levels on Portland cement concrete surfaces is to use an exposed aggregate finish. This type of finish can be used on new, reconstructed, or recycled Portland cement concrete pavements. The grain size of the exposed aggregate should preferably be .16 - .28 in (4 - 7 mm) in order to give optimum macrotexture [Descornet and Sandberg 1980]. There are two methods that can be used to expose the aggregate. The first method, which is older and less preferred today, involves simultaneously watering and brushing the fresh concrete surface by means of a rotary brush. The second method involves spraying an appropriate setting retarder on the fresh concrete. After the concrete hardens (24 - 30 hours after laying), the surface is mechanically brushed in order to remove the mortar that has not yet set [Sandberg 1992].

From an economical standpoint, the additional costs for the exposed aggregate procedure cause and increase of approximately 10 % of the total pavement cost [Sommer 1992].

Thin overlays, or surface dressings, can be used to reduce noise on smooth Portland cement concrete surfaces. To obtain the greatest potential reduction in noise, the aggregate size should be kept as small as possible with respect to wear and drainage. These surfaces have the ability to produce reductions in noise levels equivalent to those of open graded asphalt. However, when the thin overlays are worn, they gradually reach the level similar to a dense graded asphalt pavement [Sandberg 1992].

The type, method, and direction of texturing Portland cement concrete surfaces has been known to be a significant factor when considering reducing tire/road noise [Sommer 1992-II]. Most of the PCC pavements used on ODOT roadways have been finished with a surface texture composed of transverse grooves. The original groove design included a specification for a constant spacing between adjacent grooves, similar to the design used by most other states. However, the constant spacing tended to promote a tonal quality, or whine, to the noise produced by tires rolling on the pavement. To combat the “whine” problem associated with constant spaced transverse grooved PCC pavements, ODOT changed the groove specifications for tined PCC pavements to a random spaced transverse groove pattern. This design change was made to spread the peak sound level over a wider range of frequencies.

Sound level data was collected in Ohio in 1998 using ISO 11891-1, The Statistical Pass-By Method, for the major ODOT pavement types. The sound level data was used to develop the Statistical Pass-By Index (SPBI) values for each pavement type. The SPBI data indicated that random-transverse grooved PCC pavement produced the highest sound levels of the pavement types measured. These levels averaged 3.9 dB higher than the levels for the average pavement, which was one-year old dense graded asphalt, and 6.7 dB higher than the quietest pavement, which was one-year old open-graded asphalt [Herman, Ambroziak, and Pinckney 2000].

Sound level data was also collected in a sub-study, using a single test vehicle to compare tire/road noise levels for six different PCC sites. The six sites included three different groove types: longitudinal (1 site), transverse (2 sites), and random-transverse (3 sites). The site with the longitudinal grooves produced the lowest sound levels (3.0 dB below the mean of all six sites, for a vehicle speed of 65.2 mi/hr (105 km/hr)), followed by the transverse grooved sites, then the random-transverse grooved sites (as much as 3.2 dB above the mean of all six sites, for a vehicle speed of 65.2 mi/hr (105 km/hr)). However, there was significant variation (almost 2 dB) between the random-transverse sites. The sample size for this sub-study was very small, only one test vehicle was used, only two vehicle speeds were measured, and there was only one site with longitudinal grooves [Herman and Ambroziak 2000]. While these results supported the strategy to remove the random-transverse grooves of the SUM-76-15.40 pavement and replace them with longitudinal grooves, the magnitude of these results could not be used as a predictor for the SUM-76-15.40 project results.

The results of other studies have supported the decision to retexture the surface to longitudinal grooves. Longitudinal grinding was shown to reduce noise on both old and new Portland cement concrete surfaces based on measurements performed in Sweden. A noise level reduction in the range of 0.5 - 3.0 dB was achieved after grinding an old Portland cement concrete surface. [Sandberg 1992]. Also, an Arizona Department of Transportation study, which compared rubberized asphalt to concrete pavements, found improvements of 3.3 - 5.7 dBA over transverse grooved concrete and 0.2 – 1.5 dBA over longitudinally grooved concrete [Henderson and Kalevela 1996]. It could be inferred then, that this study observed a 1.8 – 4.2 dBA difference in noise level between transverse and longitudinally grooved concrete.

2. RESEARCH OBJECTIVES

The goal of the research project, to quantify traffic noise differences due to re-texturing the concrete pavement surface through diamond grinding, was be reached by completing the following objectives:

1. Collect traffic noise level and frequency data, at a series of positions, to characterize the traffic noise sound field between the roadway and the most distant residence of interest (Tucker residence, 290 Hanna Dr.) both before and after diamond grinding of the pavement.

2. Identify traffic noise level and frequency differences due to the re-texturing of the pavement surface.

3. Identify traffic noise level and frequency differences due to the re-texturing of the pavement surface that correlate with distance from the source.

3. GENERAL DESCRIPTION OF RESEARCH

3.1 Site Selection

Through coordination with ODOT, several potential sites were identified within the project limits. The sites were then qualified with reference to criteria established in the U.S. for the measurement of traffic noise reference levels [Lee and Fleming 1996] and for the international standard for the statistical pass-by method of tire/road noise measurement [International Organization for Standardization 1994]. These criteria were developed to enable valid comparisons of noise measurements between different highway sites. They are necessarily more stringent than the requirements for BEFORE and AFTER measurements at the same site. Therefore, every effort was made to find sites that met as many of these criteria as possible, recognizing that the terrain variations and the relatively short project length would preclude meeting all criteria. Further, any criteria that related to the measurement of individual vehicle pass-bys or test lanes were not considered.

1. The roadway test sections extended at least 164 ft (50m) on each side of the microphone locations. This space was free of large reflecting surfaces, such as parked vehicles, signboards, buildings, or hillsides.

2. The roadways were relatively level and straight. It was permissible to have roads with slight bends or with grades less than or equal to 1%.

3. The sites exhibited constant-speed vehicle operating conditions with cruise conditions of at least 54.7 mi/h (88 km/h). Therefore, the site was located away from interchanges, merges, or any other feature that would cause traffic to accelerate or decelerate.

4. The sites had a prevailing ambient noise level that was low enough to enable the measurement of uncontaminated vehicle pass-by sound levels.

5. The road surfaces were in good condition and were homogeneous over the entire measurement sections. The surfaces were free from cracks, bitumen bleeding (asphalt pavements), and excessive stone loss.

6. The traffic volumes for each vehicle category were large enough to permit an adequate numbered sample to be taken to perform the statistical analysis but also low enough to permit the measurement of individual vehicle pass-bys.

7. The sites were located away from known noise sources such as airports, construction sites, rail yards, and other heavily traveled roadways.

8. The ground surface within the measurement area was essentially level with the road surface, varying by no more than 2 ft (0.6 m) parallel to the plane of the pavement along a line from the microphones to the pavement. The ground was also no more than 2 ft (0.6 m) above or below the roadway elevation at the microphones. Any roadside ditch or other significant depressions were at least 16.4 ft (5 m) from the center of the test lane.

9. At least half of the area between the center of the test lane and the first microphone had acoustical properties similar to the pavement being measured. The ground surface was free from any vegetation that was higher than 2 ft (0.6 m) or could be cut down at any sites that did not meet this requirement.

10. To ensure free field conditions, at least 82 ft (25 m) of space around the microphones was free of any reflecting objects. Also, the line-of-site from the microphones to the roadway was unobscured within an arc of 150 degrees.

3.2 Measurement Site Locations

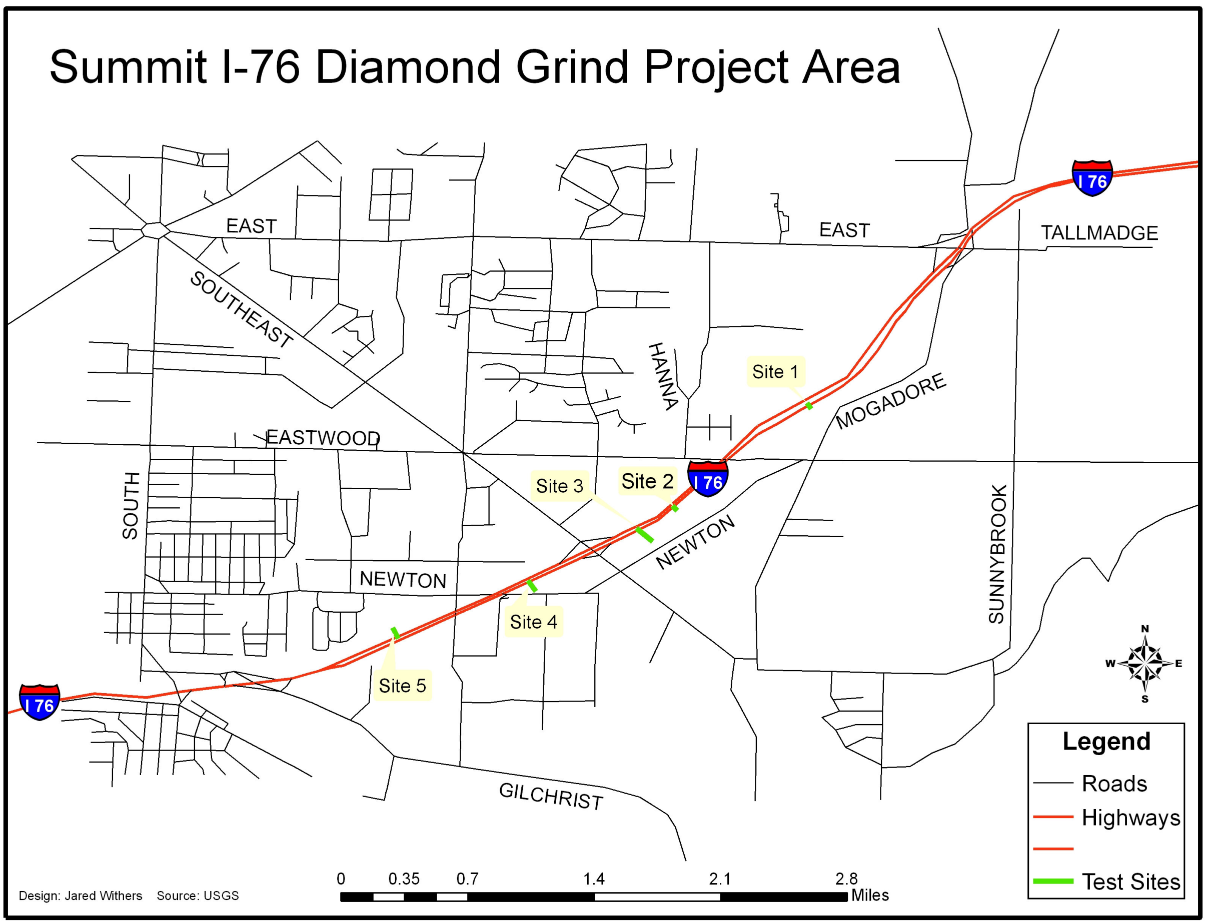

Figure 1: Project area map showing site locations.

4. INSTURMENTATION AND SETUP

This section describes the instrumentation techniques used for the field data collection. Full descriptions of instruments and settings are included for both acoustical and supplemental equipment. A complete listing of the equipment used can be found in Appendix C.

4.1 Acoustical Instrumentation and Setup

The system used to acquire the acoustical data included random incidence microphones each connected to a preamplifier.

The microphones and preamplifiers were positioned in nylon holders and then mounted on tripods located at distances of 24.6 ft (7.5 m) and 49.2 ft (15 m) from the centerline of the near travel lane for all sites. The microphone at 24.6 ft (7.5 m) was positioned at a height of 4.9 ft (1.5 m (+/- .1 m)) above the plane of the roadway and its reference axis for random incidence conditions was orientated 70 degrees to horizontal and directed perpendicularly towards the path of the vehicles.

The 49.2 ft (15 m) microphone was set at a height of 4.9 ft (1.5 m (+/- .1 m)) above the plane of the roadway and was also orientated 70 degrees to horizontal and directed perpendicularly towards the path of the vehicles. Figure 2 shows a plan view of the microphones and their positions.

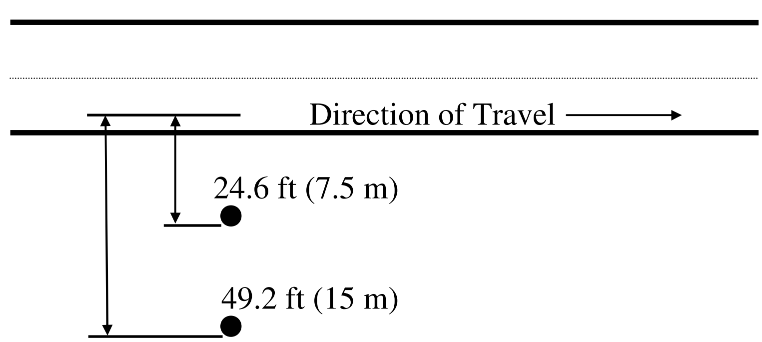

Figure 2: Plan view of typical microphone layout (not to scale).

The microphones and preamplifiers were connected to a dual channel, one-third octave band analyzer by cables which were 98.4 ft (30 m) in length. Recording and storage of the measured acoustical data was achieved by the analyzer. Data was stored for the frequency range of 50-10,000 Hz every 1/2 second using a fast response, $1/8^{th}$ second exponential averaging method. The data from the internal memory of the analyzer was transferred to floppy disk for later off-site processing and analysis.

4.2 Supplemental Instrumentation

ODOT District 4 supplied lane-specific speed, count, and classification data at two locations during measurement times. Because there were interchanges located within the project limits, two locations were required to accurately represent the traffic at all test sites. Traffic data was later used to compare traffic conditions between before and after measurements.

A digital weather station was used to continuously monitor the temperature, wind speed, and wind direction. Temperatures were recorded at an accuracy of +/- 0.5°F and wind speeds of +/- 5%. The relative humidity was measured using a digital hygrometer with an accuracy of +/- 3% full scale. The road surface temperature was measured at the wheel path using a hand held infrared thermometer with an accuracy of +/- 1% of the reading. The instrument was positioned at a height of 3 ft (0.9 m (+/- 0.1 m)) above the roadway surface during temperature measurements.

Calibration of the analyzer was made using an acoustic calibrator which produced a signal of 1000 Hz at a sound pressure level of 94 dB. Additionally, the measurement microphones were replaced with a passive microphone simulator (dummy microphone) prior to each measurement to determine the electronic noise floor of the analyzer, which could be influenced by any sources of electromagnetic radiation near the site.

5. MEASUREMENT PROCEDURE

Primary measurements were made at each site with microphones located at distances of 24.6 ft (7.5 m) and 49.2 ft (15 m) from the centerline of the near travel lane. These two positions were selected somewhat arbitrarily for this project. However, the 24.6 ft (7.5 m) distance is prescribed in the international standard for the statistical pass-by method of tire/road noise measurement, and the 49.2 ft (15 m) position is the standard microphone distance for measuring vehicle reference noise levels for use in the Federal Highway Administration's Traffic Noise Model (TNM) [International Organization for Standardization 1994] [Menge 1998]. Both of these standard measurement procedures are used to measure vehicle pass-by noise levels for isolated vehicles on the roadway. However, I-76 traffic volumes during daylight hours produced a density that was generally too high to permit the measurement of noise from individual vehicles. Therefore, the measured traffic noise was a composite for all of the vehicle pass-bys for all lanes during each measurement period.

All sites included, as a minimum, both of these primary microphone positions with one exception: at Site 3, 1185 Newton St., the merge of an on-ramp with the mainline occurred where the 24.6 ft (7.5 m) microphone was normally placed. While omitting the 24.6 ft (7.5 m) microphone position was not desirable, there were few acceptable sites that afforded the terrain conditions to allow simultaneous step-back measurements to be made. This site was the most favorable in all other respects for the step-back setup; therefore, it was not eliminated.

5.1 Primary Sound Level Measurement Procedure

After the equipment was set up and the microphones calibrated at each site, a two-channel spectrum analyzer was programmed to measure the sound level in one-third octave frequency bands from 50 Hz to 10 kHz range and store an un-weighted average spectrum every minute for one hour. Channel 1 of the spectrum analyzer was connected to the 24.6 ft (7.5 m) microphone, and Channel 2 was connected to the 49.2 ft (15 m) microphone. A digital audio tape recorder was also connected to each channel to provide a backup of the measured signals. During the measurement period, the spectrum analyzer operator noted any significant ambient noise interference (aircraft, lawn mowers, etc).

5.2 Simultaneous Step-back Measurement Procedure

According to the statement of objective 1, data was to be collected simultaneously at a series of positions between the roadway and the most distant residence of interest (290 Hanna Dr.). The measurements from the series of microphones is referred to in this report as "step-back" measurements, because the microphones were spaced at distances that doubled with respect to the distance from the roadway to the previous microphone for the series of positions. This procedure produces increasing distance between microphones with distance from the roadway such that the normal attenuation due to geometrical spreading of the sound waves will result in a constant decrease in sound level between the microphones. Typically, other factors such as ground attenuation will influence the rate of sound level decrease. However, using these procedures the influence of other factors will be apparent, showing up on a plot of sound levels as a deviation from a straight line from the first microphone to the last. Further, the measurements at each of these positions were made simultaneously to preclude any differences due to traffic and atmospheric variations and allow direct comparisons of the measured sound levels for each microphone position within a series.

The procedure outlined in the work plan of the proposal described the most direct means to achieve this objective, simultaneous measurements using a series of microphones between the I-76 roadway and the residence at 290 Hanna Dr. During the site reconnaissance step, however, the Ohio Department of Transportation technical liaison, the District 4 representative, and the principal investigator inspected this area and found it unsuitable to make these measurements. Therefore, the decision was made to address objective 1 by performing several series of simultaneous step-back measurements at other more suitable sites in the project area, and by performing an independent spot measurement at the 290 Hanna Dr. residence.

Sites 3, 4, and 5 were selected for the simultaneous step-back measurements. Each series included five microphone positions (24.6 ft (7.5 m) to 393.7 ft (120 m)) with the exception of the 24.6 ft (7.5 m) microphone at Site 3, as described above, and the 98.4 ft (30 m) microphone at Site 5, where the terrain was prohibitive. The procedure described above for the primary measurements using the spectrum analyzer was also used for the first two microphone positions for each of these measurements. However, a system comprised of a sound level meter and a digital recorder was used at each remaining microphone position in the series. During the measurements, an operator was monitoring these remote receivers to note any environmental or ambient noise interferences. The acoustic signal was directly recorded by the digital recorder for subsequent laboratory and analysis using the spectrum analyzer.

5.3 Community Spot Measurement Procedure

The residents at 290 Hanna Dr., in particular, had perceived an unacceptable deterioration in their noise environment subsequent to the reconstruction of I-76, and they had expressed their concern to the Ohio Department of Transportation. Therefore, spot noise measurements before and after the diamond grinding were planned for this location. However, the distance between the I-76 roadway and the residence was 2625 ft (800 m). Due to the long distance involved, it was anticipated that the atmospheric equivalence required for a valid comparison of before and after measurements would be nearly impossible to achieve. However, the acoustical data was collected and recorded on digital tape for subsequent sound level and frequency analysis in the laboratory.

5.4 System Calibration Procedure

Bias errors, though small, are to be expected with each receiver microphone system. These errors must be known and accounted for in order to provide valid comparisons between receivers. As a first step to the management of these errors the individual microphones, preamps, sound level meters (SLM), and digital audio tape recorders (DAT) required for each receiver location were never mixed but rather maintained as a system through a numbering system and always used for the same receiver position in a measurements series.
As a second step to the management of bias errors, a system correction curve was calculated for each SLM-DAT setup and each spectrum analyzer input channel. This correction was required to accurately compare noise levels at each receiver. To obtain this curve, all receivers and the RTA were set up close together (less than 1 foot between receivers) in a line 49.2 ft (15 m) from and parallel to the near travel lane. After a calibration tone was recorded at the beginning of each tape, all the receivers were set to simultaneously record traffic noise for 15 minutes. Subsequently, the tapes were all played back through Channel 1 of the spectrum analyzer. The difference between the taped levels for each microphone/digital recording system and the spectrum analyzer channel 1 levels (originally captured in the field) were tabulated for later use

as "system correction factors" to adjust for any bias errors within each microphone system. The goal of this procedure was to produce a measurement from each microphone system that would be essentially the same as if the Channel 1 of the spectrum analyzer had been used for the same measurement.

5.5 Traffic Data Acquisition

Traffic volume, classification, and speed data were collected and compiled by ODOT District 4 personnel for this project while traffic noise measurements were being made. Pneumatic tubes were placed at two locations within the project limits such that each microphone location had an accurate traffic count source not compromised by interchanges or lane merges. Speed data for Sites 1 and 2 was collected manually by laser speed detection for the before noise measurements, and speed data was automatically calculated by the pneumatic counters for all other sites for both before and after noise measurements.

6. DATA REDUCTION

6.1 DAT Tape Recording Format

All collected data was recorded to digital audio tape at a sample rate of 48 KHz and 16 bit resolution. Prior to recording the traffic noise, an acoustic calibrator was placed on the microphone producing a 94 dB, 1 KHz tone and was recorded at the beginning of the tape. This recorded tone was used to calibrate the spectrum analyzer during subsequent laboratory analysis of the tape recordings.

6.2 DAT Tape Analysis

Each tape was played back through the analyzer using the same DAT player/recorder that was used to make the initial recording. The player/recorder was connected to the direct input of the spectrum analyzer, which was then calibrated using the tone that was recorded to the tape in the field. Next the tape was played into RTA and analyzed just as if it was measuring the signal from the field microphones. After the analysis, the un-weighted 1/3 octave band data was copied to a spreadsheet for corrections and analysis.

6.3 Acoustical Corrections

The correction factors for the spectrum analyzer and the microphone/digital recording measurement systems generated by the procedure outlined in section 5.5 were applied to the un-weighted spectrum analyzer output in the spreadsheet. These correction factors were generally small (less than +/- .5dB). Next the A-weighted correction curve was applied to the un-weighted data and an A-weighted sum was calculated. These calculations were performed on the “before” and “after” measurements for all sites.

6.4 Traffic Data Reduction

Traffic volume, speed and classification in data was supplied in text file format by ODOT District 4. Data for time periods in which no acoustical data was being collected was discarded. The data that corresponded with the collected acoustical data was organized by travel lane in a spreadsheet. Once in the spreadsheet, lane specific values were combined to create total volumes and the corresponding mean speed for each vehicle classification.

7. DATA ANALYSIS

7.1 Acoustic Data Analysis

After the raw data was organized in a spreadsheet (see section 6), tables and figures were generated to display the data. Before/After and difference by frequency graphs were created for each receiver at all sites. Also, the average differences in level by both 1/3 octave frequency band and broadband A-weighted levels were plotted for the 24.6 ft (7.5 m) and 49.2 ft (15 m) microphone positions for all sites.

7.1.1 Community Spot Measurements

The acoustical data at the 290 Hanna Dr. location was collected before the diamond grinding in August under low wind conditions, but with a general wind direction of west. The I-76 traffic noise source was almost completely masked by the ambient noise in the neighborhood. The neighborhood noise included typical sounds in the neighborhood, such as lawn mowing and children playing, which were punctuated at times with hammering, sawing, and communication between workers involved in a carpentry project next door. The sound level shown in Figure 3 was measured from only a few seconds of recorded noise that was found on the tape to have very low ambient noise, even so the traffic noise was nearly imperceptible. The acoustical data was collected after the diamond grinding in December under low wind conditions; however, the general wind direction was south. The lower ambient neighborhood noise level, which is typical for the winter months compared to the summer months, differences in ground attenuation (described in Appendix A) and the difference in meteorological conditions are the main causes for the increased levels measured subsequent to diamond grinding.

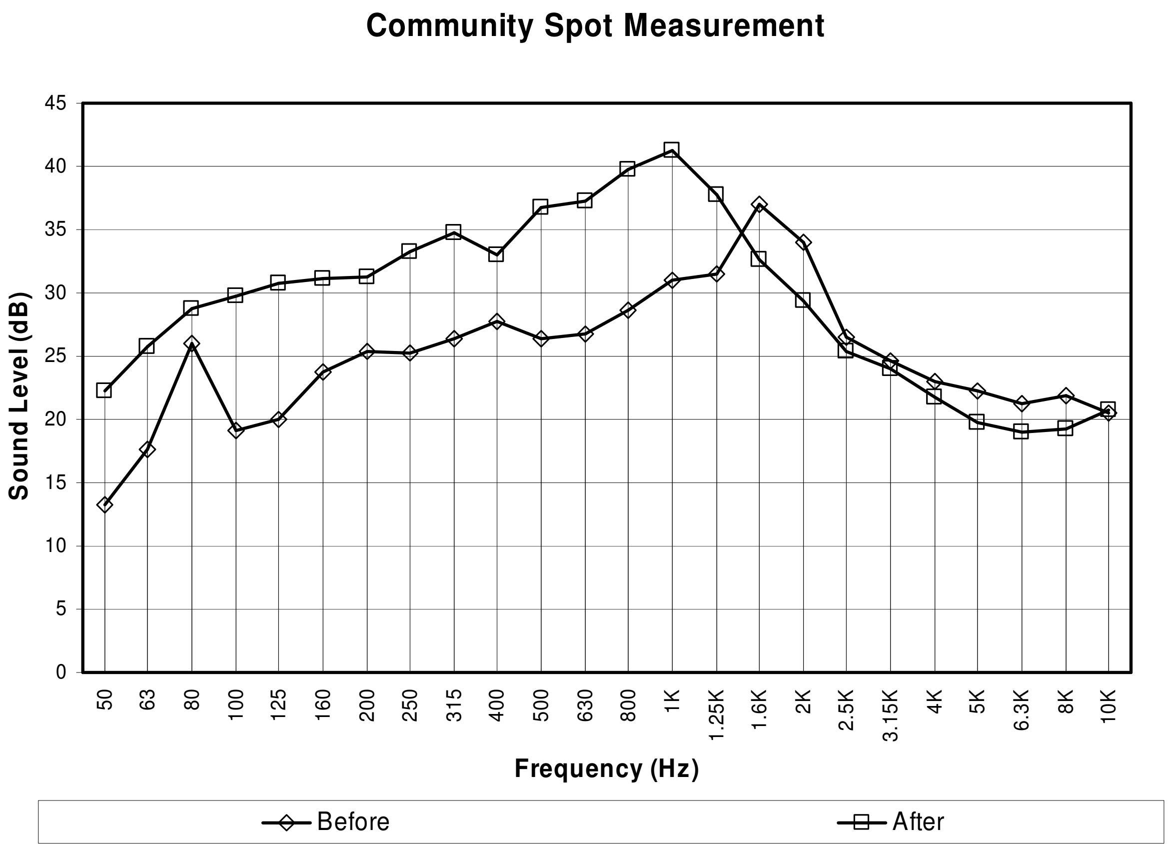

Figure 3: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding at 290 Hanna Dr.

Previous ODOT sponsored research has shown meteorological effects on sound level measurements to be substantial. The extensive meteorological monitoring used in conjunction with step-back traffic noise measurements for this research demonstrated that cross wind speed, wind shear, lapse rate, and turbulence all influence the attenuation experienced at the various microphone positions, which ranged to over 1312 ft (400 m) from the traffic noise source. In the field, each of these variables was found to fluctuate almost continuously. The effect of these fluctuations on noise attenuation depended on the combination of individual variables at any one time. Further, these meteorological effects increased in magnitude as the distance from source to receiver increased. At the 1312 ft (400 m) distance the sound level was found to be attenuated under modest downwind conditions by as much as 12 dB, depending on the other atmospheric variables, while the level was increased under upwind conditions by as much as 8 dB. [Herman et al. 2002]. These results suggest that atmospheric conditions will often affect the sound environment for receivers at such distant locations by greater magnitudes than the magnitudes associated with many abatement strategies.

7.2 Traffic Data Analysis

The tabulated traffic data is shown in Table 1. As expected there were differences in the traffic volumes, classifications, and speeds between the "before" and "after" measurements. The Federal Highway Administration's Traffic Noise Model (TNM) was used to predict the effect of the differences in these traffic parameters on the traffic noise measurements, as described in the next section.

Table 1: Traffic count and speed data collected before and after diamond grinding.

	Before Measurements				After Measurements			
Data Description	Cars	Medium Trucks	Heavy Trucks	Avg. Speed (MPH)	Cars	Medium Trucks	Heavy Trucks	Avg. Speed (MPH)
<u>Site 1</u>								
Eastbound Slow Lane……..	507	33	276	61.8	450	41	270	69.9
Eastbound Fast Lane……..	476	6	44	68.3	487	4	51	72.7
Westbound Fast Lane…….	564	5	60	67.8	630	8	45	76.5
Westbound Slow Lane…….	464	34	307	60.5	445	20	281	59.3
Totals………………………..	2011	78	687	64.6	2012	73	647	69.6
<u>Site 2</u>								
Eastbound Slow Lane……..	534	22	281	61.5	349	22	230	66.6
Eastbound Fast Lane……..	497	2	67	67.1	444	4	25	73.1
Westbound Fast Lane…….	610	12	69	68.46	552	6	58	75.5
Westbound Slow Lane…….	431	28	334	61.7	434	21	282	59.1
Totals………………………..	2072	64	751	64.7	1779	53	595	68.6
<u>Site 3</u>								
Eastbound Slow Lane……..	539	31	263	62.7	601	31	243	67.0
Eastbound Fast Lane……..	457	5	39	72.5	623	3	35	71.5
Westbound Fast Lane…….	603	7	48	error	881	6	43	72.7
Westbound Slow Lane…….	480	30	277	59.8	644	26	204	62.9
Totals………………………..	2079	73	627	65.0	2749	66	525	68.5
<u>Site 4</u>								
Eastbound Slow Lane……..	452	20	266	62.0	1069	12	183	61.6
Eastbound Fast Lane……..	594	9	72	69.5	1167	0	66	71.0
Westbound Fast Lane…….	728	8	66	72.2	968	6	42	71.4
Westbound Slow Lane…….	516	29	308	61.5	741	16	173	62.0
Totals………………………..	2290	66	712	66.3	3945	34	464	66.5
<u>Site 5</u>								
Eastbound Slow Lane……..	602	36	220	61.2	521	39	295	65.3
Eastbound Fast Lane……..	577	3	47	66.2	753	6	63	77.0
Westbound Fast Lane…….	762	10	57	67.2	717	2	48	75.4
Westbound Slow Lane…….	565	31	291	63.5	560	29	261	58.6
Totals………………………..	2506	80	615	64.5	2551	76	667	69.1

7.3 <u>TNM Simulation Analysis</u>

Using the reduced traffic data corresponding to each measurement period, a TNM simulation of a typical roadway section in the project area was made to determine the theoretical difference in noise levels between the "before" and "after" measurements. Table 2 shows the results of the simulation for the 24.6 ft (7.5 m) and 49.2 ft (15 m) microphone positions. The results of this analysis were then used to adjust the broadband A- weighted levels shown in the Results section. While the TNM results, being broadband levels only, could not be used to adjust the 1/3 octave frequency band levels, they do provide an indication of the relatively small acoustical errors associated with the "before" and "after" traffic differences.

Table 2: Generated TNM differences due to traffic.

	Sound Level (dB)	
	24.6 ft (7.5m)	49.2 ft (15m)
Site 1		
Before………………….	78.2	74.1
After…………………….	78.8	74.7
Difference……………..	0.6	0.6
Site 2		
Before………………….	78.3	74.6
After…………………….	77.7	73.8
Difference……………..	-0.6	-0.8
Site 3		
Before………………….	78.1	74.1
After…………………….	78.2	74.1
Difference……………..	0.1	0.0
Site 4		
Before………………….	78.3	74.5
After…………………….	77.6	73.7
Difference……………..	-0.7	-0.8
Site 5		
Before………………….	78.5	74.1
After…………………….	78.1	74.5
Difference……………..	-0.4	0.4

7.4 Atmospheric Data Analysis

Atmospheric and environmental data was collected and used to establish the degree to which atmospheric equivalence was achieved between "before" and "after" measurements. The following table represents the conditions present during each field measurement.

Table 3: Average environmental conditions

	Average Ambient Temp °F (°C)	Average Pavement Temp °F (°C)	Average Relative Humidity (%)	Average Wind Speed mi/h (km/h)	Average Wind Direction
Site 1					
Before……………….	81 (27)	82 (28)	61	4 (7)	ENE
After………………….	46 (8)	39 (4)	70	1 (2)	SSE
Site 2					
Before……………….	81 (27)	82 (28)	82	5 (8)	WNW
After………………….	46 (8)	45 (7)	71	1 (2)	S
Site 3					
Before……………….	72 (22)	75 (24)	63	1 (2)	S
After………………….	48 (9)	36 (2)	56	3 (4)	S
Site 4					
Before……………….	75 (24)	86 (30)	55	5 (8)	WSW
After………………….	37 (3)	39 (4)	76	1 (2)	W
Site 5					
Before……………….	70 (21)	75 (24)	62	2 (3)	NNE
After………………….	45 (7)	37 (3)	76	3 (5)	ESE

There were atmospheric differences between "before" and "after" measurements as anticipated. The significance of these differences can be realized by referring to criteria established in the international standard for the statistical pass-by method of tire/road noise measurement [International Organization for Standardization 1994]. These criteria were developed for the measurement of absolute noise levels and are therefore necessarily more stringent than the criteria needed for a study such as this one where the differences in noise levels are of primary interest. This standard requires that the wind speed be less than 11.2 mi/h (5 m/sec), the atmospheric temperature between 41 and 86 °F (5 and 30 °C), and the pavement temperature be between 41 and 122 °F (5 and 50 °C) during the measurements. These requirements were only exceeded by a relatively small amount in several instances.

8. RESULTS

8.1 Objective 1 Results

Objective 1, the collection of traffic noise level and frequency data to characterize the traffic noise sound field between the roadway and the most distant residence of interest, was achieved through the procedures described in Sections 5, 6, and 7. This data was then used to achieve objectives 2 and 3.

8.2 Objective 2 Results

Objective 2, the identification of traffic noise level and frequency differences due to the re-texturing of the pavement surface, was achieved by considering the primary measurement data. This data was obtained from the 24.6 ft (7.5 m) and 49.2 ft (15 m) microphone positions at each site, with the exception of the 24.6 ft (7.5 m) microphone for Site 3, as noted in the measurement procedures of Section 5. Tables and figures have been created to display this data from several perspectives for each microphone receiver at each site. These tables and figures have been included in the report appendix.

8.2.1 Spectral Data Results

The table and figures of frequency band data from the 24.6 ft (7.5 m) microphone position at both Site 1 and Site 5 are shown below. The data from these two sites was chosen for display in this section in order to provide the reader with the range in results observed for the 24.6 ft (7.5 m) microphone position in this study. The smallest reduction in noise levels due to the diamond grinding was observed at Site 1 and the greatest reduction in noise levels was observed at Site 5. Note, this data has not been corrected for any differences in traffic between before and after measurements. However, the analysis of predicted noise level differences due to observed differences in traffic conditions, as described in Section 7, suggests that the actual corrections, if known, would be quite small or negligible for each frequency band.

Table 4 shows the measured sound level, A-weighted, for each one-third octave frequency band at the 24.6 ft (7.5 m) microphone position, before and after the diamond grinding for Site 1. The broadband sum of all frequency bands and the difference between before and after measurements is also shown. Note the 2.7 dB broadband noise level reduction, attributed to the diamond grinding, is also uncorrected for any differences in traffic conditions. The corrected values are given below in the broadband results.

Table 4: Equivalent continuous sound level, A-weighted by 1/3 octave frequency band for the 24.6 ft (7.5 m) microphone location at Site 1.

Frequency (Hz)	Site 1, 7.5m (Before)	Site 1, 7.5m (After)	Difference
50	40.6	40.3	-0.3
63	49.6	48.1	-1.5
80	54.4	55.5	1.1
100	54.2	54.5	0.3
125	56.7	56.5	-0.2
160	60.7	60.0	-0.7
200	63.8	63.1	-0.7
250	64.5	63.8	-0.7
315	66.8	65.7	-1.1
400	69.1	67.4	-1.7
500	73.4	72.7	-0.7
630	74.3	73.8	-0.5
800	77.0	75.2	-1.8
1K	78.7	75.8	-2.9
1.25K	78.2	74.3	-3.9
1.6K	76.4	72.0	-4.4
2K	74.2	69.4	-4.8
2.5K	71.1	66.8	-4.3
3.15K	68.1	64.0	-4.1
4K	65.8	61.7	-4.1
5K	63.4	58.9	-4.5
6.3K	61.1	57.0	-4.1
8K	58.1	54.7	-3.4
10K	54.4	52.0	-2.4
Sum	85.5	82.8	-2.7

The one-third octave frequency band data from Table 4 is displayed in Figure 4. The greatest differences between the before and after measurements at Site 1 occur in the higher frequencies, especially those at or greater than 1000 Hz. Therefore, most of the effectiveness of the diamond grinding can be attributed to differences in the higher frequencies, for Site 1. These differences are displayed separately in Figure 5 where the greatest reduction, 4.8 dB, occurred in the one-third octave frequency band centered at 2 kHz. There seems to be a transition in the effectiveness of the diamond grinding in the lower frequencies, as evidenced by the alternating positive and negative differences in the lower frequencies. The presence of this transition suggests that the effect of longitudinal grooves in concrete pavement is similar to transverse grooves at these frequencies.

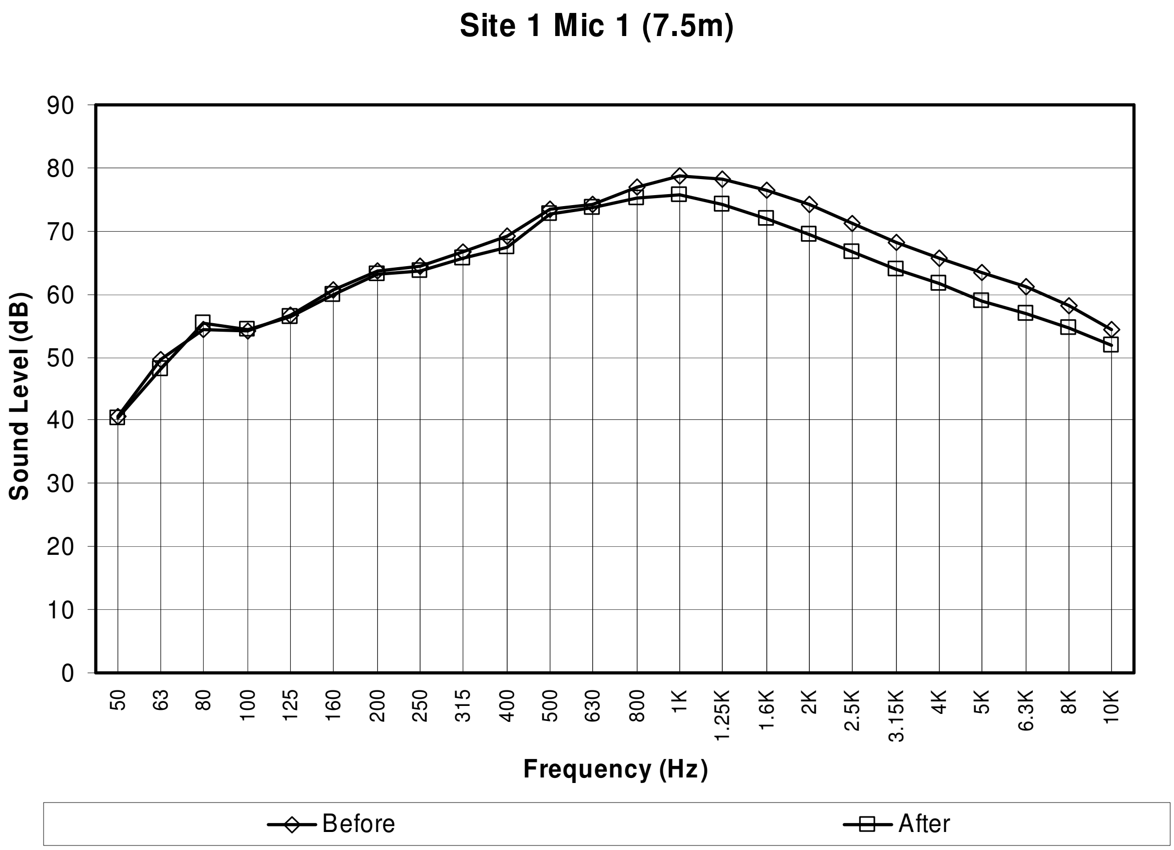

Figure 4: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 24.6 ft (7.5 m) microphone location at Site 1.

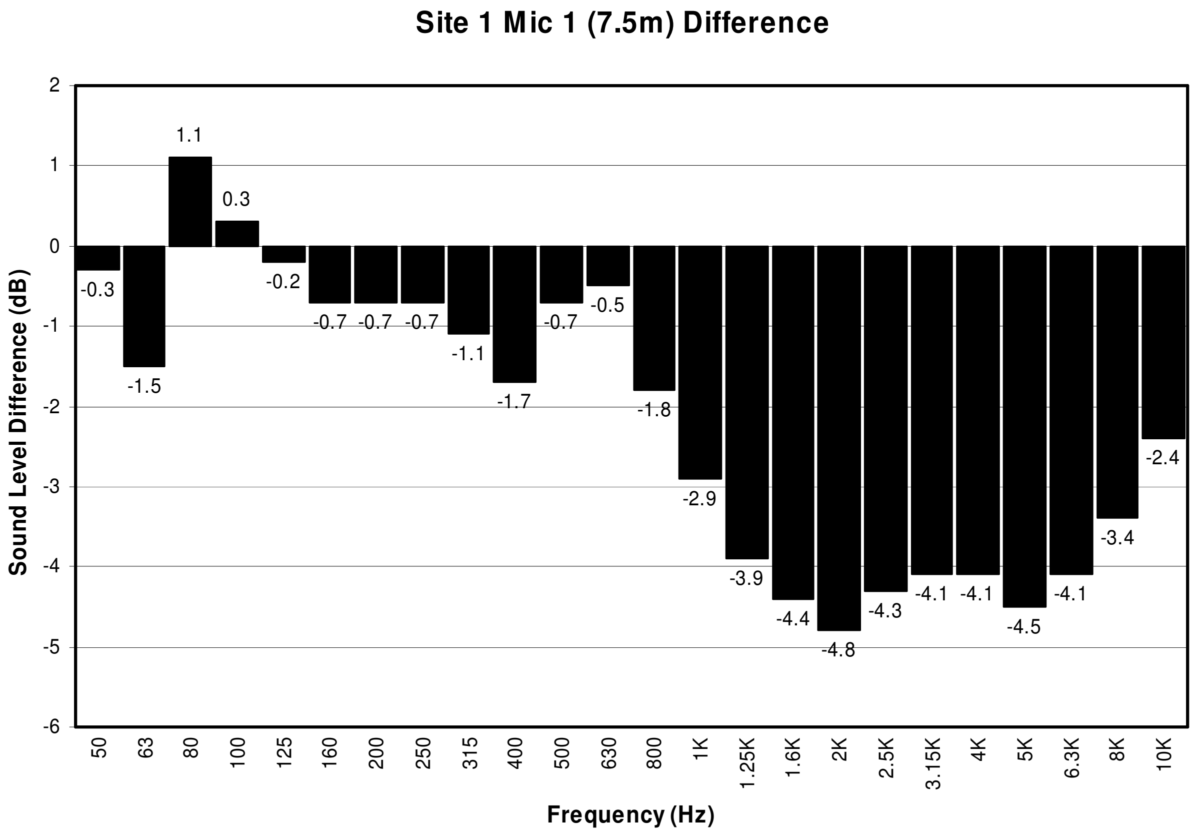

Figure 5: The difference in equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 24.6 ft (7.5 m) microphone location at Site 1.

The greatest broadband traffic noise level reduction due to the diamond grinding occurred at Site 5, as shown in Table 5. The one-third octave frequency band data from Table 5 is displayed in Figure 6.

Table 5: Equivalent continuous sound level, A-weighted by 1/3 octave frequency band for the 24.6 ft (7.5 m) microphone location at Site 5.

Frequency(Hz)	Site 5, 7.5m (Before)	Site 5, 7.5m (After)	Difference
50	41	38.8	-2.2
63	48.6	49.5	0.9
80	53.5	53.4	-0.1
100	54.8	54.1	-0.7
125	58	56.4	-1.6
160	61.1	58.1	-3
200	64.5	61.5	-3
250	65.1	62.6	-2.5
315	67.2	63.5	-3.7
400	70.2	65.6	-4.6
500	73.9	71.5	-2.4
630	75.1	71	-4.1
800	77.9	73.9	-4
1K	79.8	75.3	-4.5
1.25K	79.3	73.9	-5.4
1.6K	77.7	72	-5.7
2K	75	69.3	-5.7
2.5K	71.8	66.2	-5.6
3.15K	68.5	63.3	-5.2
4K	66	60.9	-5.1
5K	63.6	58.7	-4.9
6.3K	61.3	56.5	-4.8
8K	58.5	54.5	-4
10K	55.4	52.3	-3.1
Sum	86.5	81.9	-4.6

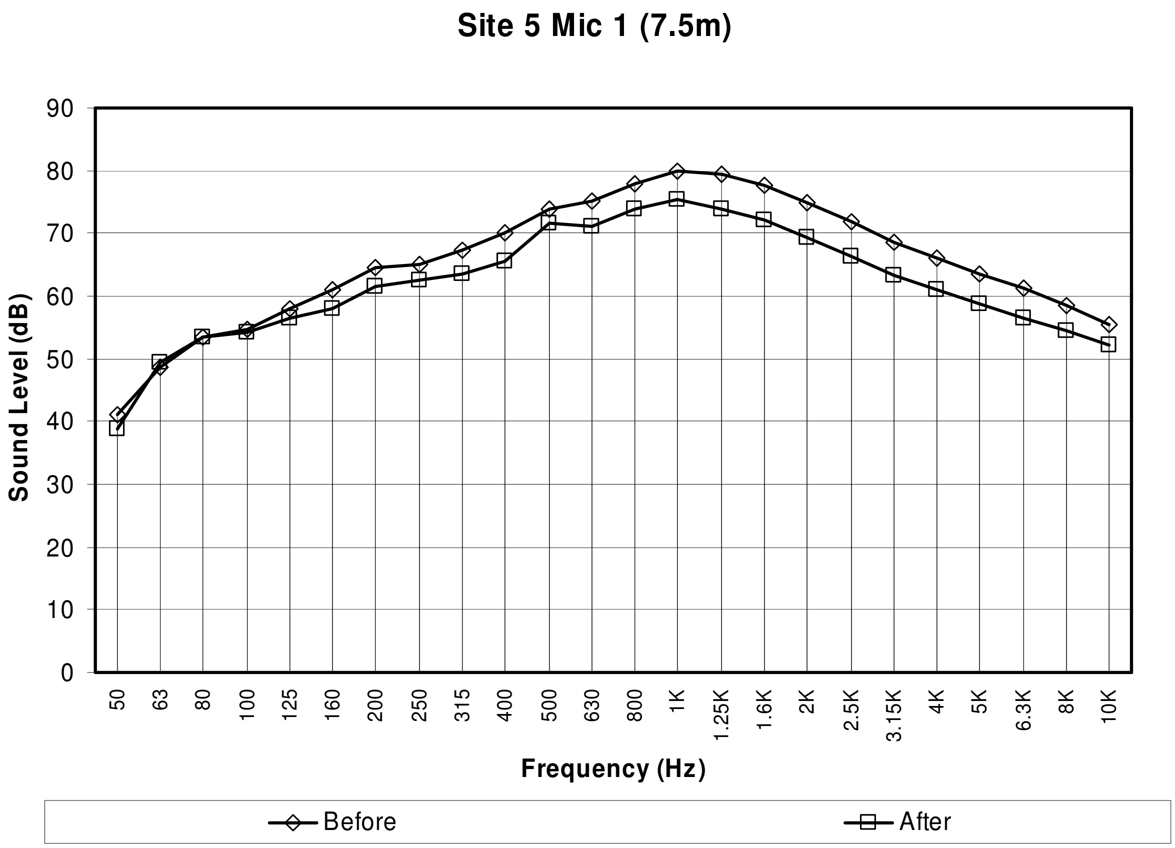

Figure 6: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 24.6 ft (7.5 m) microphone location at Site 5.

Not only was there a greater difference in the higher frequency bands at Site 5 than those measured for Site 1, but also there were observed differences in the frequency bands, even as low as 125 Hz. These differences are displayed separately in Figure 7, where the greatest reduction, 5.7 dB, occurred in the one-third octave frequency bands centered at 1.6 kHz and 2 kHz. As observed for Site 1, there seems to be a transition in the effectiveness of the diamond grinding in the lowest frequencies, as evidenced by the alternating positive and negative differences.

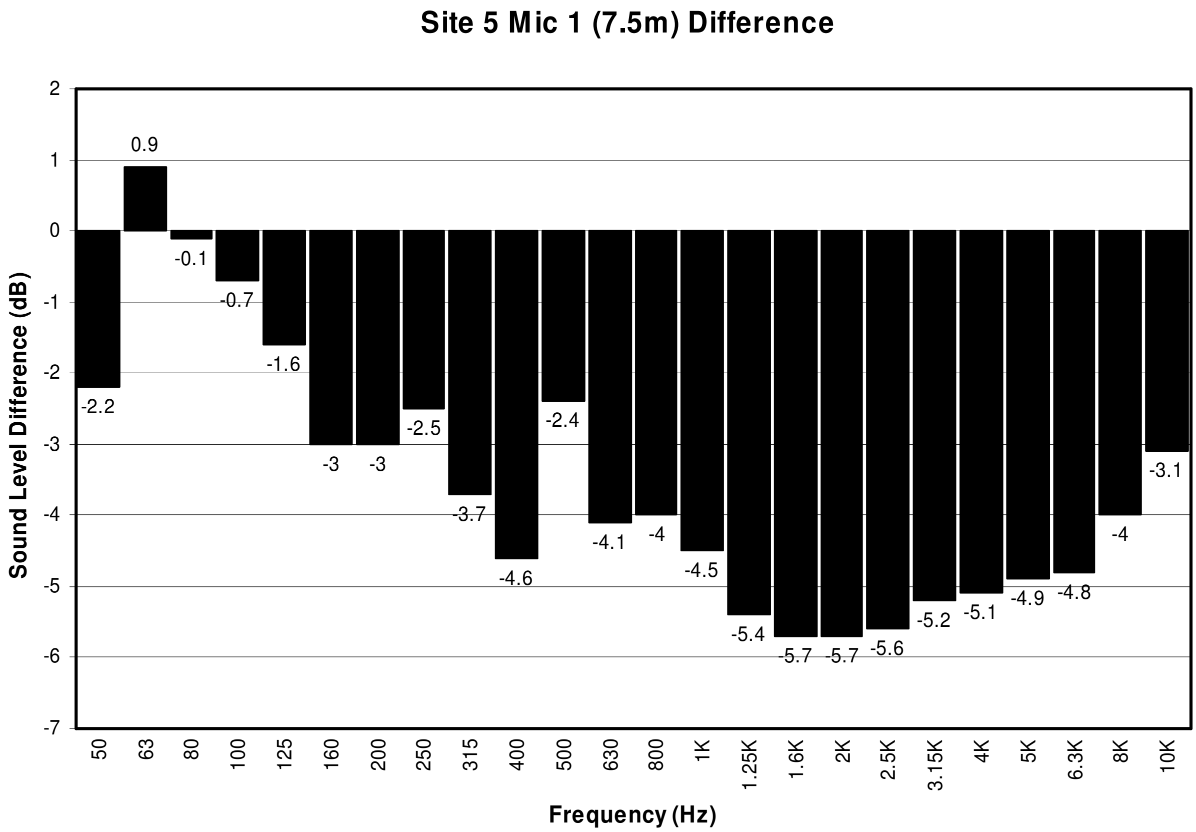

Figure 7: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 24.6 ft (7.5 m) microphone location at Site 5.

While Site 1 represents the smallest, and Site 5 the greatest reduction in traffic noise levels for the primary measurements, it is the mean values of all the primary measurements that provide the best estimate of the expected benefit of diamond grinding if one were to measure at an arbitrary site in the project area. To obtain this estimate the measured values for each one-third octave frequency band were averaged for all sites, for both the 24.6 ft (7.5 m) and the 49.2 ft (15 m) microphone positions. The results are shown in Table 6.

Table 6: Average equivalent continuous sound level, A-weighted by 1/3 octave frequency band for the 24.6 ft (7.5 m) and 49.2 ft (15 m) microphone locations.

Frequency (Hz)	Average Before 7.5m (dB)	Average After 7.5m (dB)	Average Before 15m (dB)	Average After 15m (dB)
50	40.7	39.2	37.2	36.2
63	49.4	49.2	46.8	46.8
80	54.5	54.8	52.4	52.8
100	54.8	54.8	52.1	52.2
125	57.1	56.9	53.4	53.6
160	60.3	59.2	56.3	55.7
200	64.2	61.9	59.9	58.1
250	65.1	62.9	61.0	59.4
315	67.1	64.5	62.9	60.8
400	69.4	66.4	65.2	62.7
500	73.7	71.4	69.8	67.7
630	74.7	71.7	70.1	68.2
800	77.5	74.4	72.6	70.4
1K	79.3	75.7	74.7	72.0
1.25K	79.0	74.3	74.9	71.0
1.6K	77.2	72.2	73.4	69.1
2K	74.8	69.5	70.9	66.2
2.5K	71.5	66.7	68.3	63.6
3.15K	68.4	63.9	65.3	60.5
4K	66.0	61.5	62.8	57.7
5K	63.7	59.0	59.9	54.4
6.3K	61.5	56.9	57.5	51.9
8K	58.7	54.9	55.1	49.3
10K	55.4	52.4	51.7	46.8
Sum	86.1	82.3	81.9	78.7

The mean measured values given in Table 6 are also plotted in Figure 8 and Figure 9 for the 24.6 ft (7.5 m) microphone positions and the 49.2 ft (15 m) microphone positions, respectively. Most of the observed noise level reduction due to the diamond grinding appears to occur at frequency bands greater than 160 Hz, on the average, though the higher frequencies display the greatest differences between before and after levels. These average differences are shown in Figure 10 and Figure 11 for the 24.6 ft (7.5 m) microphone positions and the 49.2 ft (15 m) microphone positions, respectively. When all of the primary measurements are considered, the greatest reduction in noise levels, attributed to the diamond grinding, occurs at 2 kHz for the 24.6 ft (7.5 m) microphone positions and at 8 kHz for the 49.2 ft (15 m) microphone positions.

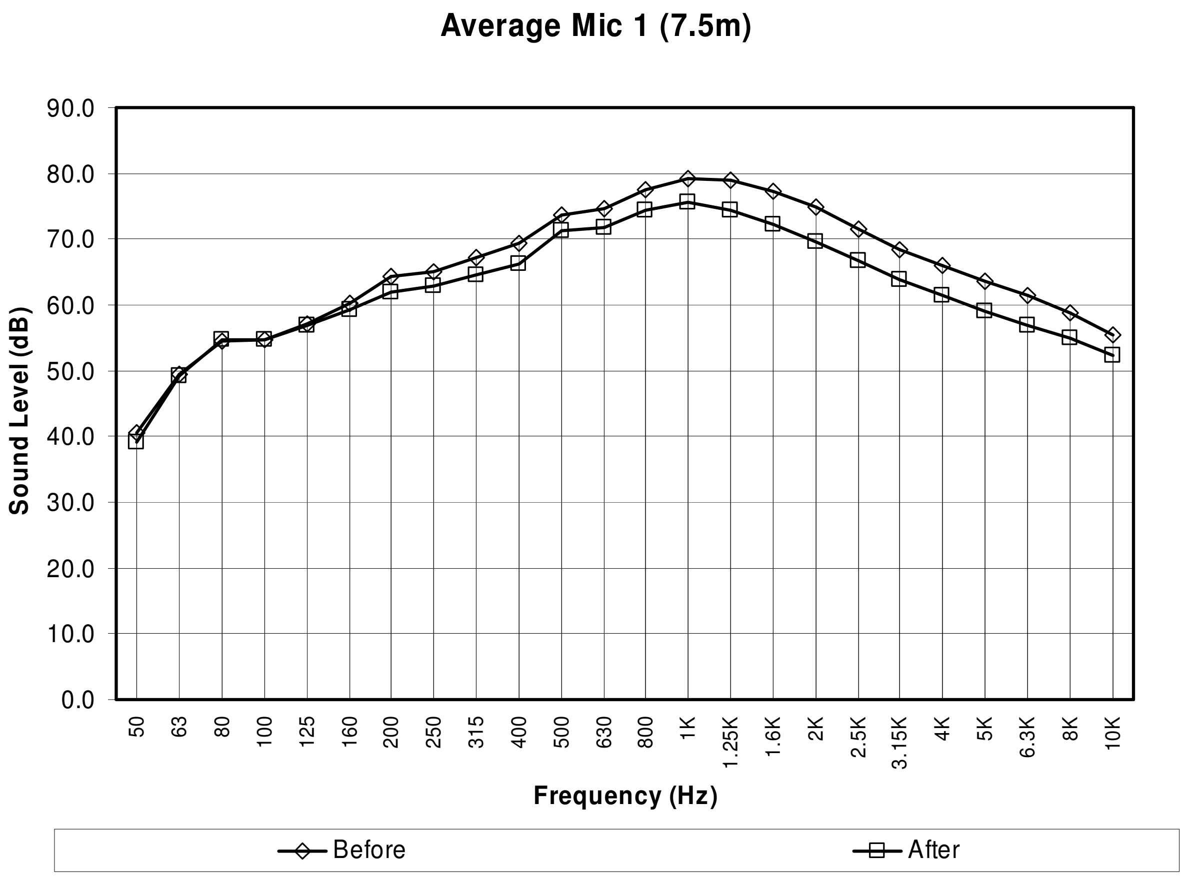

Figure 8: Average equivalent continuous sound level, A-weighted by 1/3 octave frequency band for the 24.6 ft (7.5 m) microphone location.

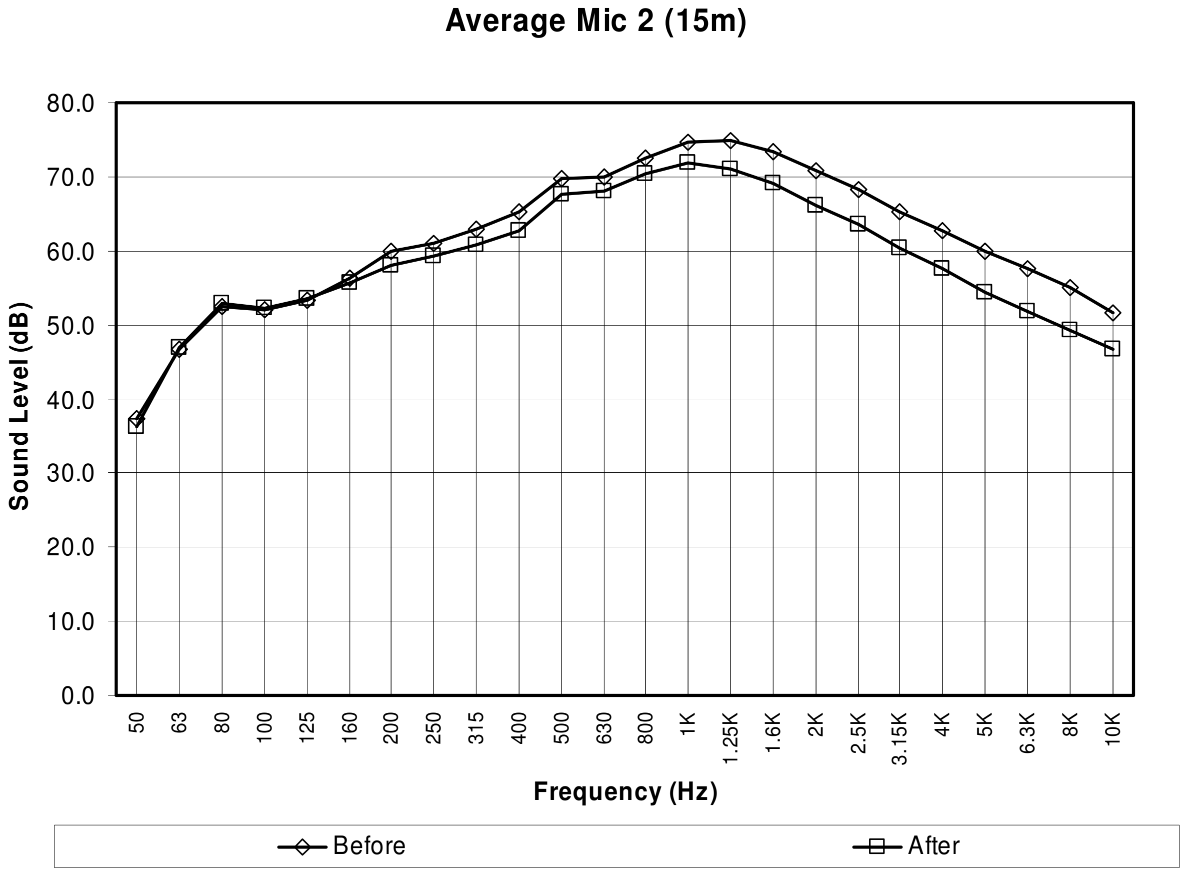

Figure 9: Average equivalent continuous sound level, A-weighted by 1/3 octave frequency band for the 49.2 ft (15 m) microphone location.

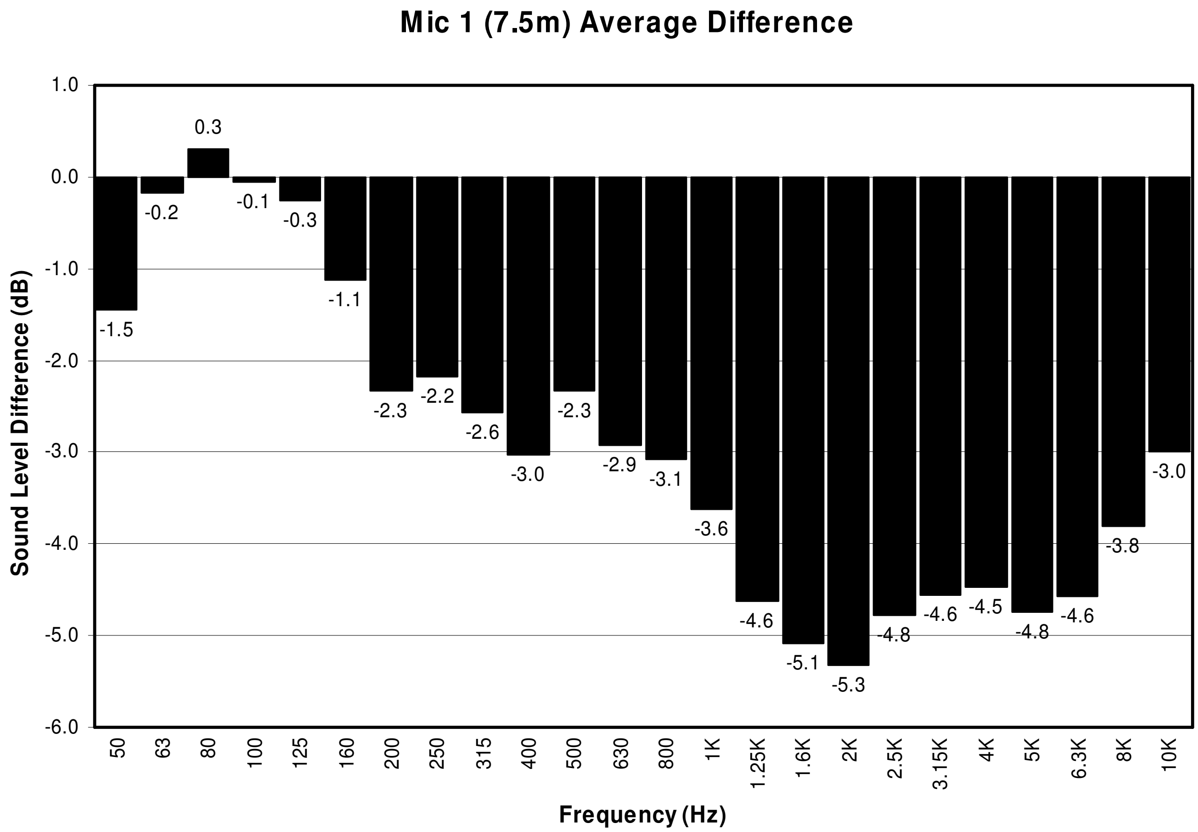

Figure 10: Average equivalent continuous sound level difference, A-weighted by 1/3 octave frequency band for the 24.6 ft (7.5 m) microphone location.

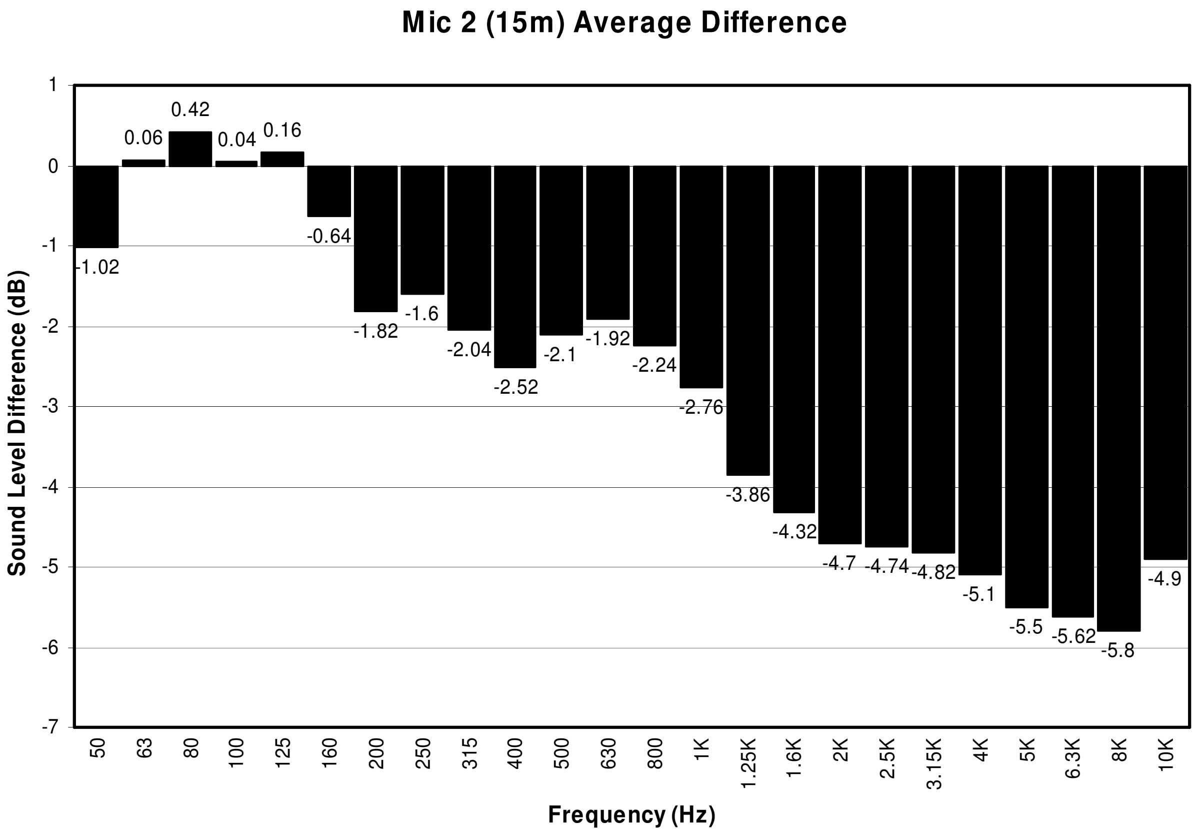

Figure 11: Average equivalent continuous sound level difference, A-weighted by 1/3 octave frequency band for the 49.2 ft (15 m) microphone location.

8.2.2 Broadband Results

The differences in before and after broadband traffic noise levels, A-weighted, for the primary measurements at the 24.6 ft (7.5 m) and 49.2 ft (15 m) microphone positions are shown in Table 7. The uncorrected differences from the previous tables are shown, along with the TNM correction derived from the predictions based upon before and after traffic differences. Finally, the corrected difference in broadband microphone levels at each site, for each primary microphone position is also calculated and shown in the table and plotted in Figure 12. The mean broadband noise level difference, attributed to diamond grinding, of 3.5 dB for the 24.6 ft (7.5 m) microphone and 3.1 dB for the 49.2 ft (15 m) microphone is also shown in the Figure 12.

Table 7: The differences in before and after broadband traffic noise levels, A-weighted, for the primary measurements at the 24.6 ft (7.5 m) and 49.2 ft (15 m) microphone locations with TNM corrections.

	Sound Level (dB)	
	7.5m	15m
Site 1		
Before…………………..	85.5	81.1
After…………………….	82.8	78.7
Difference……………..	-2.7	-2.4
TNM Correction……….	0.6	0.6
Corrected Difference….	-3.3	-3.0
Site 2		
Before…………………..	85.5	81.1
After…………………….	81.7	77.8
Difference……………..	-3.8	-3.3
TNM Correction……….	-0.6	-0.8
Corrected Difference….	-3.2	-2.5
Site 3		
Before…………………..	x	82.7
After…………………….	x	79.8
Difference……………..	x	-2.9
TNM Correction……….	x	0.0
Corrected Difference….	x	-2.9
Site 4		
Before…………………..	86.9	81.8
After…………………….	82.8	78.9
Difference……………..	-4.1	-2.8
TNM Correction……….	-0.7	-0.8
Corrected Difference….	-3.4	-2.0
Site 5		
Before…………………..	86.5	82.9
After…………………….	81.9	78.4
Difference……………..	-4.6	-4.5
TNM Correction……….	-0.4	-0.4
Corrected Difference….	-4.2	-4.9

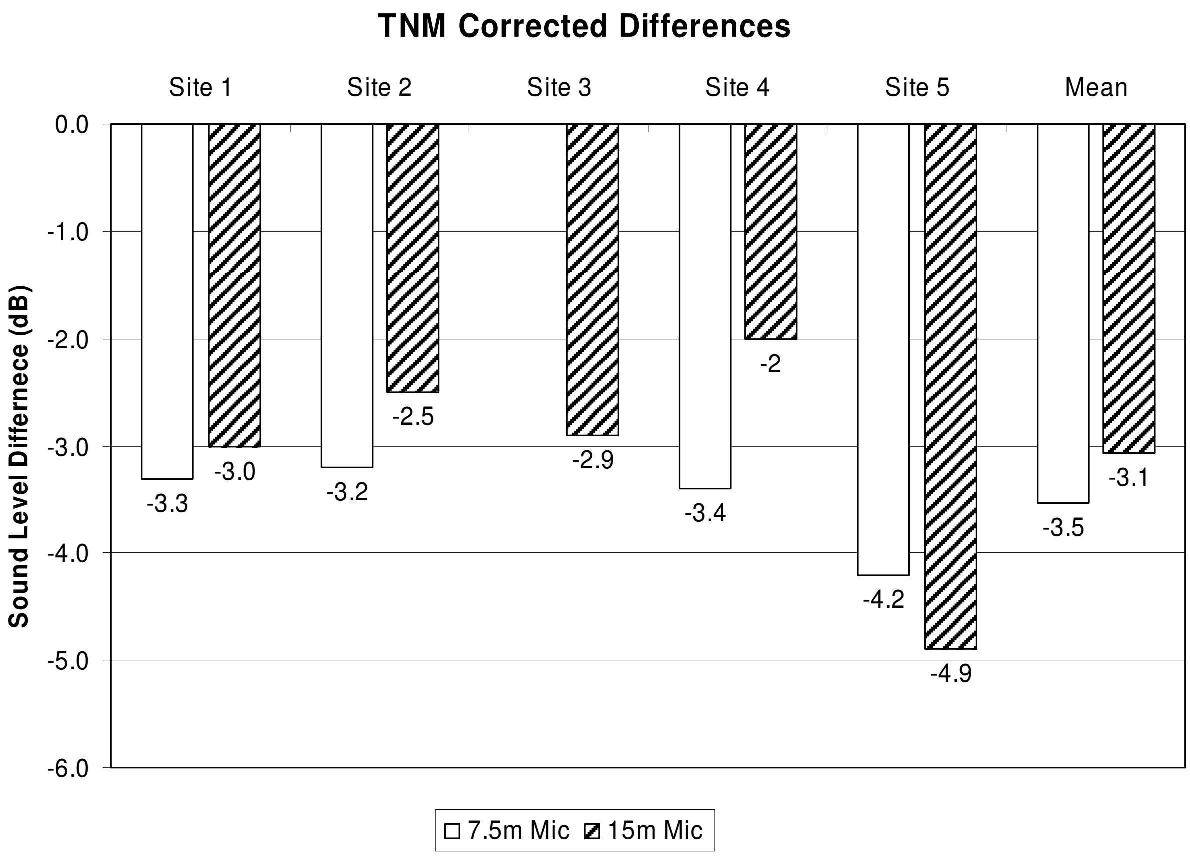

Figure 12: The differences in before and after broadband traffic noise levels, A-weighted, for the primary measurements at the 24.6 ft (7.5 m) and 49.2 ft (15 m) microphone locations with TNM corrections.

8.3 Objective 3 Results

Objective 3, the identification of traffic noise level and frequency differences, due to the re-texturing of the pavement surface, that correlate with distance from the source, was achieved by considering the measurements made at Sites 3, 4, and 5. These measurements have been referred to as "step-back" measurements due to the locations of the microphones at spacings that double with distance from the source. The differences in broadband traffic noise levels between those measured before and after diamond grinding at these sites are displayed in Figure 13, by microphone distance. The average difference between before and after levels for the three sites is indicated by the line shown in the figure. These differences represent the effect of diamond grinding. The effect diminishes with distance. The line representing the mean values indicates a 1.5 dB reduction in the differences from the 49.2 ft (15 m) location to the 393.7 ft (120 m) location. Part of this difference is due to the fact that higher frequency noise is attenuated over the path of propagation more readily than low frequency noise. Therefore, as distance increases the higher frequencies contribute less to the total noise level. Further, spectral analysis of these sites exposed an anomaly in the lower frequencies for the more distant microphone locations. A detailed investigation of this anomaly led to the explanation that attenuation mechanisms (mostly ground attenuation) were different for the measurements made after diamond grinding. Therefore, the sound levels were not attenuated as much at the distant receivers for the after measurements.   Most likely these trends combined to produce the results of Figure 13 in which it appears that the effect of diamond grinding was diminished with distance from the roadway. Furthermore, the effect is not uniform, and the data becomes more scattered with distance. These variations from site to site were not unexpected. The farther a sound wave propagates from its source the more it is affected by variations in the local terrain and other site-specific physical features, all of which influence the rate at which the various sound attenuation mechanisms dissipate sound energy.

Therefore, the primary measurements are used to directly gage the effect of diamond grinding, and the step-back measurements are used to provide an indication of the range of diamond grinding effectiveness expected for residents living in the second or third row of houses from the highway.

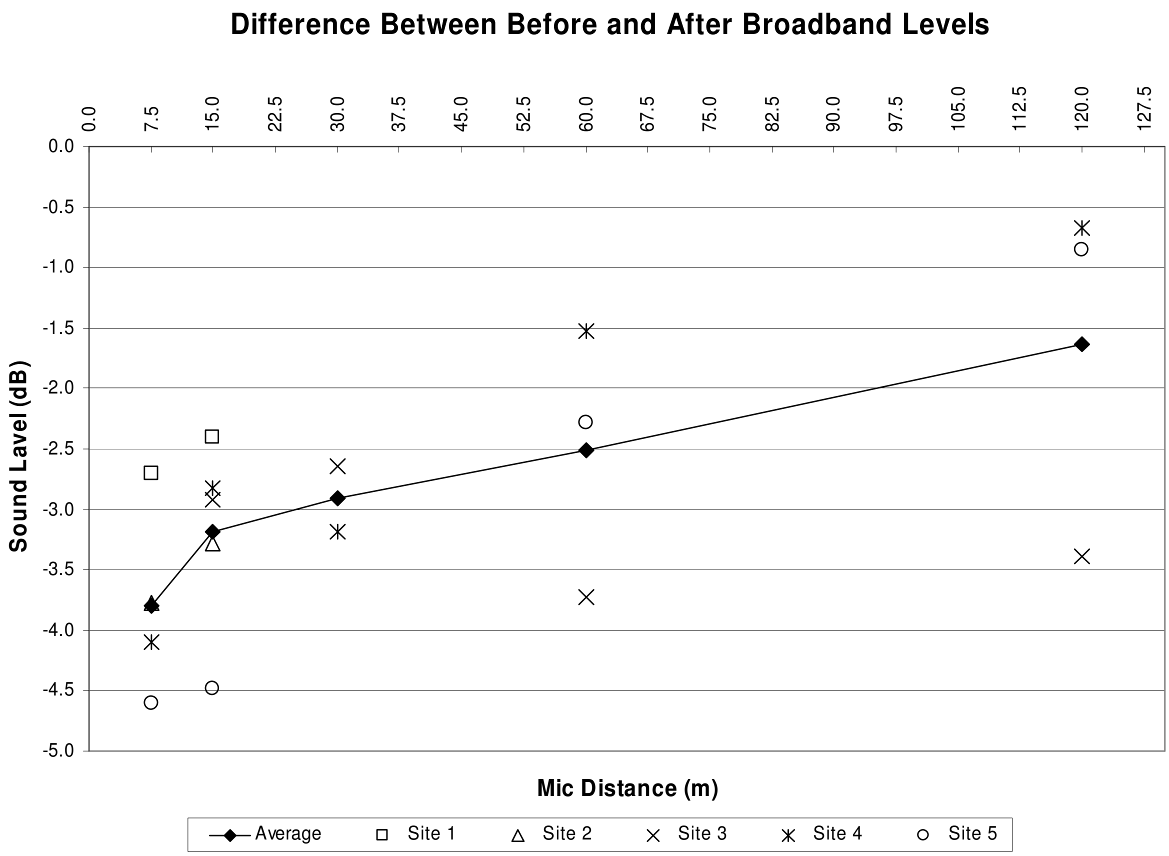

Figure 13: The differences in broadband levels between before and after diamond grinding.

The detailed investigation of the anomaly mentioned above is described in Appendix A. The results of the spectral analysis of the traffic noise level measurements at the three step-back sites are provided in Appendix A using the same table and figure format as used for the primary measurements.

9. CONCLUSIONS

9.1 Conclusions

The analysis of the traffic noise measurements made before and after retexturing the Portland cement concrete pavement to change the random transverse grooves to longitudinal grooves resulted in the following findings:

1. The reduction in broadband noise at the 24.6 ft (7.5 m) distance from the centerline of the near travel lane ranged from 3.2 dB to 4.2 dB, while the range for the 49.2 ft (15 m) distance was 2.0 dB to 4.9 dB.

2. The average reduction in broadband noise for 4 test sites at 24.6 ft (7.5 m) from the center of the near travel lane was 3.5 dB, and the average reduction for the 15m location for 5 sites was 3.1 dB.

3. Spectrum analysis showed the greatest reduction in noise occurred at frequencies above 1 kHz and that the retexturing had little to no effect on frequencies less than 200 Hz.

4. The effect of diamond grinding initially appeared to have diminished with distance, since the mean difference between before and after levels was reduced, on the average, by 1.5 dB between the 49.2 ft (15 m) and 393.7 ft (120 m) distances from the roadway. However, further analysis suggests that a difference in ground attenuation between "before" and "after" measurements was responsible for this trend. Therefore, under equivalent conditions the effect of diamond grinding is predicted to diminish little, if any, for the range of distances measured.

9.2 Recommendations

1. For future cases where ODOT is concerned about traffic noise levels at sites with random transverse tined concrete pavement, diamond grinding should be considered. It is an effective mitigation strategy providing an expected overall average noise level reduction of 3 dB or more for receivers located adjacent to the roadway.
2. ODOT should consider the development of a new surface texture specification for concrete pavements to replace the current specification (451.09) in order to reduce tire/pavement noise levels while maintaining or improving safety and durability characteristics.

9.3 Implementation

Based on the findings from this study, the following implementation steps are suggested.

1. Initiate a temporary moratorium on the use of transverse-tined PCC pavement on projects with noise sensitive land uses within 200 m of the roadway.

2. Consider an additional study to determine the cost effectiveness of widespread use of diamond grinding on other projects.

3. Consider an additional study of locations where noise barriers have been installed while simultaneously replacing the original asphalt pavement with transverse tined concrete pavement.

This study should address the following:

a. Does the replacement of transverse tined concrete pavement negate, or partially negate, the benefit of noise barrier installation?

b. If the effectiveness of noise barriers has been compromised at these locations, what is the estimated cost to restore the full effectiveness of the noise barriers?

c. What policy changes should be made with regard to pavement selection and its effect on noise abatement design and mitigation efforts?

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11. APPENDIX A

Step-back Measurement Results and Analysis

The measured noise level after diamond grinding was higher than the level measured before diamond grinding for a number of the lower frequency bands for the 196.9 ft (60 m), and 393.7 ft (120 m) microphone distances. While some variation in spectral content is expected due to slight differences in the traffic noise source, this observation was unexpected because the measurements at the 24.6 ft (7.5 m) and 49.2 ft (15 m) microphone distances did not give such a result. The most extreme example of this phenomenon occurred at the 196.9 ft (60 m) microphone position at Site 3 and is shown in Figure 14. In the figure the measurement after diamond grinding shows as much as a 7 dB increase at the 250 Hz frequency band.

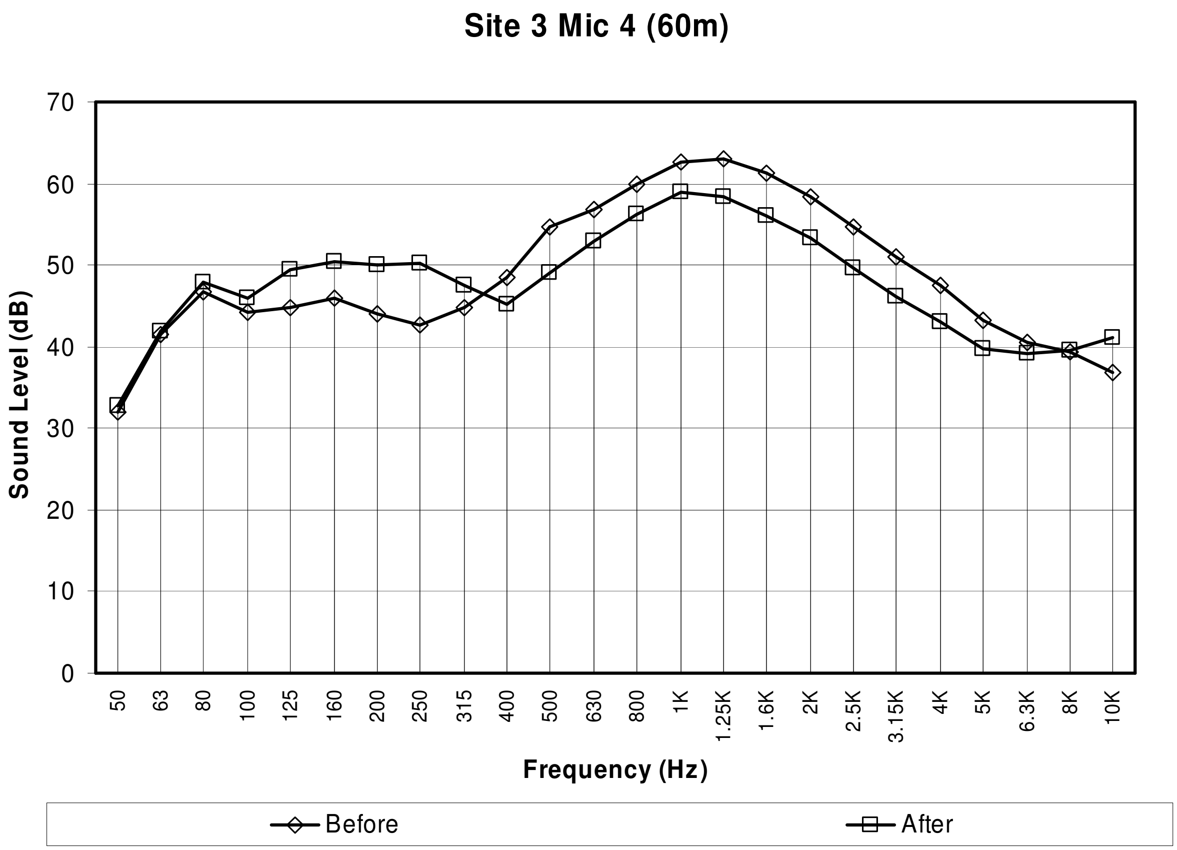

Figure 14: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 196.9 ft (60 m) microphone location at Site 3.

The most reliable measurements of the effect of diamond grinding are the measurements made close to the traffic noise source, the primary measurements at 24.6 ft (7.5 m) and 49.2 ft (15 m). Therefore, an analysis was performed to investigate the unexpected results for the distant microphone positions. Site 4 was chosen for analysis because it was the only site that had a complete set of five microphones, spaced at each doubling of distance from 24.6 ft (7.5 m) to 393.7 ft (120 m).

The before and after spectra for the 393.7 ft (120 m) microphone position at Site 4 are shown in figure L where the noise levels measured after the diamond grinding are unexpectedly higher than the before levels for the frequency range of 63 Hz to 250 Hz. The change in noise level with respect to distance was investigated by finding the difference in noise levels between the 24.6 ft (7.5 m) microphone position and each of the more distant microphone positions for each frequency band. These differences, which represent the attenuation of the noise in each frequency band due to the factors affecting the propagation path between a given microphone and the 24.6 ft (7.5 m) microphone, are shown in Figure 15 for the measurements made before diamond grinding. This figure displays a pattern that one might expect. The attenuation mechanisms associated with sound propagation are commonly referred to as geometric spreading, barrier attenuation, ground attenuation, air attenuation, and other miscellaneous attenuations, such as, reflections from walls of buildings or other vertical surfaces, foliage, houses located in the propagation path, and the effects of atmospheric weather conditions.[1]

Geometric spreading, the dissipation of acoustical energy as sound waves continually expand as they propagate through the air, produces an equal attenuation for all frequencies. If geometric spreading were the only attenuation mechanism, the four lines in the figure would all appear as straight horizontal lines with a constant spacing of 3 dB between them. However, the effect of the other attenuation mechanisms varies by both frequency and distance. The attenuation associated with these mechanisms is greater for the higher frequencies compared to the lower frequencies, and greater for the more distant microphones.

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[1] The reader is referred to standard acoustical references for a discussion of these attenuation mechanisms. One such reference is Handbook of Acoustical Measurements and Noise Control, 3rd Ed. by Cyril M. Harris, McGraw-Hill. Chapter 3 of this reference, titled "Sound Propagation in the Open Air" contains a discussion of these attenuation mechanisms, as well as, typical values of attenuation by frequency band and distance.

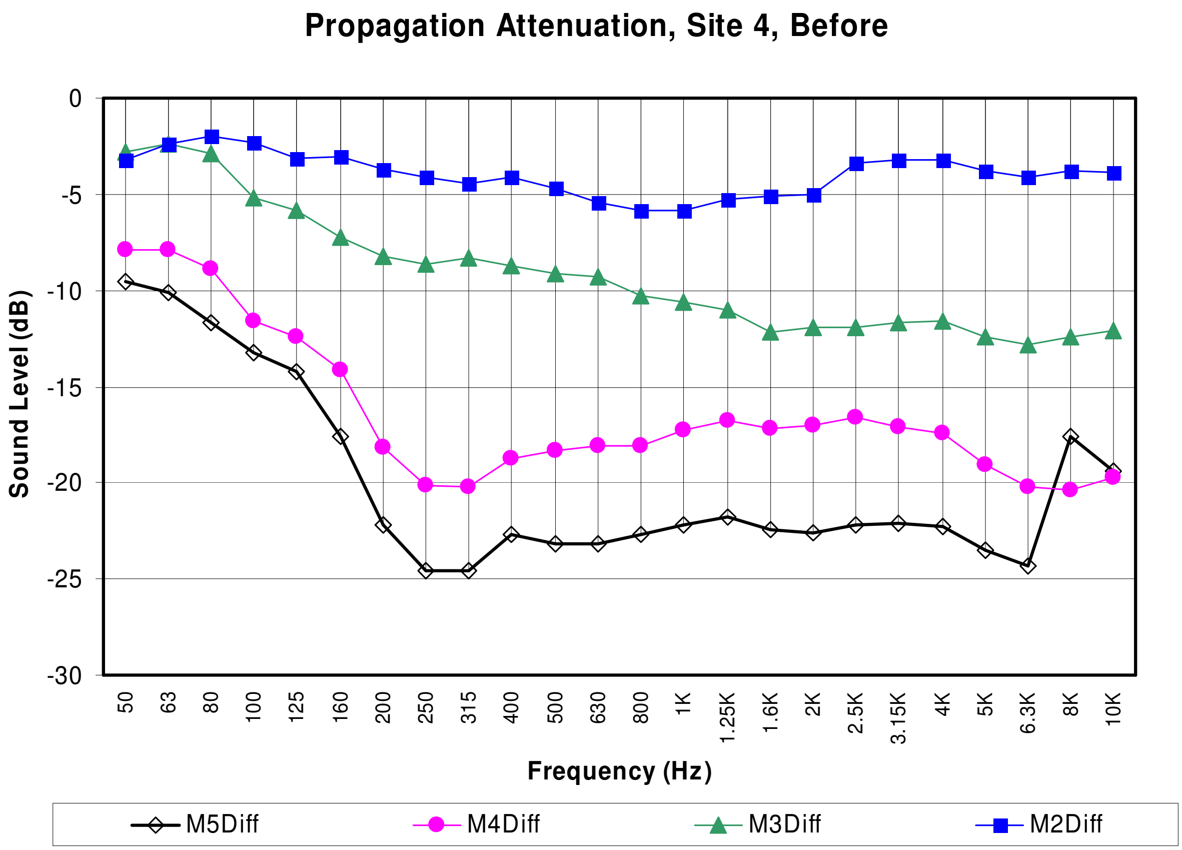

Figure 15: The difference in noise levels, before diamond grinding, between the 24.6 ft (7.5 m) microphone position and each of the more distant microphone positions for each frequency band.

The difference in noise levels between the 24.6 ft (7.5 m) microphone position and each of the more distant microphone positions for each frequency band was also plotted for the measurements made after diamond grinding and shown in Figure 16. As with the before measurements, the attenuation was greater for the higher frequencies and greater for the more distant microphones.

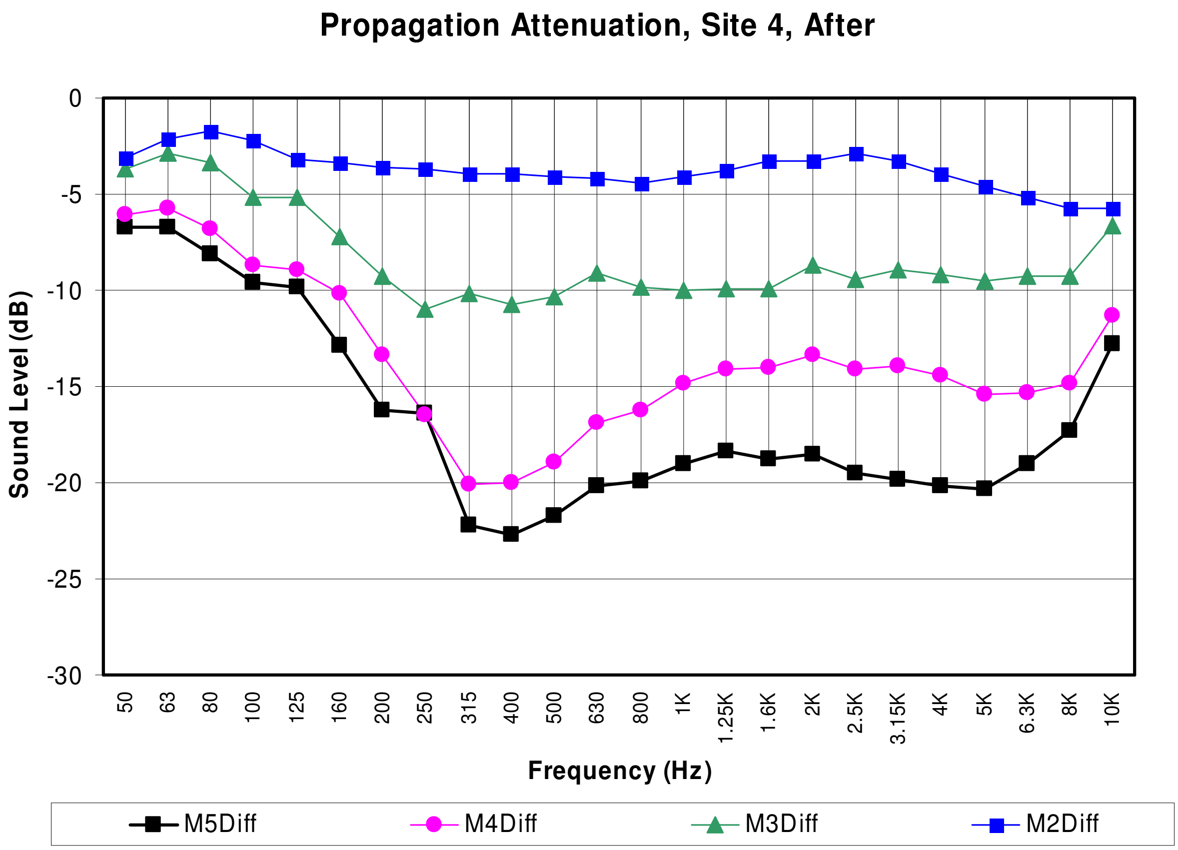

Figure 16: The difference in noise levels, after diamond grinding, between the 24.6 ft (7.5 m) microphone position and each of the more distant microphone positions for each frequency band.

If one were to overlay Figures 15 and 16, the plots for each of the four microphone positions for the after measurements would be above the before measurements for the most part. Therefore, the traffic noise was being attenuated less as it propagated from source to receiver during the after measurements. This result is clearly seen in Figure 17 for the 393.7 ft (120 m) microphone position.

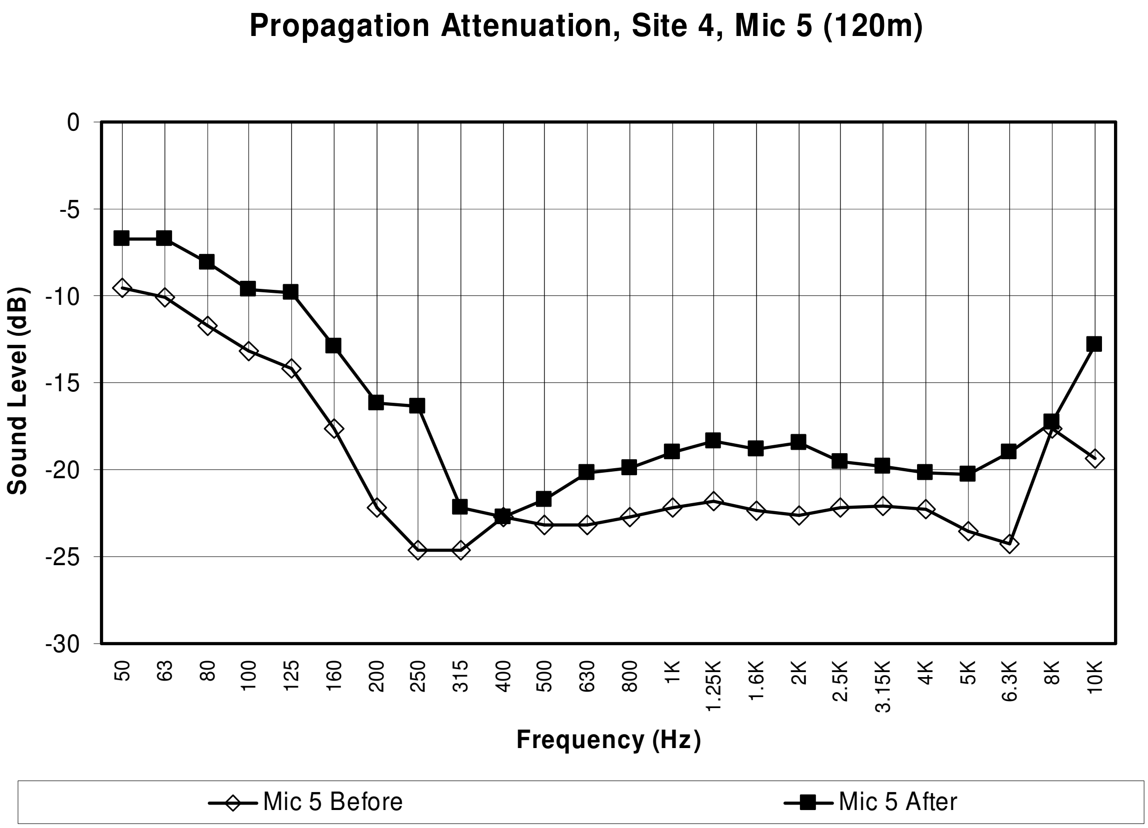

Figure 17: The difference in noise levels between the 24.6 ft (7.5 m) and 393.7 ft (120 m) microphone position, before and after diamond grinding, for each frequency band.

The attenuation for the after measurement was equal to or greater than the attenuation for the before measurement for every frequency band. The difference in the attenuation was significant in both the lower and upper frequencies. However, it was previously demonstrated in the results of the primary measurements that the diamond grinding had little effect for the lowest frequencies, but it had a significant effect for the higher frequencies. This trend in the effect of the diamond grinding coupled with the difference in attenuation for the distant microphone, which is illustrated in Figure 17, has led to the unexpected results for the step-back measurements. In other words, if the after measurements could have been made under the same conditions as the before measurements this difference in attenuation would have been eliminated. This hypothetical situation is approximated as shown in Figure 18 by adjusting the after measurement values in each frequency band by the corresponding difference in attenuation shown for each frequency band in Figure 17. The result of this exercise yields a comparison of before and after sound levels that appear similar to those described in the primary measurement results section.

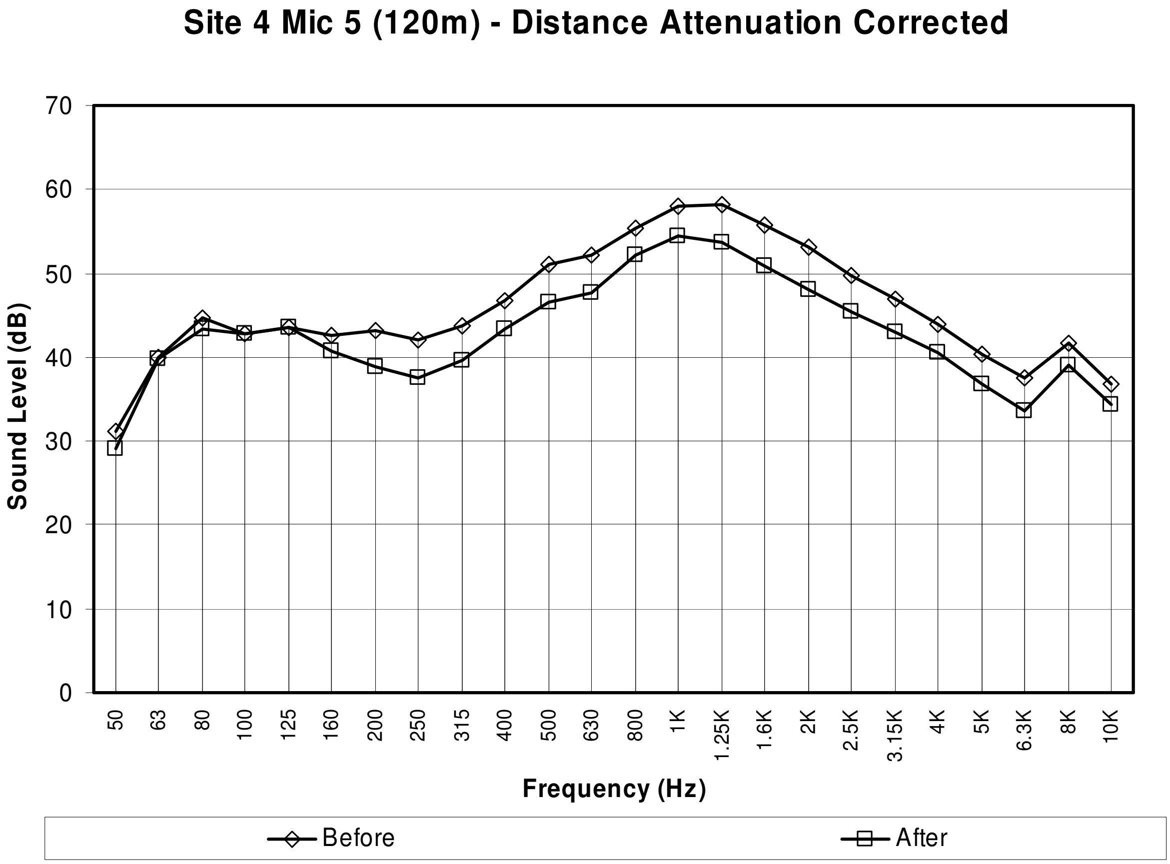

Figure 18: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding and compensated for calculated propagation attenuation differences.

It is not possible to isolate and quantify each attenuation mechanism during field measurements. Therefore, the specific cause of the unexpected results in the step-back measurements cannot be known with any certainty. However, by considering the characteristics of each mechanism, the mechanisms that are more likely to be responsible for the unexpected results have been identified in the following paragraphs.

The mechanism of geometric spreading is not a factor, since it is the same for all frequencies, as stated previously. Further, there were no barriers of any kind present at the sites used in this study; therefore, barrier attenuation was not a factor. Ground attenuation, however, could be a significant factor. All three step-back sites were covered with vegetation. Sites 3 and 4 were lawns, and therefore they were characterized by short grass. Site 5 was a field with tall grasses. As a result of the vegetation all three sites would be classified as "soft ground".

Ground attenuation theory predicts that the effect of this attenuation mechanism varies for sounds of different frequencies. For example, under conditions of soft ground, a point source of 1 ft (0.3 m) in height, a source-to-receiver distance of 328.1 ft (100 m), and a receiver height of 5.9 ft (1.8 m), the predicted attenuation is 10.8 dB for 500 Hz, 17.1 dB for 1000 Hz, and 11.1 dB for 2000 Hz [Harris 1991]. By contrast, the effect of the ground is predicted to enhance the noise level by 5.2 dB at 125 Hz. Therefore, the effect of the ground is highly variable, and it does not exhibit a trend that correlates directly with increasing or decreasing values of the sound frequency. The reason for this is that in any source-path-receiver relationship there can be both a direct path and a reflected path from the source to receiver. The reflected path will always be longer than the direct path. Therefore, the sound traveling the reflected path will require slightly more time to reach the receiver. The direct and reflected rays will arrive at the receiver either in phase, out of phase, or somewhere in between. The resulting constructive or destructive interference will either enhance or attenuate the sound levels depending on the wavelength. Further, soft ground surfaces will cause a phase change upon reflection for the reflected ray. The amount of phase change depends upon the ground impedance. Therefore, changes in ground impedance can cause a significant change in the ground attenuation realized at any given frequency. This phenomenon may have contributed to the unexpected result in the step-back measurements. The before measurements were made during the month of August. By contrast the after measurements were made in December during a break from a cool, rainy period. The cool air, unlike the conditions in August prevented the soil from drying. Though there was no rain during the measurements, the ground was observed to be saturated with water in most places at the time of the measurements. Low impedance ground is associated with a porous ground surface. However, saturated ground is not porous to the air, resulting in a higher in impedance. Therefore, it is not as absorptive and it will not cause as much of a phase change for reflected rays compared with the drier, aerated ground. As a result, ground attenuation will be reduced for saturated ground, in varying amounts depending upon the frequency.

Air attenuation is a mechanism that causes dissipation in acoustical energy as sound waves interact with the molecules in the air. The amount of air attenuation is temperature, relative humidity, frequency, and distance dependent. The difference in relative humidity between the before and after measurements was generally less than 10%, and the temperature differences were all less than 54^{o} C (30^{o} C). Under these conditions the air attenuation at 125 Hz for the 393.7 ft (120 m) microphone position would be predicted to be approximately 0.013 dB, a negligible value. By contrast, the air attenuation would be predicted to be approximately 2 dB under these conditions for the 4000 Hz frequency band. Though there is a significant range in these attenuation values, the air attenuation mechanism, over all, is too small to account for the unexpected result in the step-back measurements.

The remaining attenuation mechanisms associated with reflections from walls and other vertical surfaces and the presence of buildings in the propagation path do not apply to the measurement sites used in this research. There was a small amount of foliage present in places at the distant perimeter of sites 3 and 4. Site 5 had a partial row of trees along a fence, which was located perpendicular to the propagation path. However, foliage could not be considered a significant attenuation factor at any of the sites.

Atmospheric conditions could have caused some of the attenuation differences between the before and after step-back measurements. The magnitude of atmospheric effects can be significant even under seemingly benign weather conditions, as discussed previously in section 7.1. The temperature, relative humidity, wind speed, and wind direction were monitored during the field measurements. The differences in conditions between before and after measurements were small and were in compliance with accepted standards for outdoor noise measurements. However, conditions were not identical. Any differences would have affected the attenuation rates to some extent. However, the differences in weather conditions between before and after measurements were not uniform among the three step-back measurement sites. Therefore, it is unlikely that this mechanism caused the uniform difference in attenuation observed at these sites, though it may have had some effect. Without extensive instrumentation of the propagation path during the field measurements it is not possible to quantify any differences. Even if there had been extensive instrumentation during the measurements, the prediction of the effect of these differences on the measured sound levels would be difficult to determine, given the current level of knowledge of atmospheric effects on sound propagation in the air.

To summarize, this discussion of the potential effect of various attenuation mechanisms has identified three mechanisms that could explain the unexpected results in the step-back measurements. Based up on the likely contribution of each of these mechanisms it is suggested that ground attenuation is probably the most significant contributor, followed by atmospheric effects, with air attenuation being a distant third.

12. APPENDIX B

Equipment	Model	Serial Number
Larson-Davis Real Time Analyzer	3200	0459
Larson-Davis Preamplifier	PRM900B	0317
Larson-Davis Preamplifier	PRM900B	0320
Larson-Davis Microphone	2559	1264
Larson-Davis Microphone	2559	1261
Larson-Davis Sound Level Meter	812	0336
Larson-Davis Sound Level Meter	812	0337
Larson-Davis Sound Level Meter	812	0338
Bruel and Kjaer Acoustic Calibrator	4231	2241909
Sony DAT Player/Recorder	TCD-D8	548971
Sony DAT Player/Recorder	TCD-D8	548631
Sony DAT Player/Recorder	TCD-D8	548973
Sony DAT Player/Recorder	TCD-D8	548974
Sony DAT Player/Recorder	TCD-D8	548975
Davis Instruments Weather Wizard	III	WC80224A51
Hygrocheck Digital Hygrometer	NA	5851
Omegascope Hand Held Infrared Thermometer	OS520	7012794
Larson-Davis "Dummy" Microphone	ADP005	74868 UG-1094/U

13. APPENDIX C

The following tables contain the raw collected data and illustrates the measurement system and A-weighting corrections discussed in Section 6.

Data Description	1/3 Octave Frequency Band 50	63	80	100	125	160	200	250	315	400	500	630	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	10K	A-wt Sum
Site 1 (Daily Monument)																									
BEFORE																									
Mic 1 (7.5m)																									
Raw, Un-weighted Leq (dB)	70.9	75.9	77	73.3	72.9	74.1	74.8	73.1	73.4	73.9	76.6	76.3	77.8	78.7	77.5	75.4	73	69.8	67	64.8	63.1	61.5	59.7	57.4	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	40.6	49.6	54.4	54.2	56.7	60.7	63.8	64.5	66.8	69.1	73.4	74.3	77	78.7	78.2	76.4	74.2	71.1	68.1	65.8	63.4	61.1	58.1	54.4	85.5
Mic 2 (15m)																									
Raw, Un-weighted Leq (dB)	68.2	73.2	74.2	70	69.3	70.2	70.8	69.1	69.7	69.9	72.3	71.3	72.8	74.1	73.2	71.4	69.1	66.3	63.6	61.4	59.7	57.6	55.9	54	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	-0.5	-0.1	0.1	0.2	-0.3	-0.2	-0.1	-0.2	-0.7	-0.3	0	-0.1	-0.2	-0.1	0.1	0	-0.4	0	0.1	0.1	-0.1	0.2	0.6	1.6	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	37.4	46.8	51.7	51.1	52.8	56.6	59.7	60.3	62.4	64.8	69.1	69.2	71.8	74	74	72.4	69.9	67.6	64.8	62.5	59.9	57.4	54.9	52.6	81.1
Mic REF (A)																									
Raw, Un-weighted Leq (dB)	70.6	76.8	76.4	72.8	70.2	69.7	69	67.3	68.2	69	71.3	70.9	72.2	73.3	72.6	71.7	69	66.5	64.1	62.4	61	59.6	57.8	53.9	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.6	1.4	0.8	0.2	0.5	0.3	0.5	0	-0.3	0	0	-0.3	-0.4	0.3	0.3	0	0.3	-0.5	0.3	0.2	0	0.3	1.2	3.2	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	41.9	51.9	54.6	53.9	54.5	56.6	58.5	58.7	61.3	64.2	68.1	68.6	71	73.6	73.6	72.7	70.5	67.3	65.5	63.6	61.3	59.5	57.4	54.1	80.9
AFTER																									
Mic 1 (7.5m)																									
Raw, Un-weighted Leq (dB)	70.6	74.4	78.1	73.6	72.7	73.4	74.1	72.4	72.3	72.2	75.9	75.8	76	75.8	73.6	71	68.2	65.5	62.9	60.7	58.6	57.4	56.3	55	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	40.3	48.1	55.5	54.5	56.5	60	63.1	63.8	65.7	67.4	72.7	73.8	75.2	75.8	74.3	72	69.4	66.8	64	61.7	58.9	57	54.7	52	82.8
Mic 2 (15m)																									
Raw, Un-weighted Leq (dB)	68	72.2	75.9	70.9	69.3	70	70.4	68.8	68.9	68.8	71.8	71.5	71.5	71.6	69.7	67.5	64.8	62	59.4	56.7	54.2	52.5	50.6	48.5	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	-0.5	-0.1	0.1	0.2	-0.3	-0.2	-0.1	-0.2	-0.7	-0.3	0	-0.1	-0.2	-0.1	0.1	0	-0.4	0	0.1	0.1	-0.1	0.2	0.6	1.6	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	37.2	45.8	53.4	52	52.8	56.4	59.3	60	61.6	63.7	68.6	69.4	70.5	71.5	70.5	68.5	65.6	63.3	60.6	57.8	54.4	52.3	49.6	47.1	78.7
Mic REF (A)																									
Raw, Un-weighted Leq (dB)	70.8	77.6	77.5	74.2	71.9	70.7	68.7	65.5	65.8	66.5	70.5	69.4	70.8	72.1	71.4	70.2	67.2	64.1	61.2	59.3	57.3	55.7	54	51.5	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.6	1.4	0.8	0.2	0.5	0.3	0.5	0	-0.3	0	0	-0.3	-0.4	0.3	0.3	0	0.3	-0.5	0.3	0.2	0	0.3	1.2	3.2	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	42.1	52.7	55.7	55.3	56.2	57.6	58.2	56.9	58.9	61.7	67.3	67.1	69.6	72.4	72.4	71.2	68.7	64.9	62.6	60.5	57.6	55.6	53.6	51.7	79.4

Data Description	1/3 Octave Frequency Band 50	63	80	100	125	160	200	250	315	400	500	630	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	10K	A-wt Sum
Site 2																									
BEFORE																									
Mic 1 (7.5m)																									
Raw, Un-weighted Leq (dB)	70.6	75.7	76.5	73.3	72.1	72.6	74.2	72.7	72.7	73.5	76.4	75.8	77.6	78.5	77.7	75.7	73.1	69.8	66.9	64.9	63.6	62.1	60.5	58.6	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	40.3	49.4	53.9	54.2	55.9	59.2	63.2	64.1	66.1	68.7	73.2	73.8	76.8	78.5	78.4	76.7	74.3	71.1	68	65.9	63.9	61.7	58.9	55.6	85.5
Mic 2 (15m)																									
Raw, Un-weighted Leq (dB)	69.1	74.5	75	70.7	68.2	67.8	69.4	69	69.7	69.3	72.5	71.4	72.8	73.9	73	71.5	69.4	66.4	63.7	61.6	59.8	58	56.2	53.2	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	-0.5	-0.1	0.1	0.2	-0.3	-0.2	-0.1	-0.2	-0.7	-0.3	0	-0.1	-0.2	-0.1	0.1	0	-0.4	0	0.1	0.1	-0.1	0.2	0.6	1.6	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	38.3	48.1	52.5	51.8	51.7	54.2	58.3	60.2	62.4	64.2	69.3	69.3	71.8	73.8	73.8	72.5	70.2	67.7	64.9	62.7	60	57.8	55.2	51.8	81.1
Mic REF (A)																									
Raw, Un-weighted Leq (dB)	71.5	77	77.2	72.5	70	69.4	68.5	67.2	67.9	69.1	71.2	70.7	71.7	72.8	72.1	71	68.4	65.9	63.5	62	60.6	59.5	57.8	54.3	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.6	1.4	0.8	0.2	0.5	0.3	0.5	0	-0.3	0	0	-0.3	-0.4	0.3	0.3	0	0.3	-0.5	0.3	0.2	0	0.3	1.2	3.2	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	42.8	52.1	55.4	53.6	54.3	56.3	58	58.6	61	64.3	68	68.4	70.5	73.1	73.1	72	69.9	66.7	64.9	63.2	60.9	59.4	57.4	54.5	80.4
AFTER																									
Mic 1 (7.5m)																									
Raw, Un-weighted Leq (dB)	69.4	75.8	77.9	73.6	73	73.6	72.9	71.8	71.3	71.1	74.7	73.3	74.4	75	72.9	70.3	67.5	64.8	62	59.6	57.7	56.7	55.4	54.5	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	39.1	49.5	55.3	54.5	56.8	60.2	61.9	63.2	64.7	66.3	71.5	71.3	73.6	75	73.6	71.3	68.7	66.1	63.1	60.6	58	56.3	53.8	51.5	81.7
Mic 2 (15m)																									
Raw, Un-weighted Leq (dB)	68.4	74.9	77	71.1	69.4	69.8	67.9	68.2	68.5	67.1	70.8	69.9	70.4	71	68.9	66.7	64.1	61.2	58.4	55.9	53.7	51.9	49.8	48	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	-0.5	-0.1	0.1	0.2	-0.3	-0.2	-0.1	-0.2	-0.7	-0.3	0	-0.1	-0.2	-0.1	0.1	0	-0.4	0	0.1	0.1	-0.1	0.2	0.6	1.6	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	37.6	48.5	54.5	52.2	52.9	56.2	56.8	59.4	61.2	62	67.6	67.8	69.4	70.9	69.7	67.7	64.9	62.5	59.6	57	53.9	51.7	48.8	46.6	77.8
Mic REF (A)																									
Raw, Un-weighted Leq (dB)	70.4	76.7	77	73.8	71.8	71.4	68.2	66.1	65.6	66.7	69.5	68.6	70.3	71.4	70.7	69.4	66.4	63.5	60.9	58.7	56.9	55.2	52.7	49.9	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.6	1.4	0.8	0.2	0.5	0.3	0.5	0	-0.3	0	0	-0.3	-0.4	0.3	0.3	0	0.3	-0.5	0.3	0.2	0	0.3	1.2	3.2	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	41.7	51.8	55.2	54.9	56.1	58.3	57.7	57.5	58.7	61.9	66.3	66.3	69.1	71.7	71.7	70.4	67.9	64.3	62.3	59.9	57.2	55.1	52.3	50.1	78.8

Data Description	1/3 Octave Frequency Band																								A-wt
	50	63	80	100	125	160	200	250	315	400	500	630	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	10K	Sum
Site 3 (1185 Newton)																									
BEFORE																									
Mic 2 (15m)																									
Raw, Un-weighted Leq (dB)	66.2	71.9	74.8	70.9	69.7	70.1	70.3	69.4	70	70.5	74.1	73.4	74.7	75.8	74.9	73.2	70.5	67.2	64	61.5	59.4	57.3	56.4	52.1	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	-0.5	-0.1	0.1	0.2	-0.3	-0.2	-0.1	-0.2	-0.7	-0.3	0	-0.1	-0.2	-0.1	0.1	0	-0.4	0	0.1	0.1	-0.1	0.2	0.6	1.6	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	35.4	45.5	52.3	52	53.2	56.5	59.2	60.6	62.7	65.4	70.9	71.3	73.7	75.7	75.7	74.2	71.3	68.5	65.2	62.6	59.6	57.1	55.4	50.7	82.7
Mic 3 (30m)																									
Raw, Un-weighted Leq (dB)	62.6	68.5	71	66.2	63.6	62.8	60.4	58.3	59	60.5	64.9	64.6	65.2	65.6	64.3	62.1	58.6	56.1	52.6	49.6	46.6	44.4	43.6	39.2	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.4	1.3	0.9	-0.2	0.7	0.3	0.3	0.1	0	-0.1	-0.2	-0.1	-0.2	0.2	0.3	0	0.5	-0.3	0.2	0.2	0.2	0.6	1.7	4	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	33.7	43.5	49.3	46.9	48.1	49.7	49.7	49.8	52.4	55.6	61.5	62.5	64.2	65.8	65.3	63.1	60.3	57.1	53.9	50.8	47.1	44.6	43.7	40.2	72.6
Mic 4 (60m)																									
Raw, Un-weighted Leq (dB)	60.7	66.3	68.5	63.4	60.3	58.6	54.9	51.1	51.4	53.1	58.1	58.9	60.9	62.4	62	60	56.7	53.5	49.5	46.1	42.8	40.3	39.5	36.6	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.5	1.4	0.9	-0.1	0.6	0.8	0.2	0.2	0	0.2	-0.2	-0.1	-0.2	0.3	0.4	0.2	0.5	-0.2	0.4	0.4	0.2	0.6	1.4	3.3	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	31.9	41.4	46.8	44.2	44.7	46	44.1	42.7	44.8	48.5	54.7	56.8	59.9	62.7	63.1	61.2	58.4	54.6	51	47.5	43.3	40.5	39.3	36.9	69.3
Mic 5 (120m)																									
Raw, Un-weighted Leq (dB)	58.1	63.2	64.9	58.9	55.6	51.9	48	45.6	46.5	48.4	53.7	55	57.1	59	58.6	56.1	52.9	50	45.3	41.6	37.7	34.8	33.8	33.5	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.4	1.2	0.7	0	0.4	0.4	0.2	0	-0.3	0	-0.2	-0.2	-0.2	0.2	0.4	-0.1	0.2	-0.4	0.2	0.1	0.1	0.4	1.3	3.5	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	29.2	38.1	43	39.8	39.8	38.9	37.2	37	39.6	43.6	50.3	52.8	56.1	59.2	59.7	57	54.3	50.9	46.6	42.7	38.1	34.8	33.5	34	65.5
Mic REF (B)																									
Raw, Un-weighted Leq (dB)	66.3	73.8	76.3	72.9	72.1	69.8	71.1	70.4	71.4	71.9	74.6	74.7	76.2	77.2	75.9	74.4	71.3	68.6	65.3	62.7	61.1	59.4	56.7	52.7	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.6	1.4	0.8	0.2	0.5	0.3	0.5	0	-0.3	0	0	-0.3	-0.4	0.3	0.3	0	0.3	-0.5	0.3	0.2	0	0.3	1.2	3.2	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	37.6	48.9	54.5	54	56.4	56.7	60.6	61.8	64.5	67.1	71.4	72.4	75	77.5	76.9	75.4	72.8	69.4	66.7	63.9	61.4	59.3	56.3	52.9	84.0

Data Description	1/3 Octave Frequency Band																								A-wt
	50	63	80	100	125	160	200	250	315	400	500	630	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	10K	Sum
Site 3 (1185 Newton)																									
AFTER																									
Mic 2 (15m)																									
Raw, Un-weighted Leq (dB)	66.4	71	73.8	69.8	70.4	69.6	70.1	68.9	69	69.1	71.9	71.7	72.6	73.4	71.4	69	65.9	62.5	59.1	56.1	53.6	51.3	49.2	46.8	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	-0.5	-0.1	0.1	0.2	-0.3	-0.2	-0.1	-0.2	-0.7	-0.3	0	-0.1	-0.2	-0.1	0.1	0	-0.4	0	0.1	0.1	-0.1	0.2	0.6	1.6	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	35.6	44.6	51.3	50.9	53.9	56	59	60.1	61.7	64	68.7	69.6	71.6	73.3	72.2	70	66.7	63.8	60.3	57.2	53.8	51.1	48.2	45.4	79.8
Mic 3 (30m)																									
Raw, Un-weighted Leq (dB)	63.5	69	71.7	67.2	67.2	65.1	62.6	59	56.9	58.4	62.3	62.4	62.7	63.2	61.1	57.9	54.7	51.8	48.7	46	43.8	42.9	42.6	43.2	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.4	1.3	0.9	-0.2	0.7	0.3	0.3	0.1	0	-0.1	-0.2	-0.1	-0.2	0.2	0.3	0	0.5	-0.3	0.2	0.2	0.2	0.6	1.7	4	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	34.6	44	50	47.9	51.7	52	51.9	50.5	50.3	53.5	58.9	60.3	61.7	63.4	62.1	58.9	56.4	52.8	50	47.2	44.3	43.1	42.7	44.2	69.9
Mic 4 (60m)																									
Raw, Un-weighted Leq (dB)	61.6	66.7	69.6	65.1	65.1	63.1	60.9	58.6	54.1	49.7	52.5	55.1	57.2	58.6	57.3	54.9	51.7	48.5	44.7	41.6	39.3	38.9	39.7	40.8	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.5	1.4	0.9	-0.1	0.6	0.8	0.2	0.2	0	0.2	-0.2	-0.1	-0.2	0.3	0.4	0.2	0.5	-0.2	0.4	0.4	0.2	0.6	1.4	3.3	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	32.8	41.8	47.9	45.9	49.5	50.5	50.1	50.2	47.5	45.1	49.1	53	56.2	58.9	58.4	56.1	53.4	49.6	46.2	43	39.8	39.1	39.5	41.1	65.6
Mic 5 (120m)																									
Raw, Un-weighted Leq (dB)	59.6	64.5	67.2	62.5	62	57.9	54.6	53	46.8	46.5	50	52.1	54.1	55.7	54.3	51.3	47.7	44.4	40.5	37.5	35.6	36	37.5	38.7	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.4	1.2	0.7	0	0.4	0.4	0.2	0	-0.3	0	-0.2	-0.2	-0.2	0.2	0.4	-0.1	0.2	-0.4	0.2	0.1	0.1	0.4	1.3	3.5	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	30.7	39.4	45.3	43.4	46.2	44.9	43.8	44.4	39.9	41.7	46.6	49.9	53.1	55.9	55.4	52.2	49.1	45.3	41.8	38.6	36	36	37.2	39.2	62.1
Mic REF (B)																									
Raw, Un-weighted Leq (dB)	67.2	74.5	78.2	75	73.3	71.4	71.7	71.4	72	72.3	75.1	74.7	77.1	78	77.6	76.4	73.3	70.3	67	64.3	62.2	60.3	57.5	53.8	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.6	1.4	0.8	0.2	0.5	0.3	0.5	0	-0.3	0	0	-0.3	-0.4	0.3	0.3	0	0.3	-0.5	0.3	0.2	0	0.3	1.2	3.2	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	38.5	49.6	56.4	56.1	57.6	58.3	61.2	62.8	65.1	67.5	71.9	72.4	75.9	78.3	78.6	77.4	74.8	71.1	68.4	65.5	62.5	60.2	57.1	54	85.3

Data Description	1/3 Octave Frequency Band 50	63	80	100	125	160	200	250	315	400	500	630	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	10K	A-wt Sum
Site 4 (Poszes)																									
BEFORE																									
Mic 1 (7.5m)																									
Raw, Un-weighted Leq (dB)	71	76.3	78.9	75.1	74	73.6	76.4	75.3	74.9	74.3	77.4	77.4	78.9	80.2	79.2	77.1	74.6	70.6	67.9	65.3	63.6	62.3	60.9	59.1	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	40.7	50	56.3	56	57.8	60.2	65.4	66.7	68.3	69.5	74.2	75.4	78.1	80.2	79.9	78.1	75.8	71.9	69	66.3	63.9	61.9	59.3	56.1	86.9
Mic 2 (15m)																									
Raw, Un-weighted Leq (dB)	68.3	74	76.8	72.6	71.2	70.8	72.8	71.4	71.2	70.5	72.7	72.1	73.3	74.5	73.8	72	70	67.2	64.6	62	59.9	58	56.5	53.6	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	-0.5	-0.1	0.1	0.2	-0.3	-0.2	-0.1	-0.2	-0.7	-0.3	0	-0.1	-0.2	-0.1	0.1	0	-0.4	0	0.1	0.1	-0.1	0.2	0.6	1.6	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	37.5	47.6	54.3	53.7	54.7	57.2	61.7	62.6	63.9	65.4	69.5	70	72.3	74.4	74.6	73	70.8	68.5	65.8	63.1	60.1	57.8	55.5	52.2	81.8
Mic 3 (30m)																									
Raw, Un-weighted Leq (dB)	66.8	72.6	75.1	70.1	67.5	66.1	67.9	66.6	66.6	65.7	68.5	68.2	68.8	69.4	67.9	64.9	62.2	59	56	53.5	51	48.9	46.8	43	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.4	1.3	0.9	-0.2	0.7	0.3	0.3	0.1	0	-0.1	-0.2	-0.1	-0.2	0.2	0.3	0	0.5	-0.3	0.2	0.2	0.2	0.6	1.7	4	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	37.9	47.6	53.4	50.8	52	53	57.2	58.1	60	60.8	65.1	66.1	67.8	69.6	68.9	65.9	63.9	60	57.3	54.7	51.5	49.1	46.9	44	76.3
Mic 4 (60m)																									
Raw, Un-weighted Leq (dB)	61.6	67	69.1	63.6	61	58.7	58	55	54.7	55.4	59.3	59.4	61	62.6	62	59.7	57.1	54.2	50.4	47.5	44.3	41.5	39.1	36.1	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.5	1.4	0.9	-0.1	0.6	0.8	0.2	0.2	0	0.2	-0.2	-0.1	-0.2	0.3	0.4	0.2	0.5	-0.2	0.4	0.4	0.2	0.6	1.4	3.3	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	32.8	42.1	47.4	44.4	45.4	46.1	47.2	46.6	48.1	50.8	55.9	57.3	60	62.9	63.1	60.9	58.8	55.3	51.9	48.9	44.8	41.7	38.9	36.4	69.5
Mic 5 (120m)																									
Raw, Un-weighted Leq (dB)	60.1	65	66.5	61.9	59.4	55.6	54	50.7	50.6	51.6	54.4	54.4	56.4	57.8	57	54.8	51.8	48.8	45.6	42.9	40	37.6	42	36.2	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.4	1.2	0.7	0	0.4	0.4	0.2	0	-0.3	0	-0.2	-0.2	-0.2	0.2	0.4	-0.1	0.2	-0.4	0.2	0.1	0.1	0.4	1.3	3.5	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	31.2	39.9	44.6	42.8	43.6	42.6	43.2	42.1	43.7	46.8	51	52.2	55.4	58	58.1	55.7	53.2	49.7	46.9	44	40.4	37.6	41.7	36.7	64.6
Mic REF (B)																									
Raw, Un-weighted Leq (dB)	68.7	74.2	76.9	73.3	71.9	70.3	71.2	71.1	71.4	72	75.2	74.9	76.1	77.1	76.5	74.6	71.6	68.8	65.6	63.1	61.4	60	57.4	53.7	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.6	1.4	0.8	0.2	0.5	0.3	0.5	0	-0.3	0	0	-0.3	-0.4	0.3	0.3	0	0.3	-0.5	0.3	0.2	0	0.3	1.2	3.2	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	40	49.3	55.1	54.4	56.2	57.2	60.7	62.5	64.5	67.2	72	72.6	74.9	77.4	77.5	75.6	73.1	69.6	67	64.3	61.7	59.9	57	53.9	84.2

Data Description	1/3 Octave Frequency Band 50	63	80	100	125	160	200	250	315	400	500	630	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	10K	A-wt Sum
Site 4 (Poszes)																									
AFTER																									
Mic 1 (7.5m)																									
Raw, Un-weighted Leq (dB)	68.9	76.1	77.7	75	73.9	71.8	72.1	70.7	70.8	70.9	72.9	72.8	75.6	76.6	74.8	72.3	69.4	66.4	63.9	61.9	59.9	58.3	58.2	56.7	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	38.6	49.8	55.1	55.9	57.7	58.4	61.1	62.1	64.2	66.1	69.7	70.8	74.8	76.6	75.5	73.3	70.6	67.7	65	62.9	60.2	57.9	56.6	53.7	82.8
Mic 2 (15m)																									
Raw, Un-weighted Leq (dB)	66.3	74.1	75.9	72.6	71	68.6	68.6	67.2	67.6	67.3	68.8	68.7	71.4	72.6	70.9	69	66.5	63.5	60.5	57.9	55.4	52.9	51.9	49.4	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	-0.5	-0.1	0.1	0.2	-0.3	-0.2	-0.1	-0.2	-0.7	-0.3	0	-0.1	-0.2	-0.1	0.1	0	-0.4	0	0.1	0.1	-0.1	0.2	0.6	1.6	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	35.5	47.7	53.4	53.7	54.5	55	57.5	58.4	60.3	62.2	65.6	66.6	70.4	72.5	71.7	70	67.3	64.8	61.7	59	55.6	52.7	50.9	48	78.9
Mic 3 (30m)																									
Raw, Un-weighted Leq (dB)	63.8	71.9	73.4	70	68	64.3	62.5	59.6	60.6	60.3	62.8	63.8	66	66.4	64.6	62.4	60.2	57.3	54.8	52.5	50.2	48.4	47.2	46.1	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.4	1.3	0.9	-0.2	0.7	0.3	0.3	0.1	0	-0.1	-0.2	-0.1	-0.2	0.2	0.3	0	0.5	-0.3	0.2	0.2	0.2	0.6	1.7	4	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	34.9	46.9	51.7	50.7	52.5	51.2	51.8	51.1	54	55.4	59.4	61.7	65	66.6	65.6	63.4	61.9	58.3	56.1	53.7	50.7	48.6	47.3	47.1	73.1
Mic 4 (60m)																									
Raw, Un-weighted Leq (dB)	61.3	69	70	66.4	64.4	60.8	58.5	54	50.7	50.7	54.2	56	59.6	61.5	60.3	58.1	55.5	52.5	49.6	47.1	44.3	42.4	42	42.1	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.5	1.4	0.9	-0.1	0.6	0.8	0.2	0.2	0	0.2	-0.2	-0.1	-0.2	0.3	0.4	0.2	0.5	-0.2	0.4	0.4	0.2	0.6	1.4	3.3	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	32.5	44.1	48.3	47.2	48.8	48.2	47.7	45.6	44.1	46.1	50.8	53.9	58.6	61.8	61.4	59.3	57.2	53.6	51.1	48.5	44.8	42.6	41.8	42.4	68.0
Mic 5 (120m)																									
Raw, Un-weighted Leq (dB)	60.8	68.2	68.9	65.4	63.7	58.5	55.7	54.3	48.9	48.2	51.4	52.8	55.9	57.4	56	53.6	50.7	47.3	43.9	41.6	39.5	38.9	39.6	40.4	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.4	1.2	0.7	0	0.4	0.4	0.2	0	-0.3	0	-0.2	-0.2	-0.2	0.2	0.4	-0.1	0.2	-0.4	0.2	0.1	0.1	0.4	1.3	3.5	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	31.9	43.1	47	46.3	47.9	45.5	44.9	45.7	42	43.4	48	50.6	54.9	57.6	57.1	54.5	52.1	48.2	45.2	42.7	39.9	38.9	39.3	40.9	64.0
Mic REF (B)																									
Raw, Un-weighted Leq (dB)	66.5	73.2	74.6	73.7	71.9	69.2	69.4	69.2	70	70.9	73.8	73.4	77	78.2	77.9	76.9	73.9	70.8	67.4	64.3	62	60.1	57.3	53.6	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.6	1.4	0.8	0.2	0.5	0.3	0.5	0	-0.3	0	0	-0.3	-0.4	0.3	0.3	0	0.3	-0.5	0.3	0.2	0	0.3	1.2	3.2	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	37.8	48.3	52.8	54.8	56.2	56.1	58.9	60.6	63.1	66.1	70.6	71.1	75.8	78.5	78.9	77.9	75.4	71.6	68.8	65.5	62.3	60	56.9	53.8	85.4

Data Description	1/3 Octave Frequency Band 50	63	80	100	125	160	200	250	315	400	500	630	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	10K	A-wt Sum
Site 5 (550 Newton)																									
BEFORE																									
Mic 1 (7.5m)																									
Raw, Un-weighted Leq (dB)	71.3	74.9	76.1	73.9	74.2	74.5	75.5	73.7	73.8	75	77.1	77.1	78.7	79.8	78.6	76.7	73.8	70.5	67.4	65	63.3	61.7	60.1	58.4	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	41	48.6	53.5	54.8	58	61.1	64.5	65.1	67.2	70.2	73.9	75.1	77.9	79.8	79.3	77.7	75	71.8	68.5	66	63.6	61.3	58.5	55.4	86.5
Mic 2 (15m)																									
Raw, Un-weighted Leq (dB)	68.4	72.3	73.7	71	71.1	70.8	71.7	70.1	70.2	71.3	73.2	72.7	74.4	75.8	75.4	74	71.4	68	64.6	61.8	59.6	57.7	55.7	52.7	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	-0.5	-0.1	0.1	0.2	-0.3	-0.2	-0.1	-0.2	-0.7	-0.3	0	-0.1	-0.2	-0.1	0.1	0	-0.4	0	0.1	0.1	-0.1	0.2	0.6	1.6	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	37.6	45.9	51.2	52.1	54.6	57.2	60.6	61.3	62.9	66.2	70	70.6	73.4	75.7	76.2	75	72.2	69.3	65.8	62.9	59.8	57.5	54.7	51.3	82.9
Mic 4 (60m)																									
Raw, Un-weighted Leq (dB)	35.3	44.8	48.1	46.6	48	45.4	44	47.6	54.3	58.8	63.1	63.6	64.6	64.6	64.1	62.2	59.3	56.2	52.7	49.3	47	43.6	42	35.1	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.5	1.4	0.9	-0.1	0.6	0.8	0.2	0.2	0	0.2	-0.2	-0.1	-0.2	0.3	0.4	0.2	0.5	-0.2	0.4	0.4	0.2	0.6	1.4	3.3	
A-wt Correction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Final A-wt Corrected Level (dB)	36.7	46.1	48.9	46.5	48.5	46.2	44.1	47.8	54.3	59	62.9	63.4	64.4	64.9	64.6	62.4	59.8	56	53	49.7	47	43.9	42.9	37.9	72.5
	Note: This mic was inadvertently a-weighted in the SLM. Therefore, no A-wgt correction curve was applied in the data reduction.																								
Mic 5 (120m)																									
Raw, Un-weighted Leq (dB)	61.5	66.4	66.9	61.8	60.3	55.9	54	50.8	50.9	52.5	57	58.5	60.4	62	61.5	59.5	56.3	52.5	47.7	43.4	40.3	39.8	45	35.5	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.4	1.2	0.7	0	0.4	0.4	0.2	0	-0.3	0	-0.2	-0.2	-0.2	0.2	0.4	-0.1	0.2	-0.4	0.2	0.1	0.1	0.4	1.3	3.5	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	32.6	41.3	45	42.7	44.5	42.9	43.2	42.2	44	47.7	53.6	56.3	59.4	62.2	62.6	60.4	57.7	53.4	49	44.5	40.7	39.8	44.7	36	68.6

Data Description	1/3 Octave Frequency Band																								A-wt
	50	63	80	100	125	160	200	250	315	400	500	630	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	10K	Sum
Site 5 (550 Newton)																									
AFTER																									
Mic 1 (7.5m)																									
Raw, Un-weighted Leq (dB)	69.1	75.8	76	73.2	72.6	71.5	72.5	71.2	70.1	70.4	74.7	73	74.7	75.3	73.2	71	68.1	64.9	62.2	59.9	58.4	56.9	56.1	55.3	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	38.8	49.5	53.4	54.1	56.4	58.1	61.5	62.6	63.5	65.6	71.5	71	73.9	75.3	73.9	72	69.3	66.2	63.3	60.9	58.7	56.5	54.5	52.3	81.9
Mic 2 (15m)																									
Raw, Un-weighted Leq (dB)	66	74	74	71	70.2	68.5	68.9	67.9	66.6	66.6	71	69.5	70.9	71.7	70.1	68.3	65.6	62.2	59	56.2	54	51.9	50.2	48.4	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	-0.5	-0.1	0.1	0.2	-0.3	-0.2	-0.1	-0.2	-0.7	-0.3	0	-0.1	-0.2	-0.1	0.1	0	-0.4	0	0.1	0.1	-0.1	0.2	0.6	1.6	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	35.2	47.6	51.5	52.1	53.7	54.9	57.8	59.1	59.3	61.5	67.8	67.4	69.9	71.6	70.9	69.3	66.4	63.5	60.2	57.3	54.2	51.7	49.2	47	78.4
Mic 4 (60m)																									
Raw, Un-weighted Leq (dB)	63.2	72.7	72.4	67.4	64.7	59.6	54.1	56.2	58.3	60	65.2	63.4	62.5	62.5	60.8	57.8	55.3	52.5	49.9	46.8	44.2	42.8	42.6	42.7	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.5	1.4	0.9	-0.1	0.6	0.8	0.2	0.2	0	0.2	-0.2	-0.1	-0.2	0.3	0.4	0.2	0.5	-0.2	0.4	0.4	0.2	0.6	1.4	3.3	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	34.4	47.8	50.7	48.2	49.1	47	43.3	47.8	51.7	55.4	61.8	61.3	61.5	62.8	61.9	59	57	53.6	51.4	48.2	44.7	43	42.4	43	70.2
Mic 5 (120m)																									
Raw, Un-weighted Leq (dB)	61	70.3	69.5	65.2	61.4	57.1	53.3	49.6	49	51	58.8	59.7	61.4	62.1	59.4	55.3	52.5	49.8	46.1	42.4	39.9	39.3	40.1	41.1	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.4	1.2	0.7	0	0.4	0.4	0.2	0	-0.3	0	-0.2	-0.2	-0.2	0.2	0.4	-0.1	0.2	-0.4	0.2	0.1	0.1	0.4	1.3	3.5	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	32.1	45.2	47.6	46.1	45.6	44.1	42.5	41	42.1	46.2	55.4	57.5	60.4	62.3	60.5	56.2	53.9	50.7	47.4	43.5	40.3	39.3	39.8	41.6	67.8

Data Description	1/3 Octave Frequency Band																								A-wt
	50	63	80	100	125	160	200	250	315	400	500	630	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	10K	Sum
Site 6 (290 Hanna Dr)																									
BEFORE																									
Mic 1 (at 290 Hanna Dr)																									
Raw, Un-weighted Leq (dB)	42	42.5	47.7	38.3	35.6	36.3	36.2	33.6	33	32.3	29.8	28.8	29.6	30.7	30.4	35.8	32.3	25.4	23.1	21.6	21.8	21.1	22.1	20.2	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.5	1.4	0.9	-0.1	0.6	0.8	0.2	0.2	0	0.2	-0.2	-0.1	-0.2	0.3	0.4	0.2	0.5	-0.2	0.4	0.4	0.2	0.6	1.4	3.3	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	13.2	17.6	26	19.1	20	23.7	25.4	25.2	26.4	27.7	26.4	26.7	28.6	31	31.5	37	34	26.5	24.6	23	22.3	21.3	21.9	20.5	42.0
AFTER																									
Mic 1 (at 290 Hanna Dr)																									
Raw, Un-weighted Leq (dB)	51	50.6	50.5	48.9	46.4	43.7	42	41.7	41.3	37.6	40.2	39.3	40.7	40.9	36.6	31.4	27.7	24.3	22.5	20.4	19.3	18.8	19.5	20.5	
RTA Correction	-0.1	-0.1	-0.1	0	-0.1	0	-0.1	0	0	0	0	-0.1	0	0	0.1	0	0	0	-0.1	0	-0.2	-0.3	-0.5	-0.5	
Measurement System Correction	1.5	1.4	0.9	-0.1	0.6	0.8	0.2	0.2	0	0.2	-0.2	-0.1	-0.2	0.3	0.4	0.2	0.5	-0.2	0.4	0.4	0.2	0.6	1.4	3.3	
A-wt Correction	-30.2	-26.2	-22.5	-19.1	-16.1	-13.4	-10.9	-8.6	-6.6	-4.8	-3.2	-1.9	-0.8	0	0.6	1	1.2	1.3	1.2	1	0.5	-0.1	-1.1	-2.5	
Final A-wt Corrected Level (dB)	22.2	25.7	28.8	29.7	30.8	31.1	31.2	33.3	34.7	33	36.8	37.2	39.7	41.2	37.7	32.6	29.4	25.4	24	21.8	19.8	19	19.3	20.8	47.4

14. APPENDIX D

This section contains all additional microphone plots not cited in the main report.

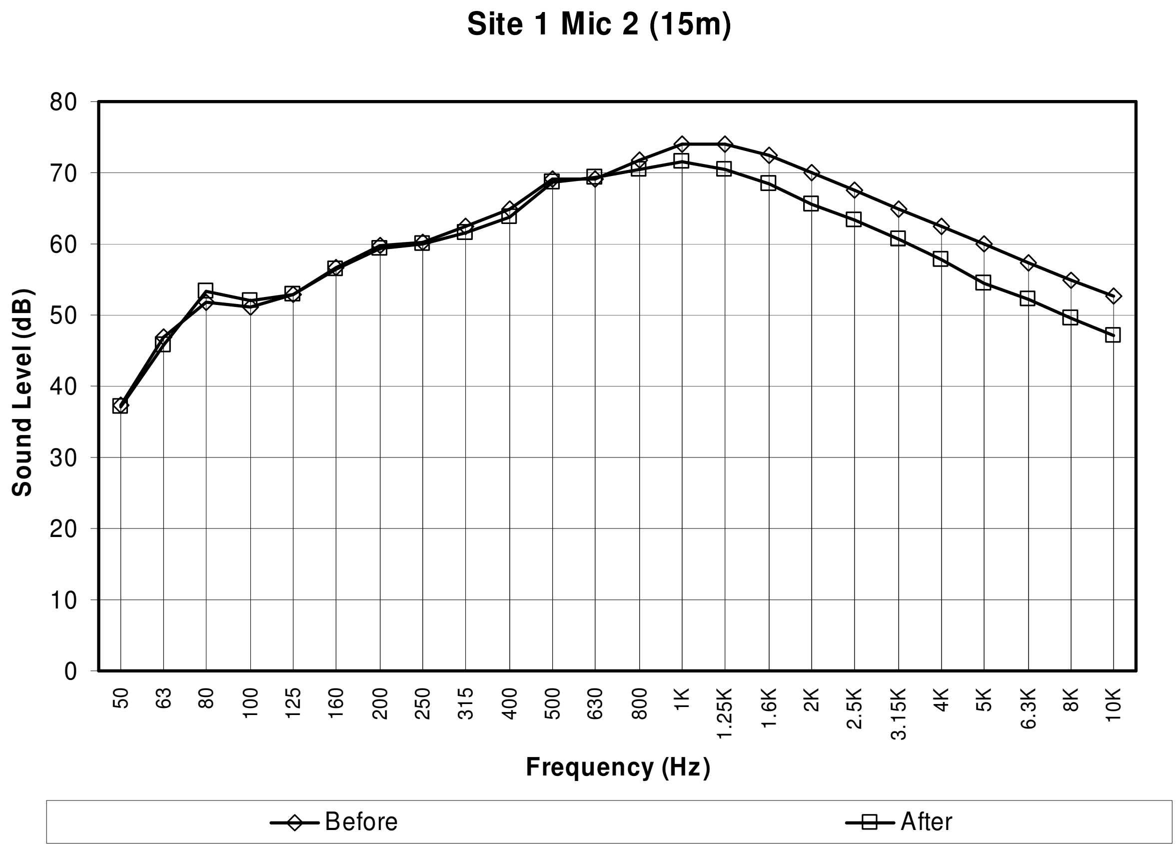

Figure 19: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 49.2 ft (15 m) microphone location at Site 1.

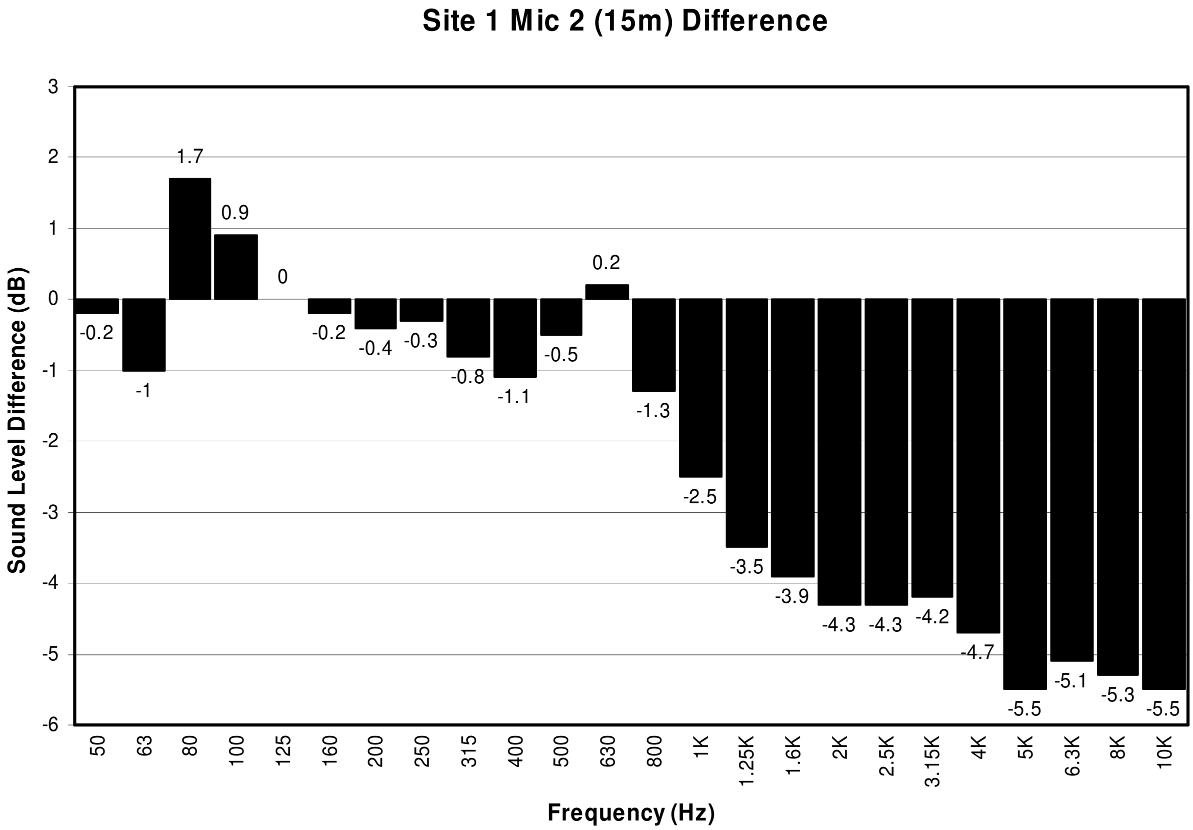

Figure 20: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 49.2 ft (15 m) microphone location at Site 1.

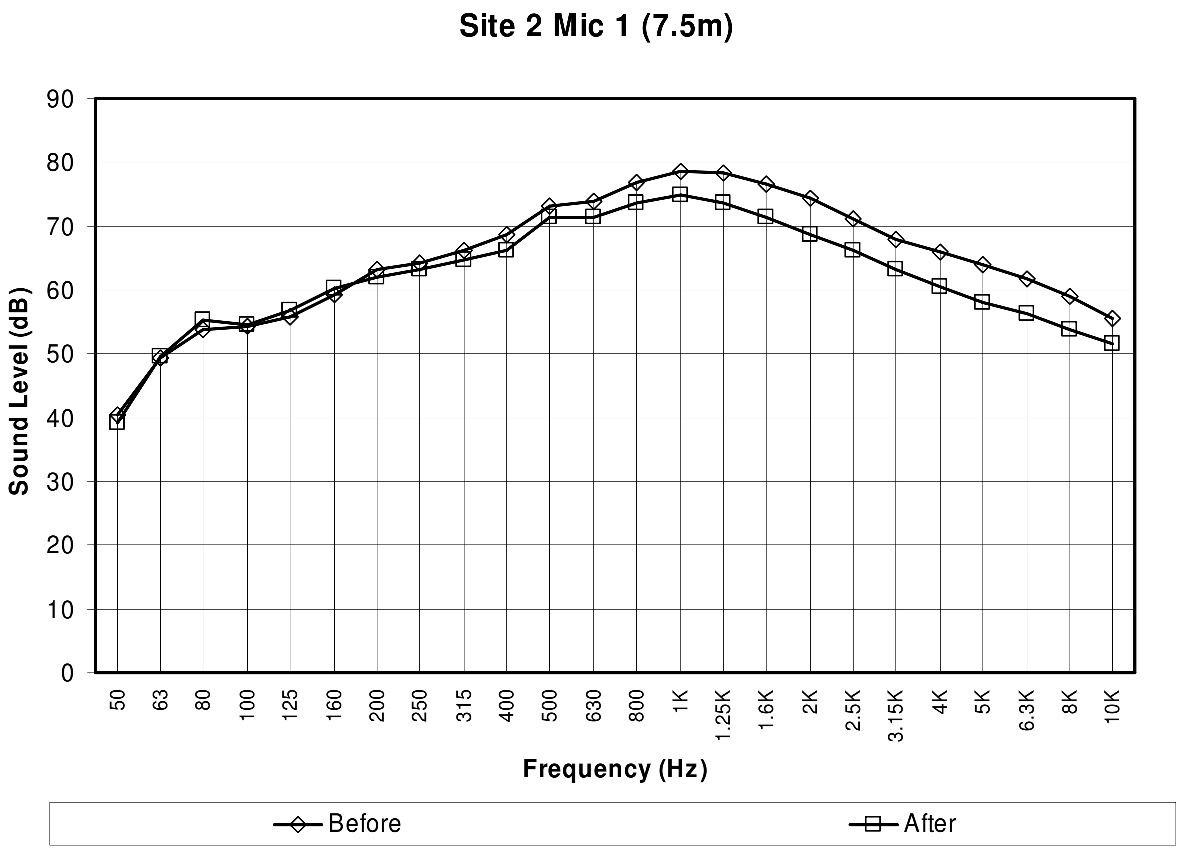

Figure 21: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 24.6 ft (7.5 m) microphone location at Site 2.

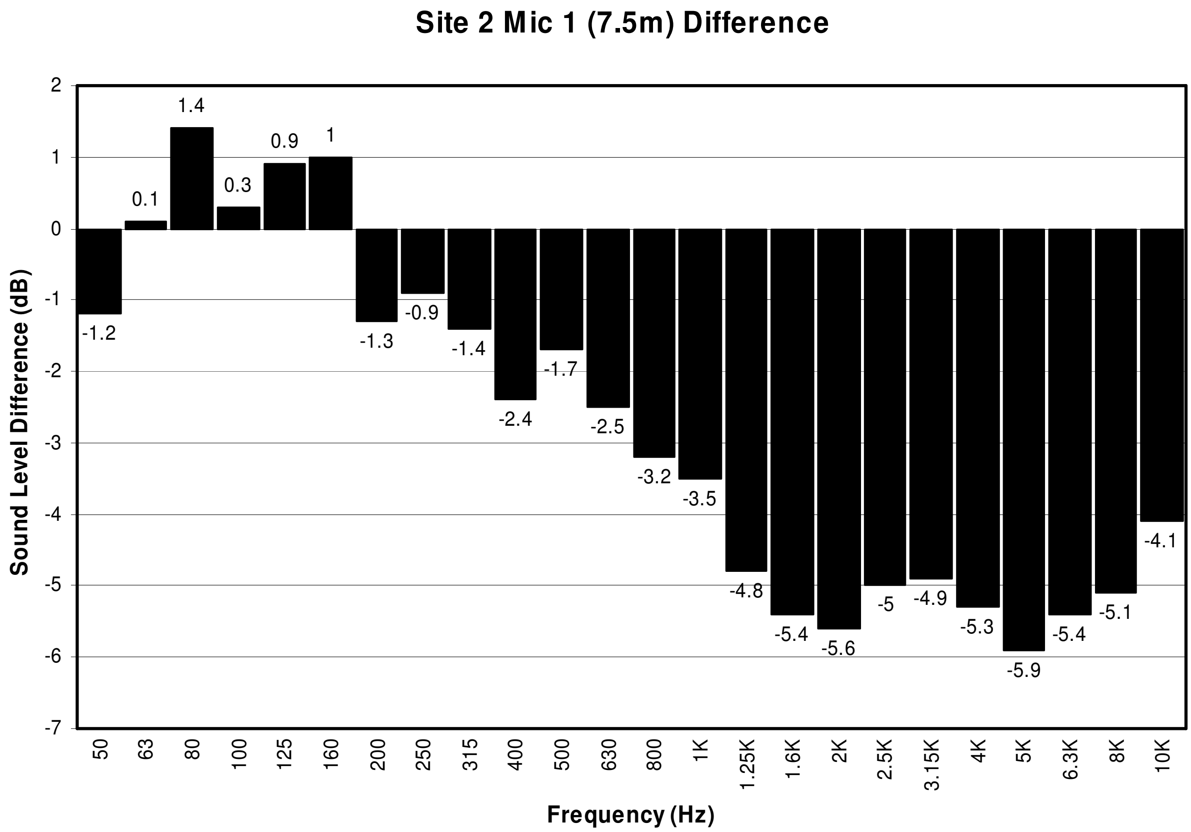

Figure 22: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 24.6 ft (7.5 m) microphone location at Site 2.

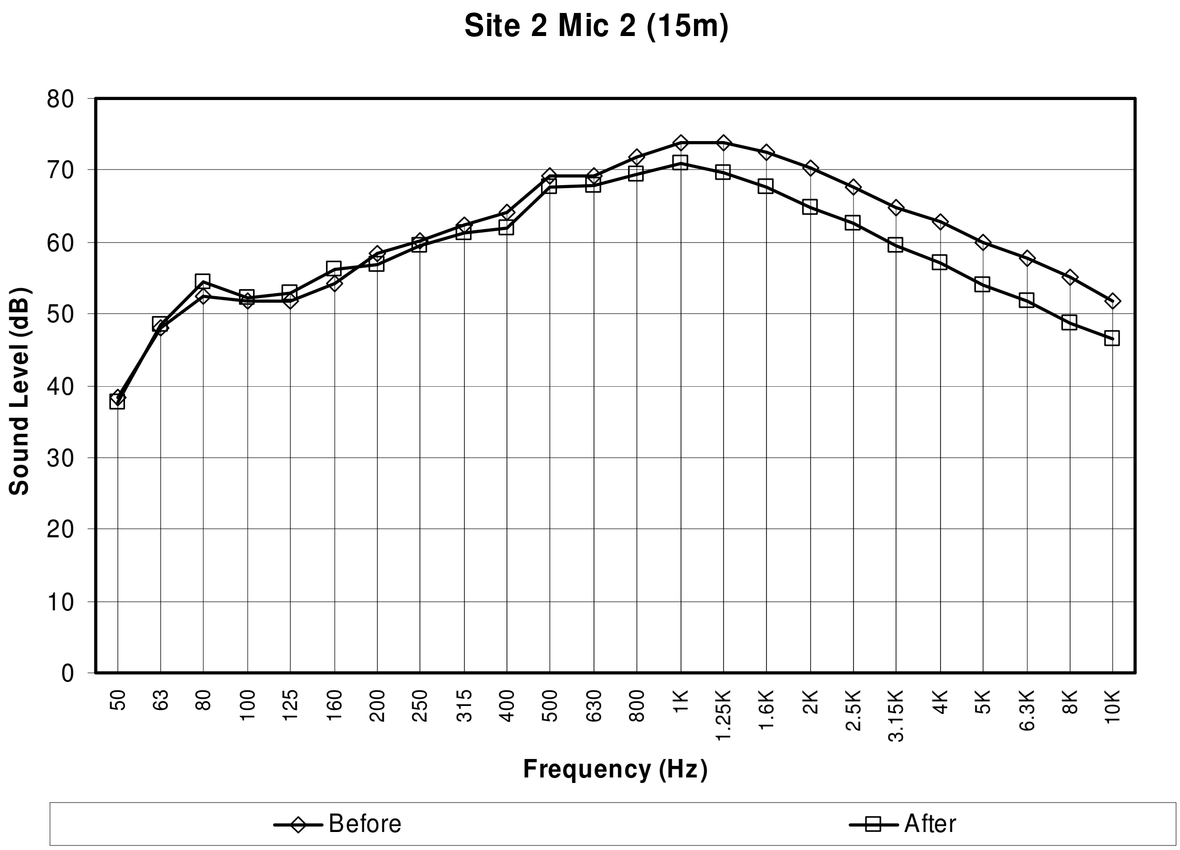

Figure 23: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 49.2 ft (15 m) microphone location at Site 2.

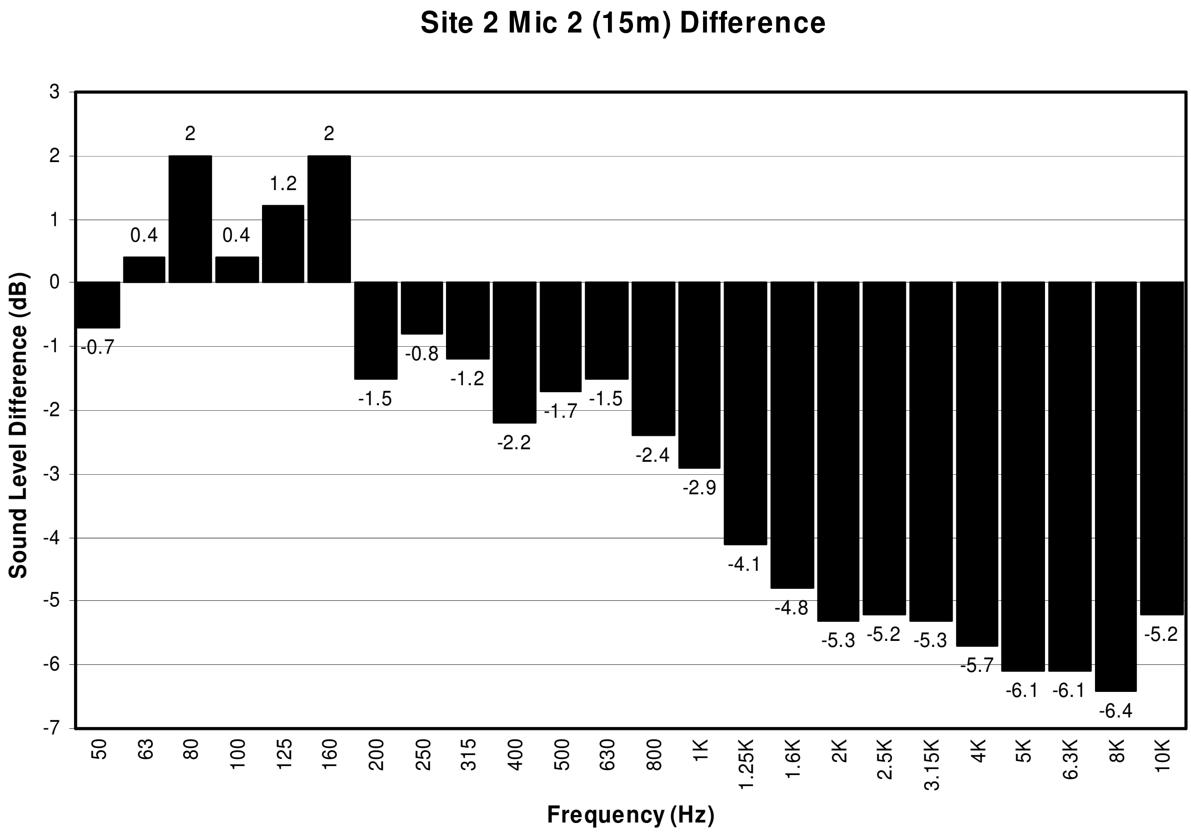

Figure 24: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 49.2 ft (15 m) microphone location at Site 2.

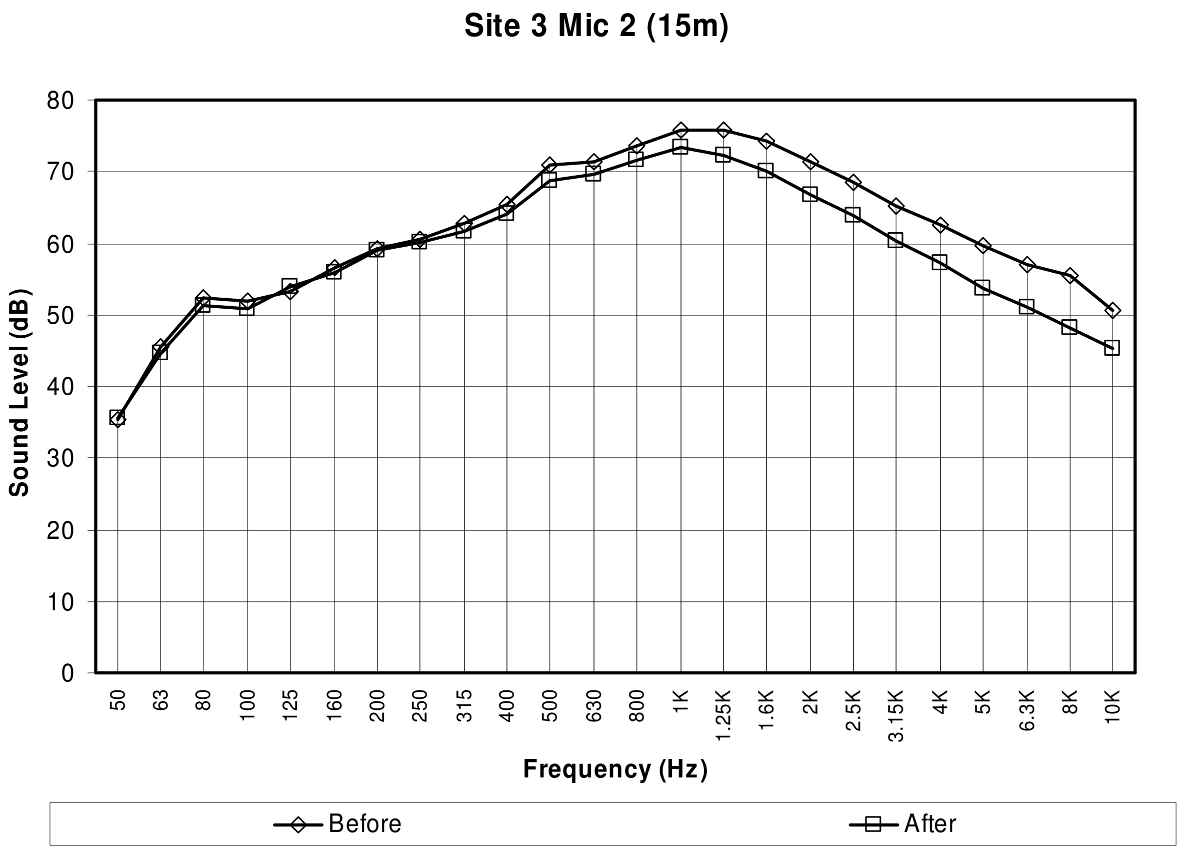

Figure 25: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 49.2 ft (15 m) microphone location at Site 3.

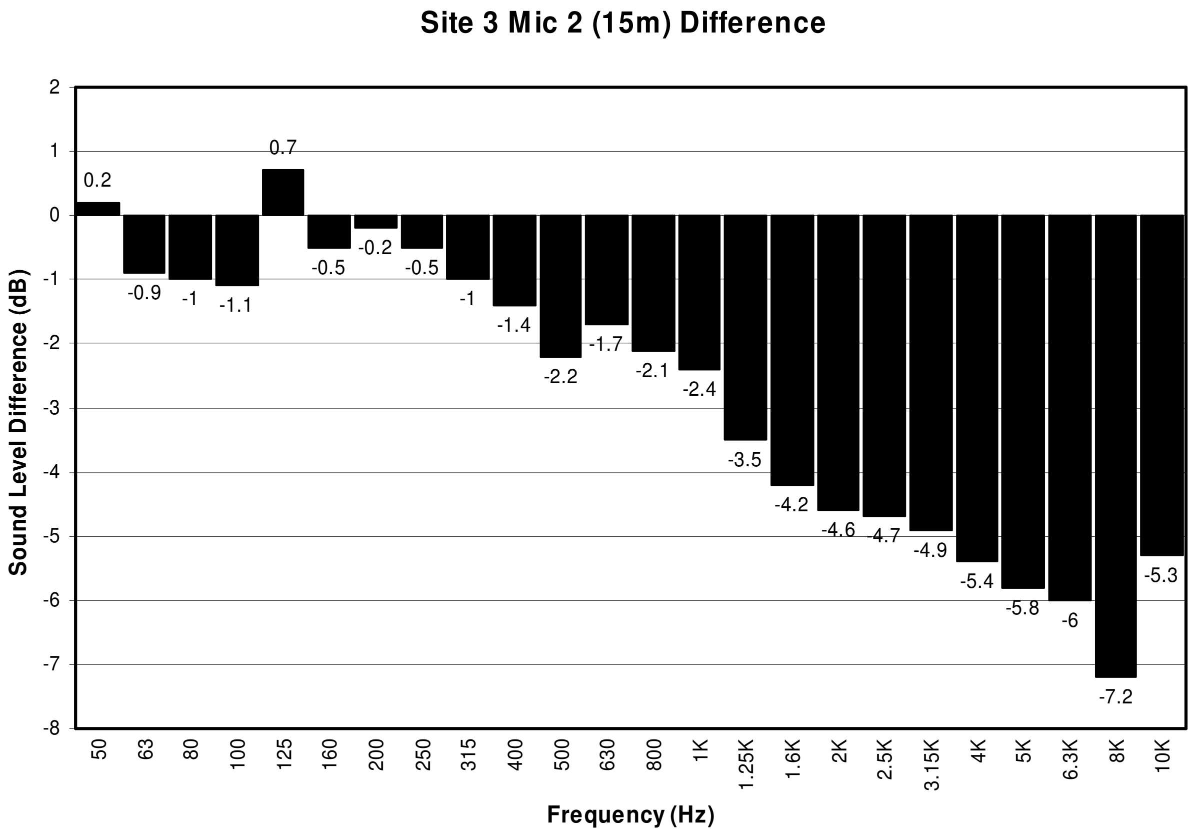

Figure 26: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 49.2 ft (15 m) microphone location at Site 3.

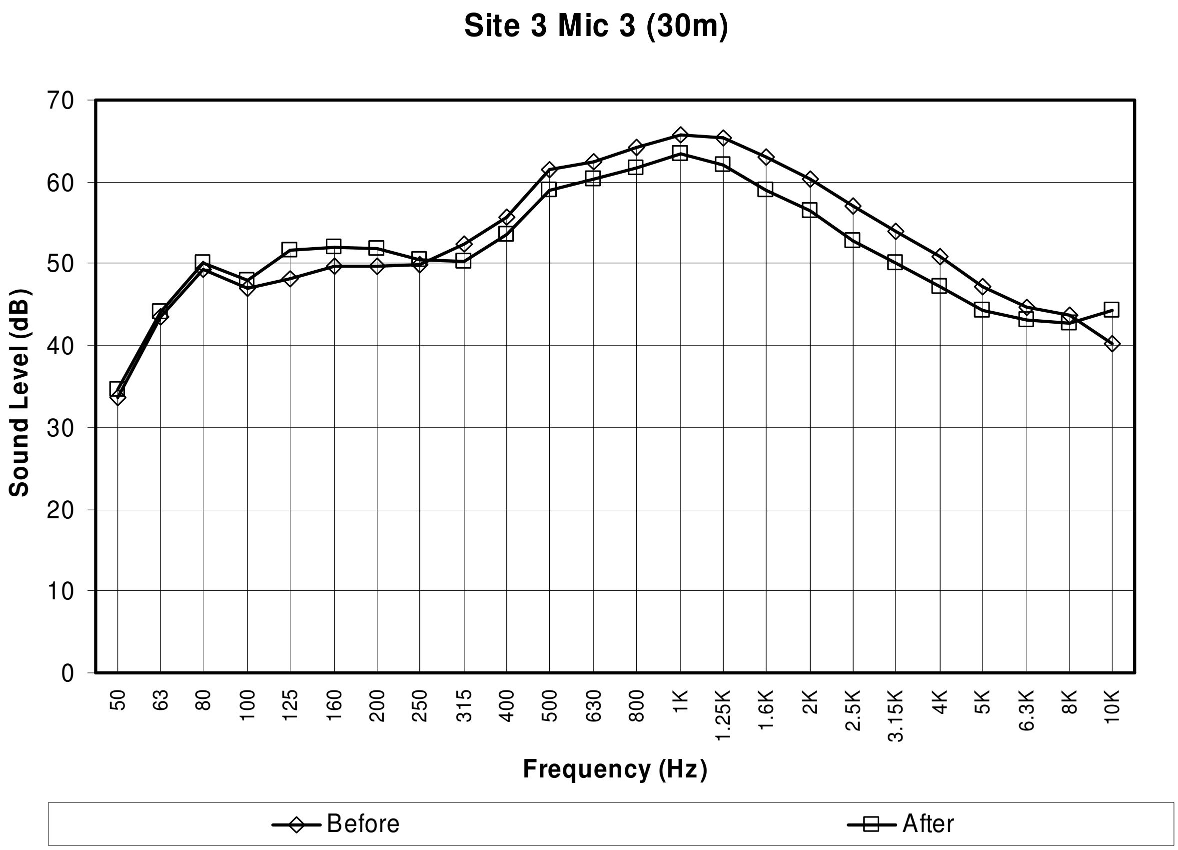

Figure 27: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 98.4 ft (30 m) microphone location at Site 3.

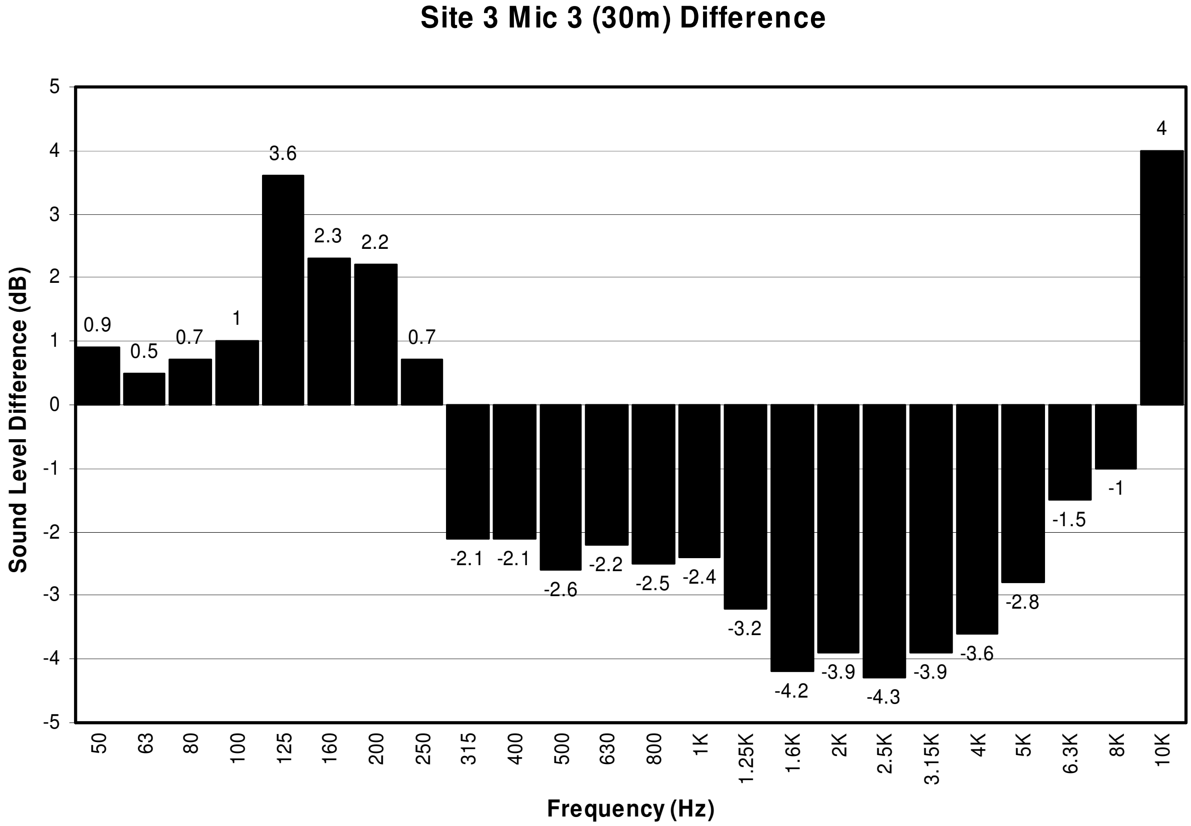

Figure 28: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 98.4 ft (30 m) microphone location at Site 3.

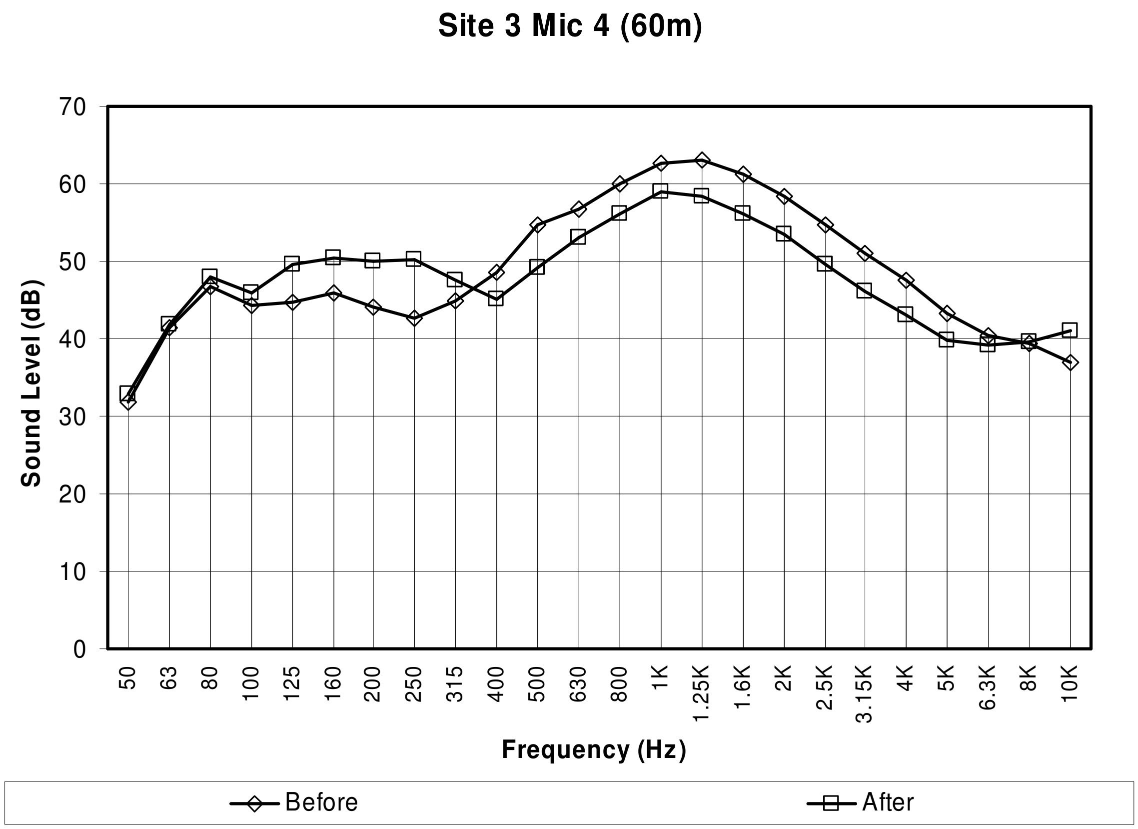

Figure 29: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 196.9 ft (60 m) microphone location at Site 3.

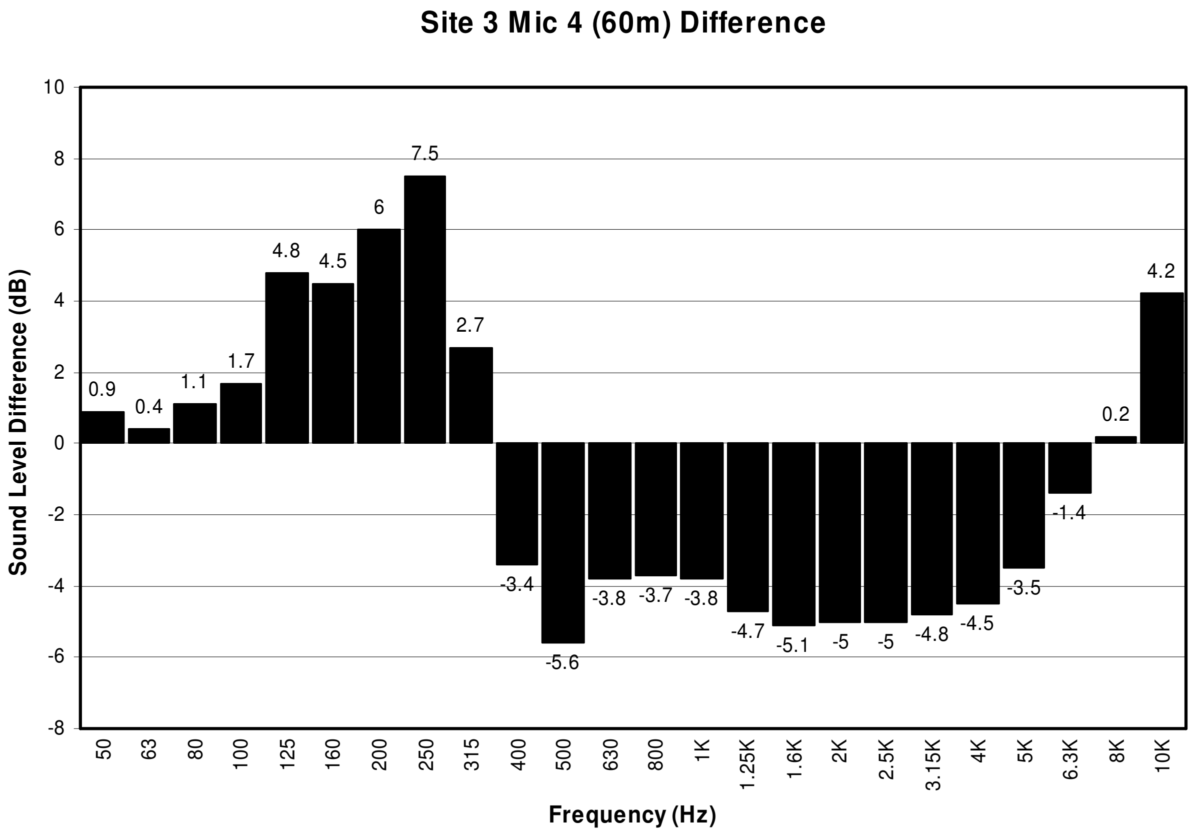

Figure 30: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 196.9 ft (60 m) microphone location at Site 3.

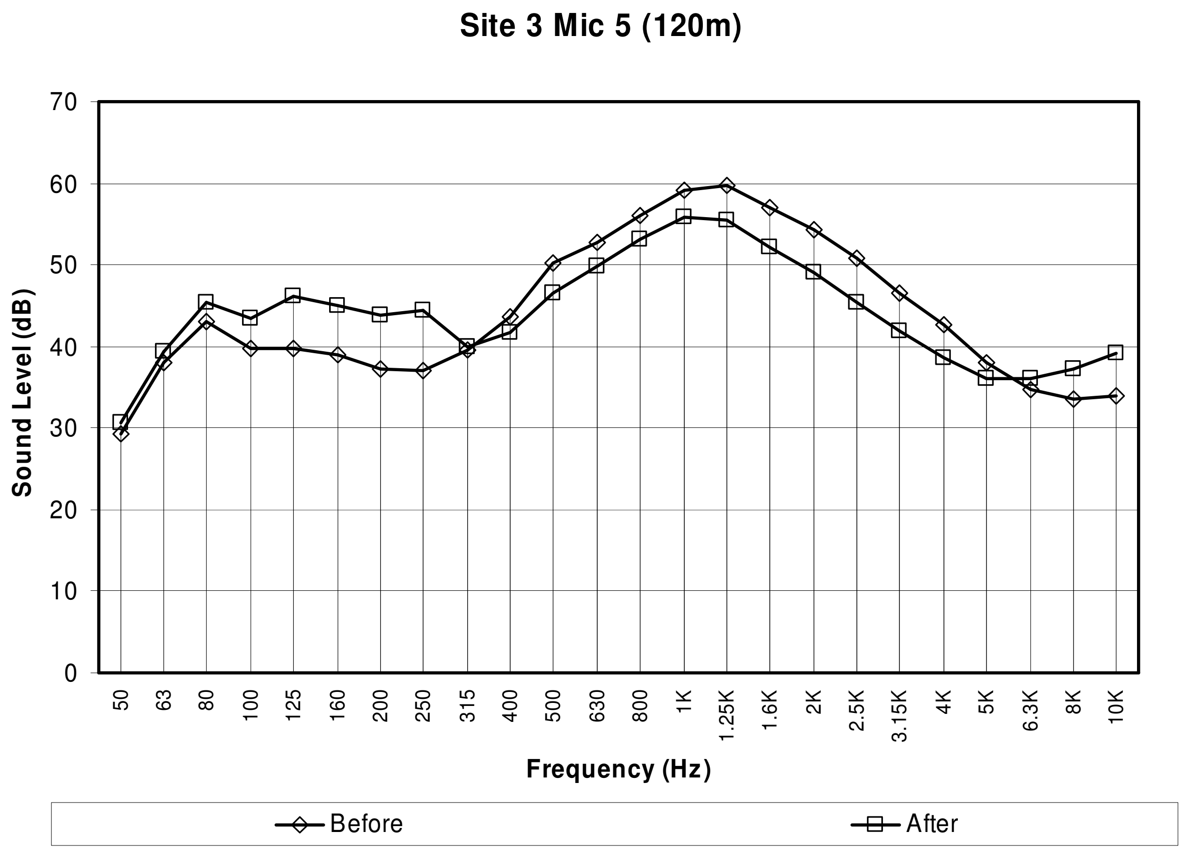

Figure 31: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 393.7 ft (120 m) microphone location at Site 3.

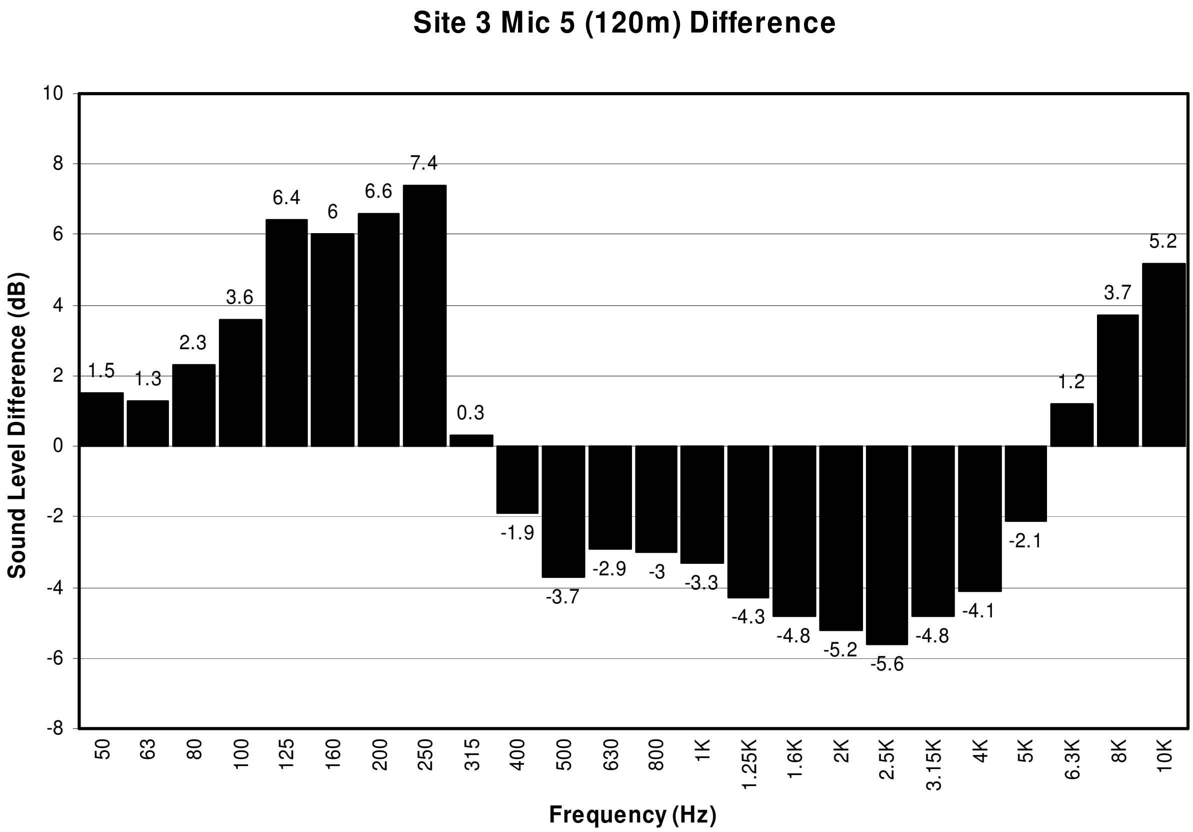

Figure 32: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 393.7 ft (120 m) microphone location at Site 3.

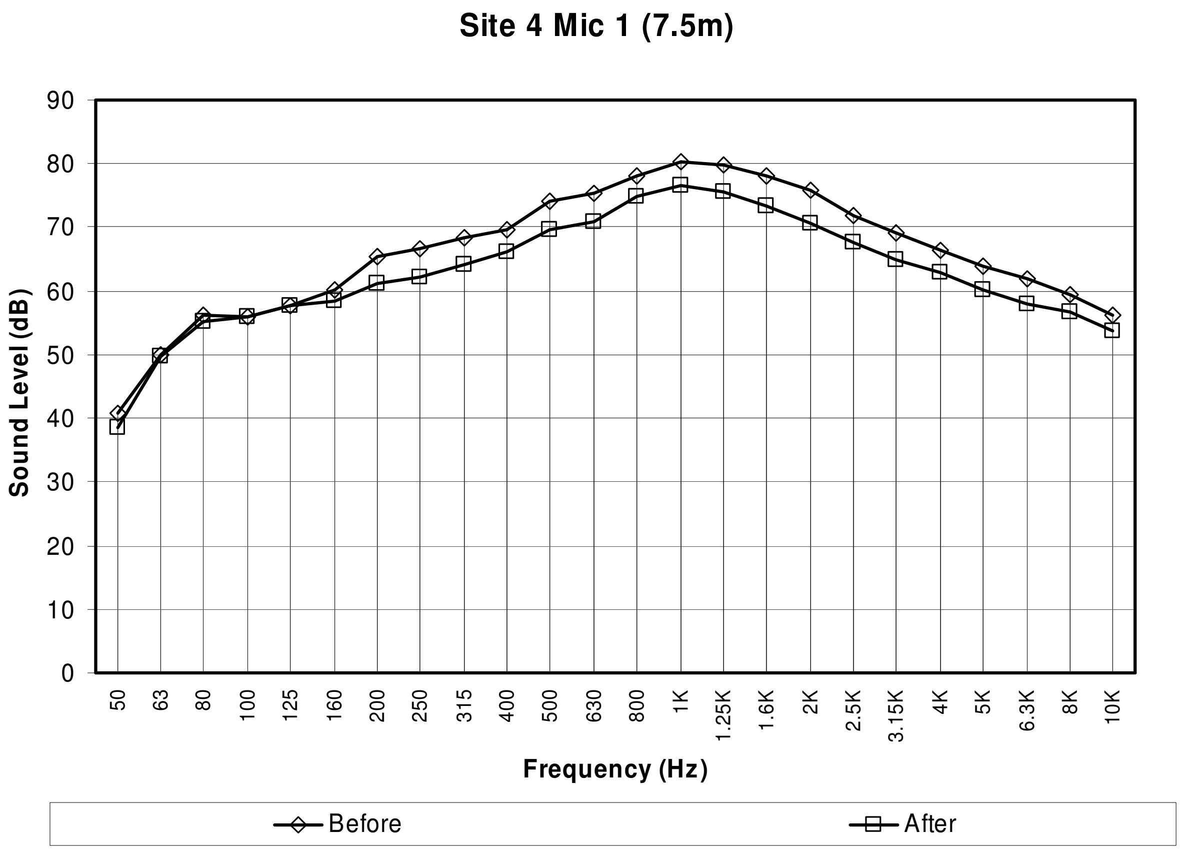

Figure 33: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 24.6 ft (7.5 m) microphone location at Site 4.

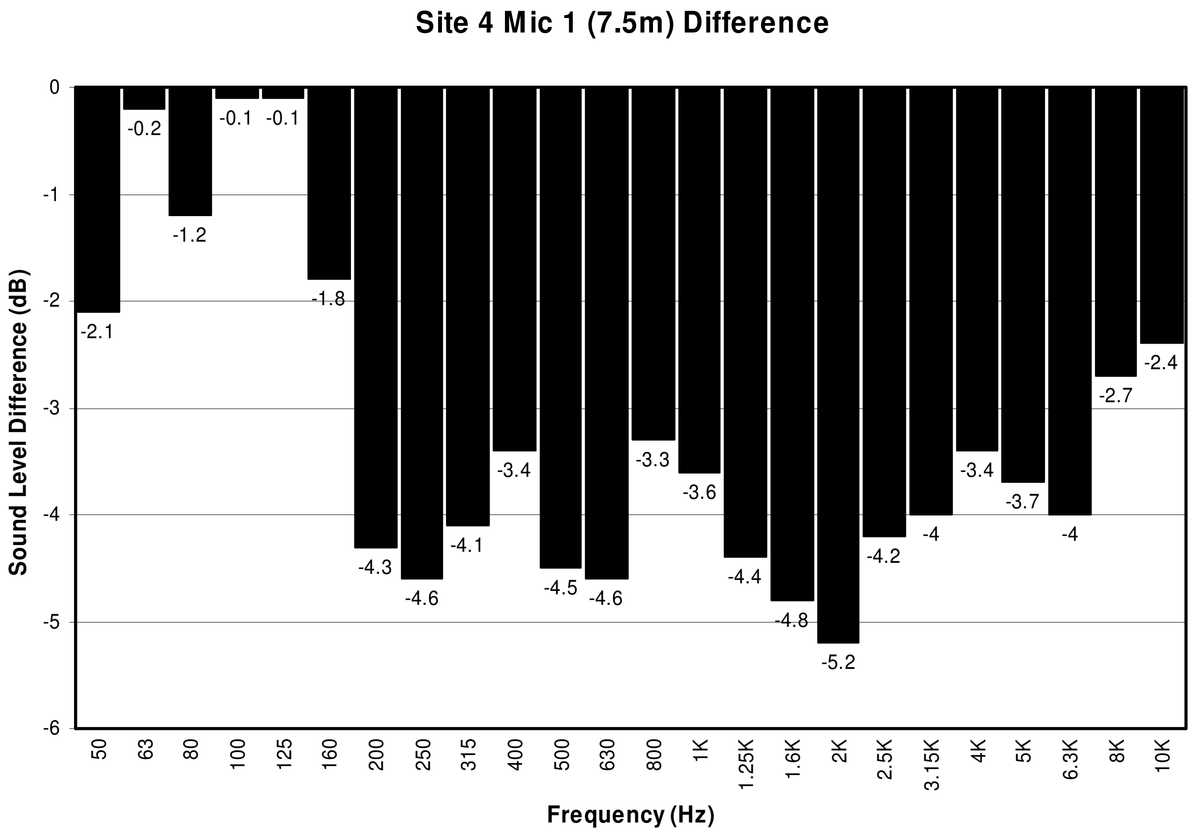

Figure 34: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 24.6 ft (7.5 m) microphone location at Site 4.

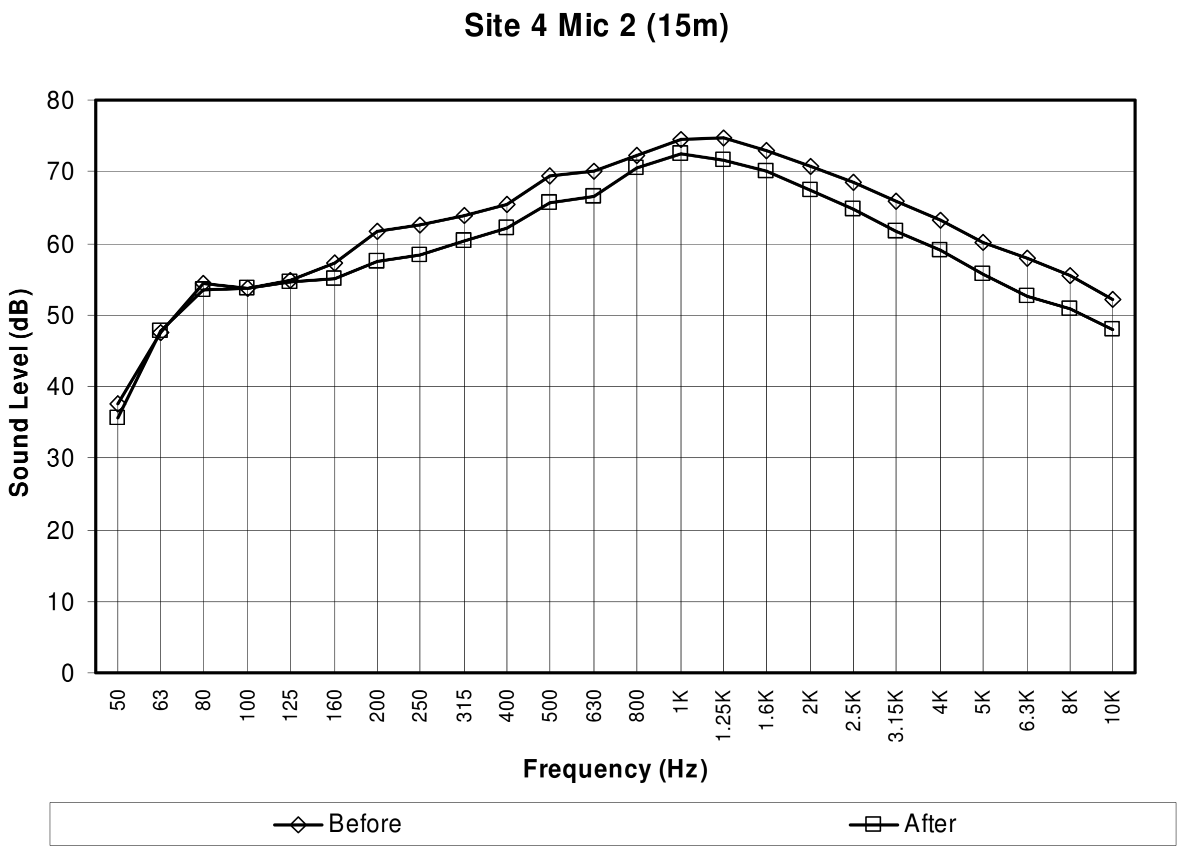

Figure 35: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 49.2 ft (15 m) microphone location at Site 4.

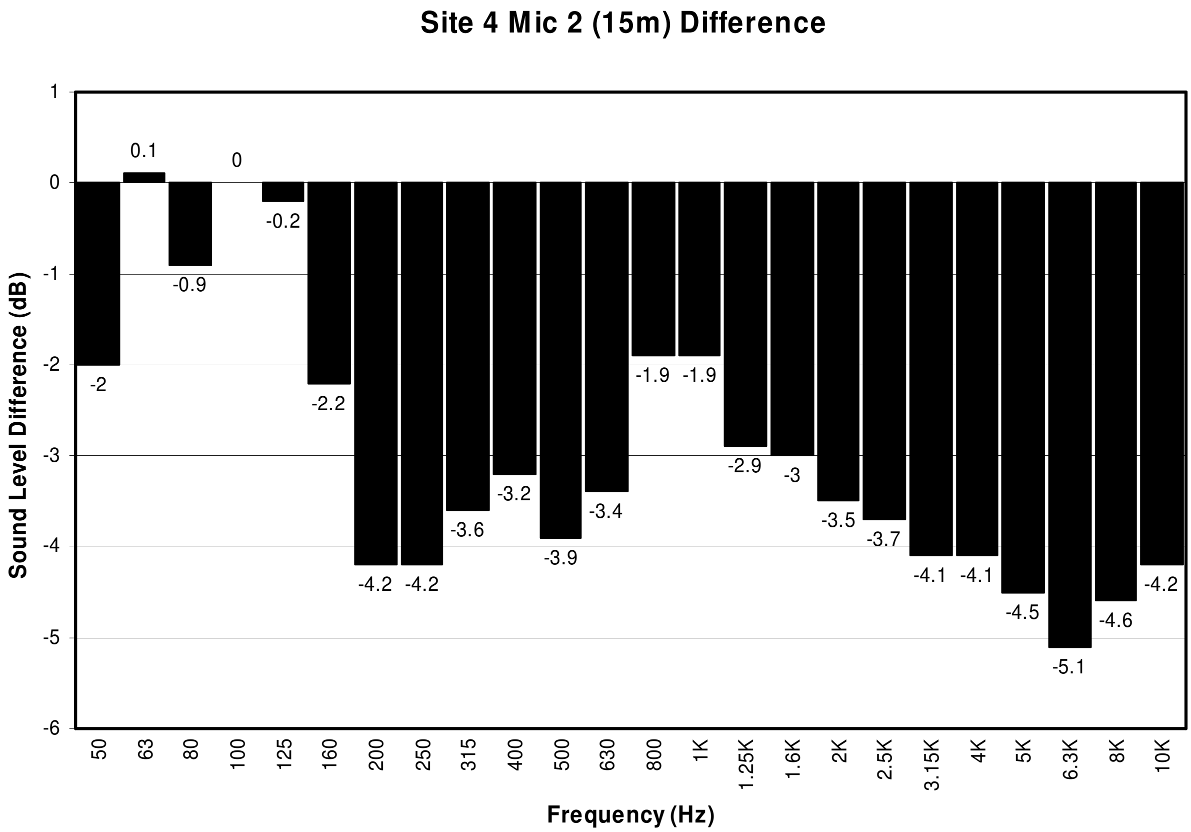

Figure 36: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 49.2 ft (15 m) microphone location at Site 4.

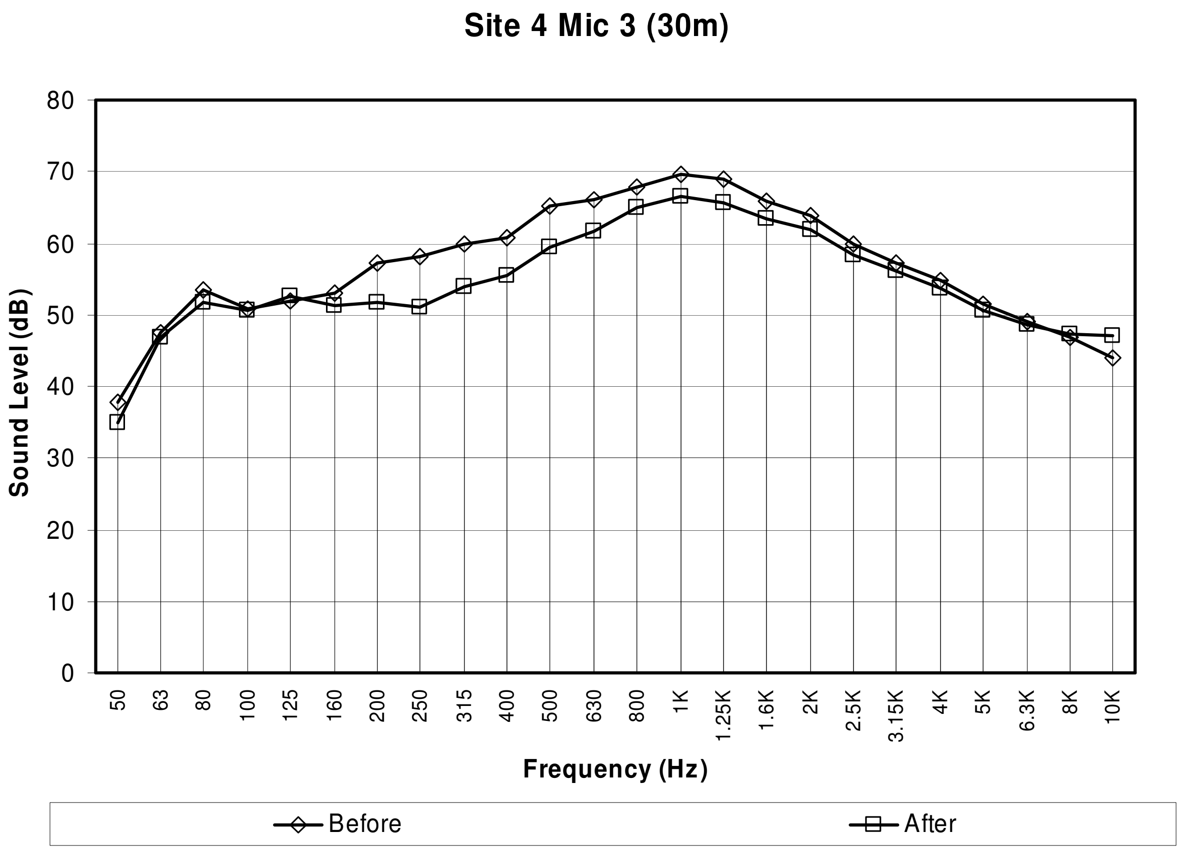

Figure 37: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 98.4 ft (30 m) microphone location at Site 4.

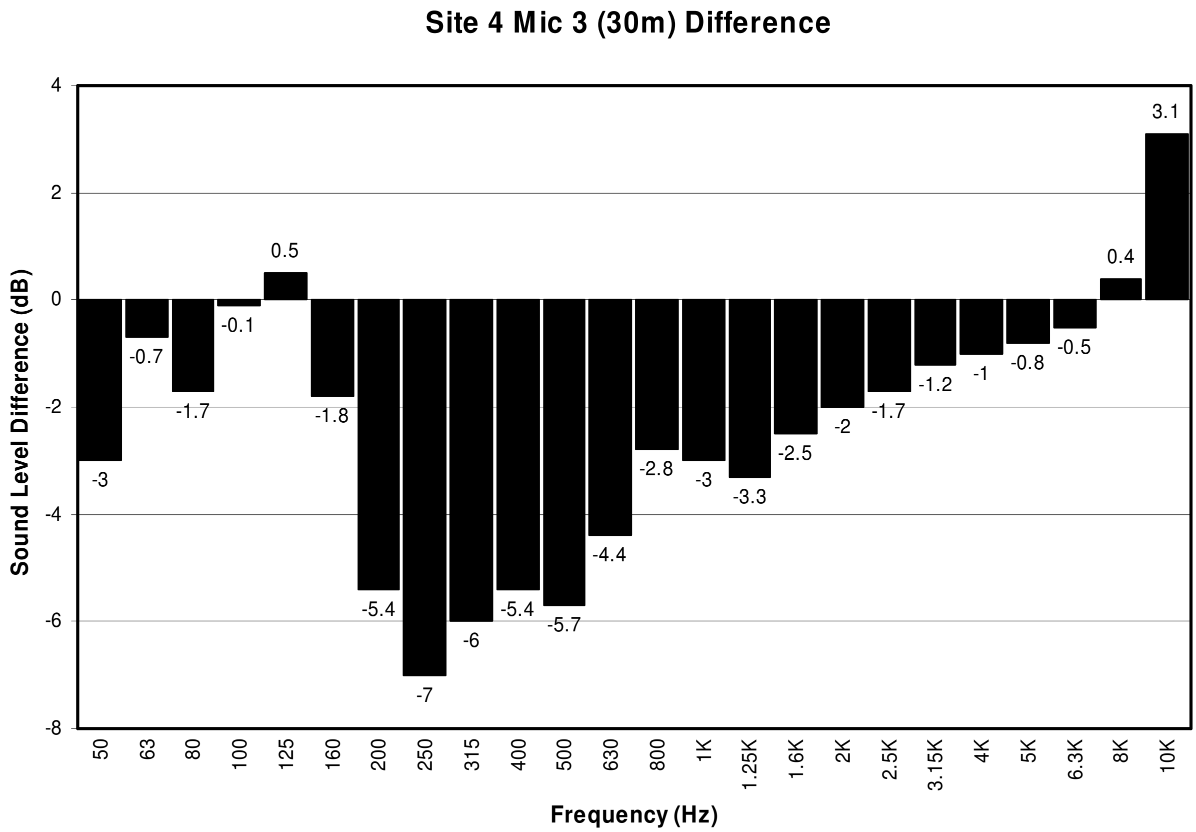

Figure 38: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 98.4 ft (30 m) microphone location at Site 4.

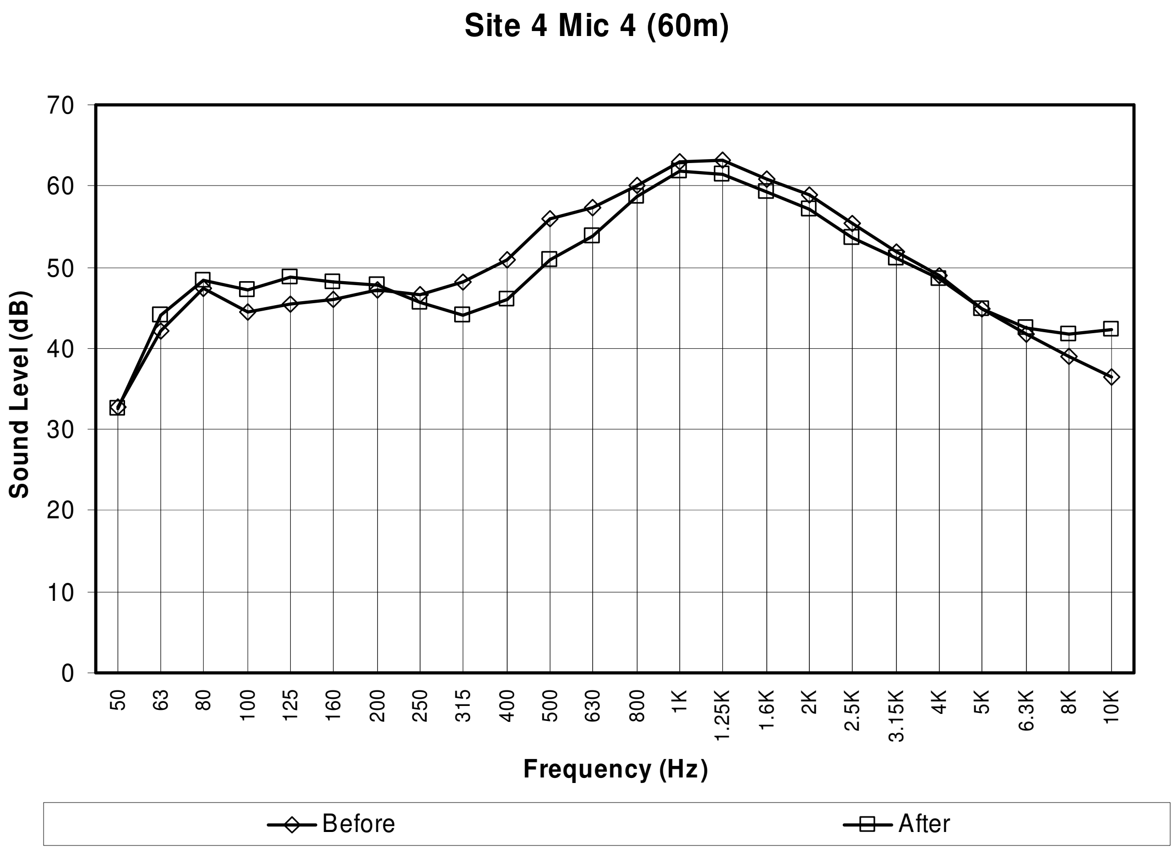

Figure 39: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 196.9 ft (60 m) microphone location at Site 4.

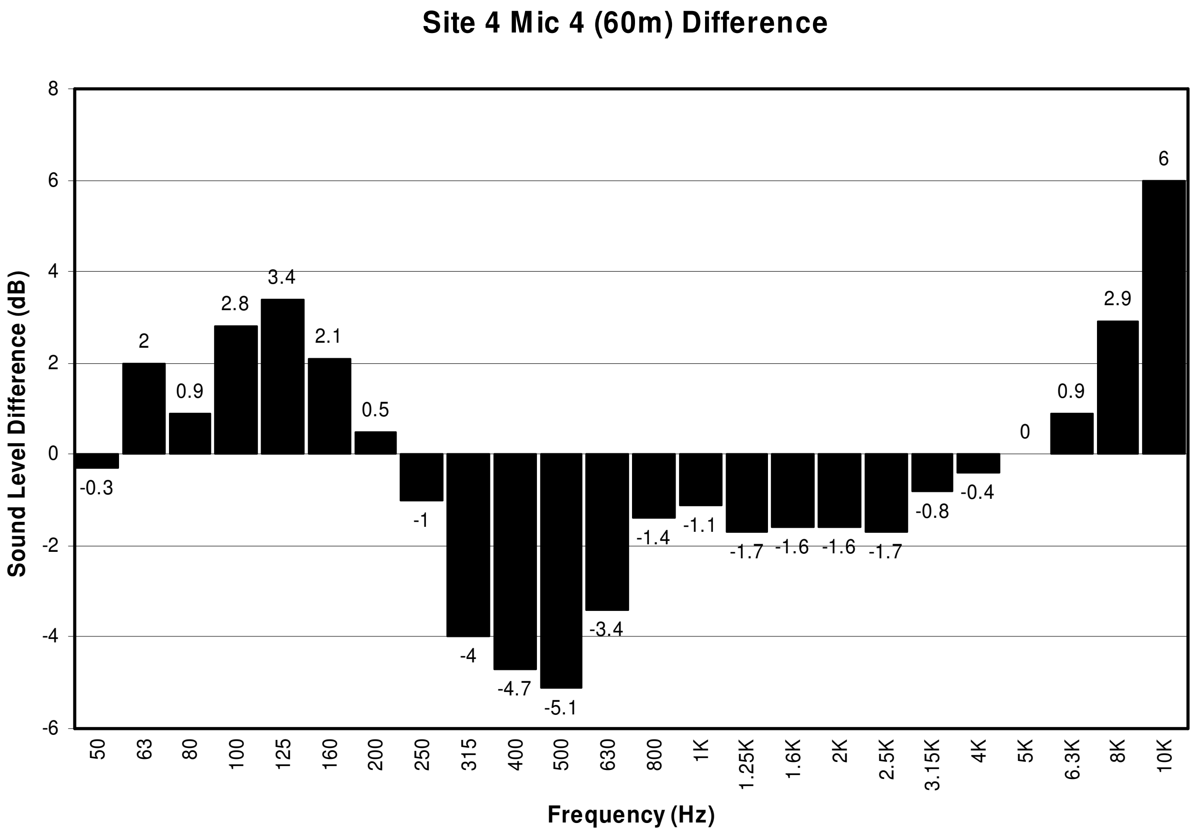

Figure 40: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 196.9 ft (60 m) microphone location at Site 4.

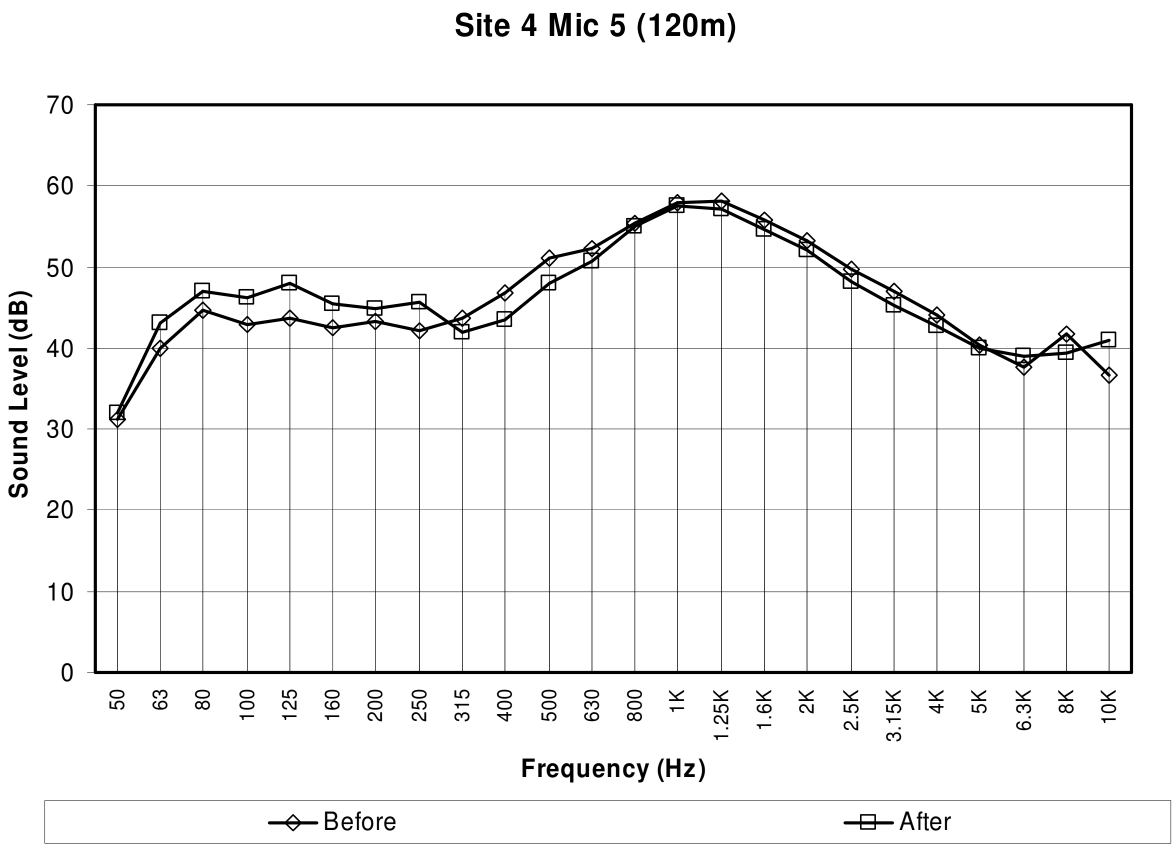

Figure 41: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 393.7 ft (120 m) microphone location at Site 4.

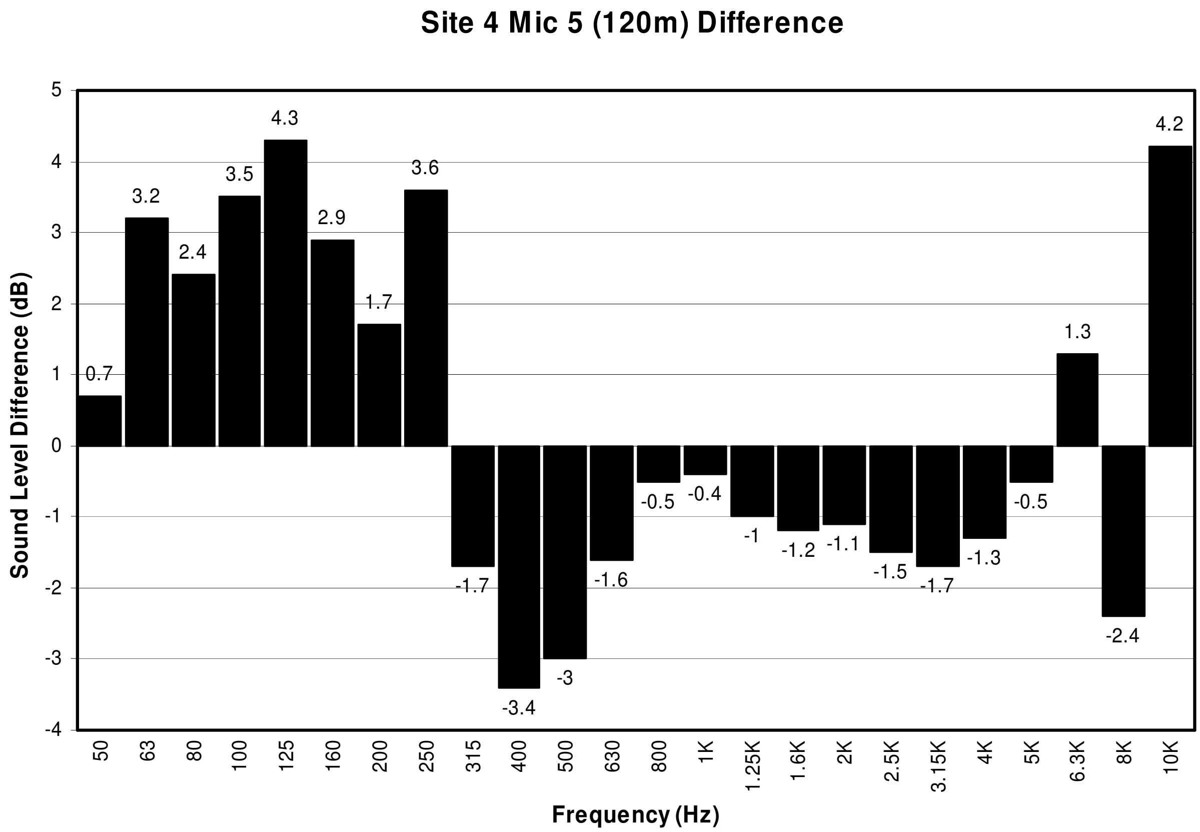

Figure 42: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 393.7 ft (120 m) microphone location at Site 4.

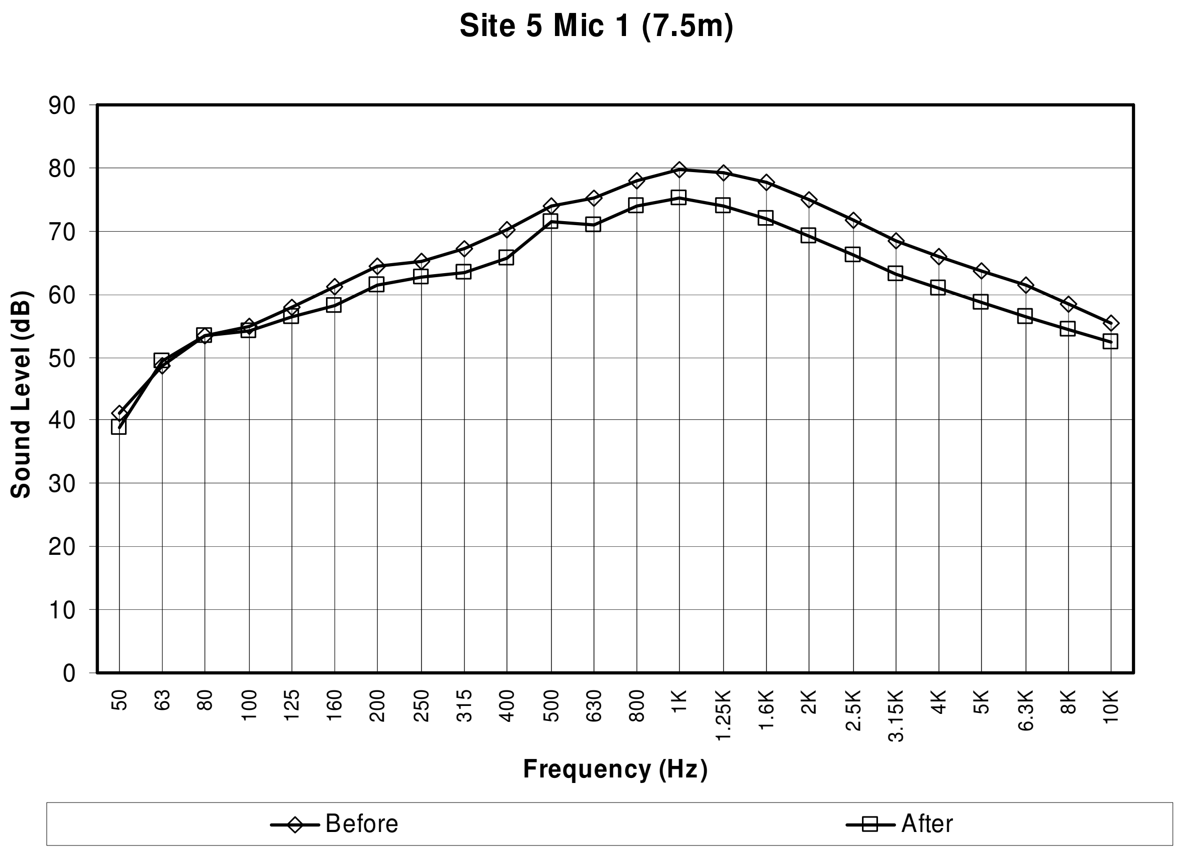

Figure 43: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 24.6 ft (7.5 m) microphone location at Site 5.

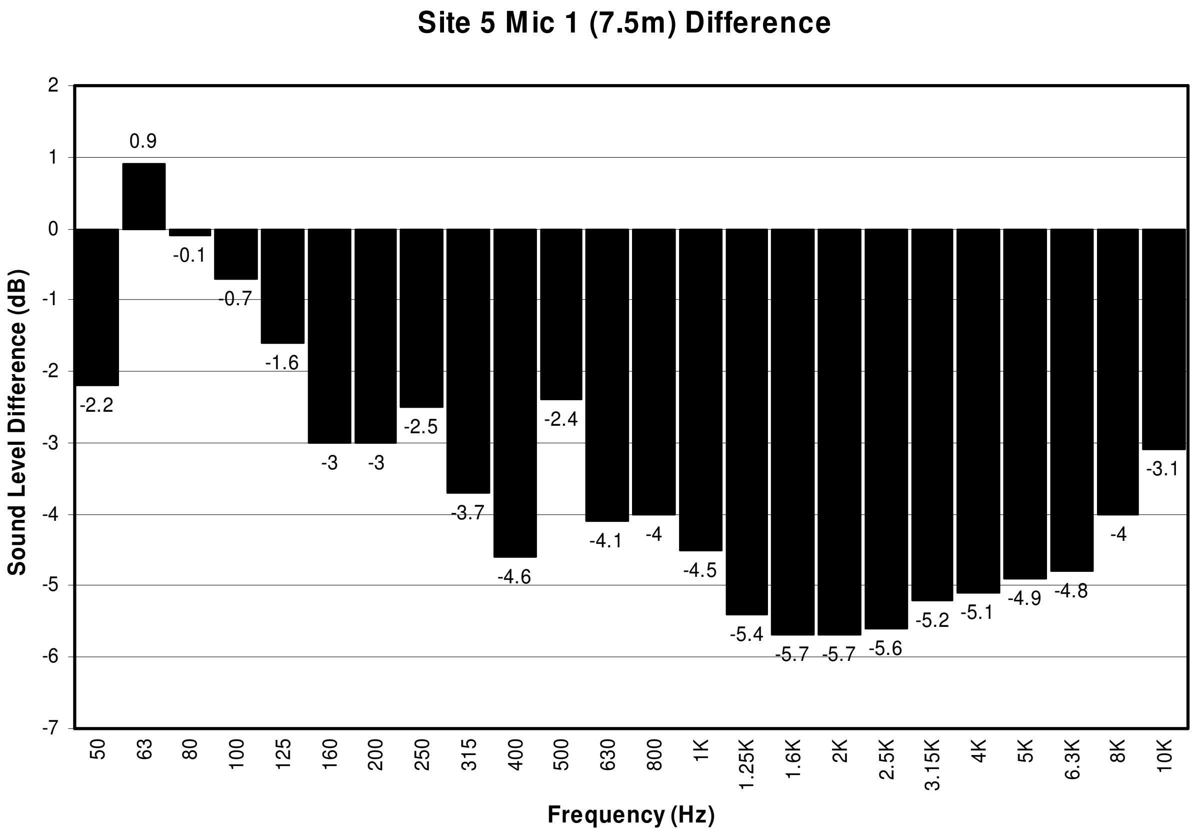

Figure 44: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 24.6 ft (7.5 m) microphone location at Site 5.

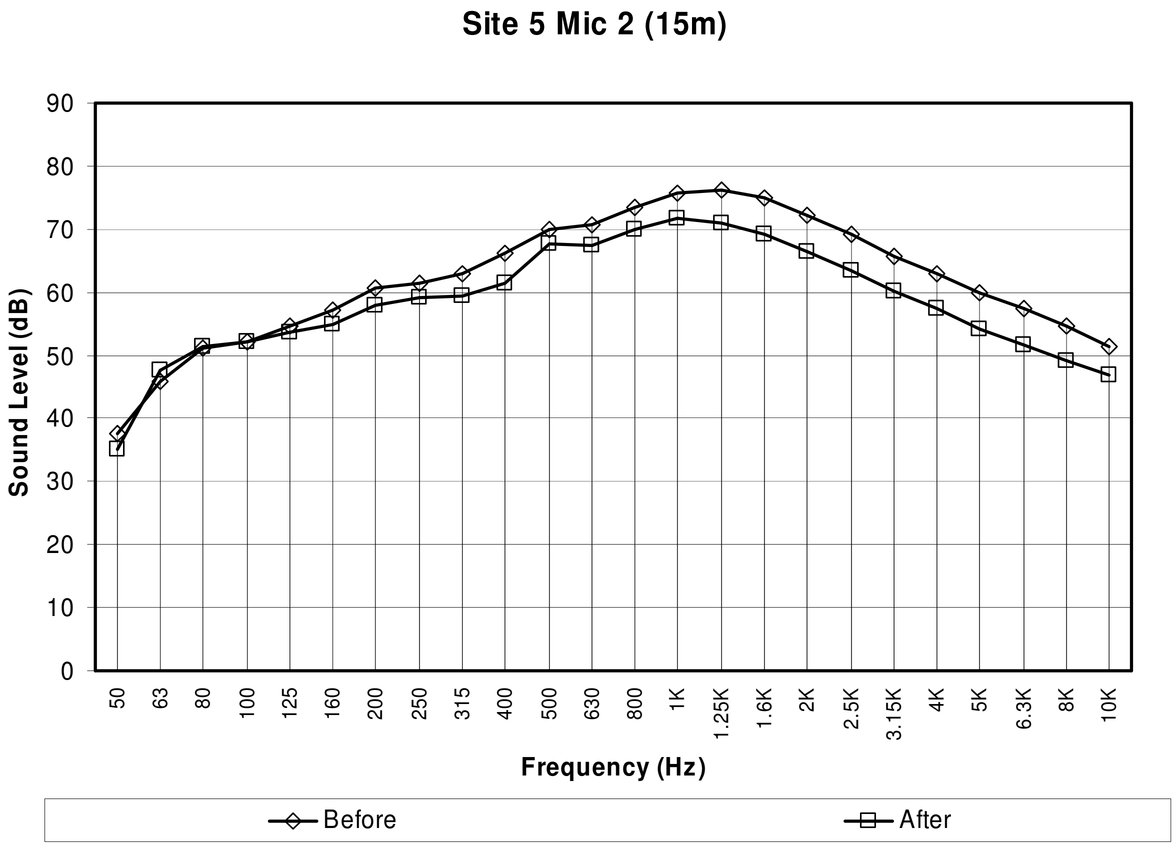

Figure 45: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 49.2 ft (15 m) microphone location at Site 5.

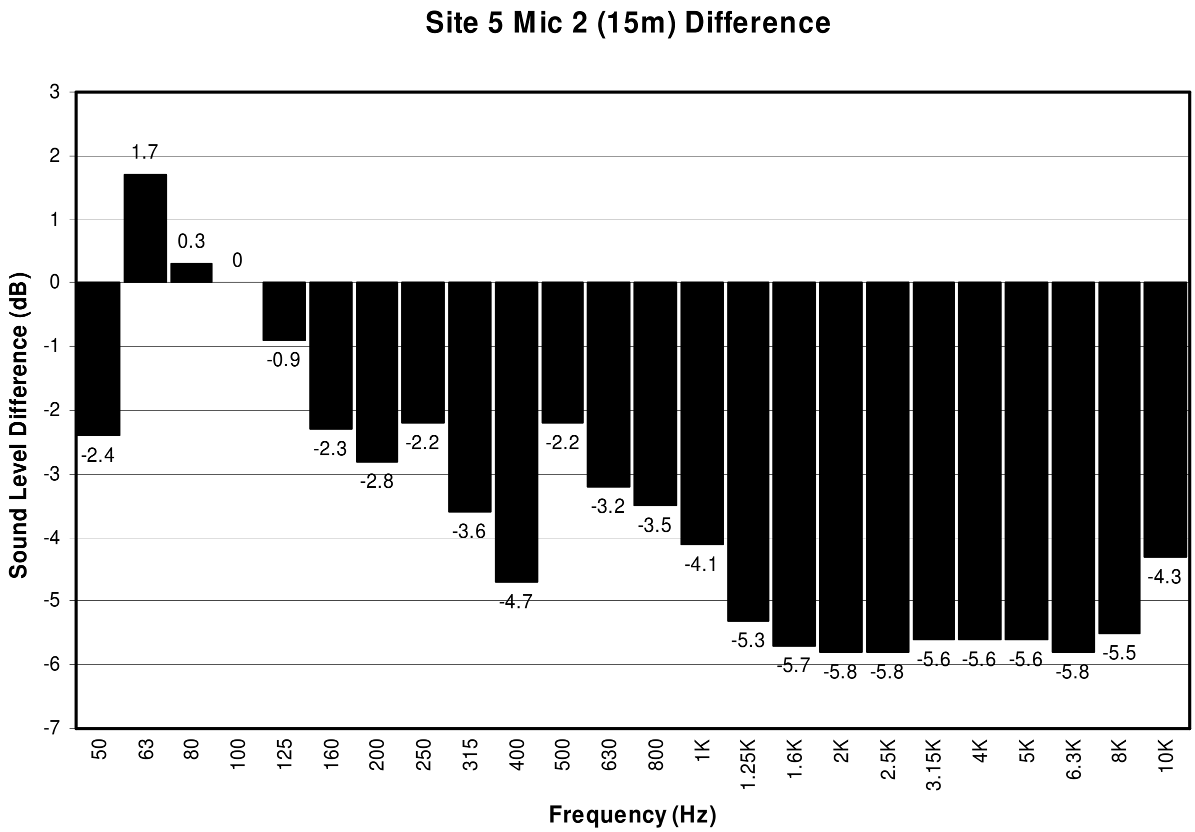

Figure 46: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 49.2 ft (15 m) microphone location at Site 5.

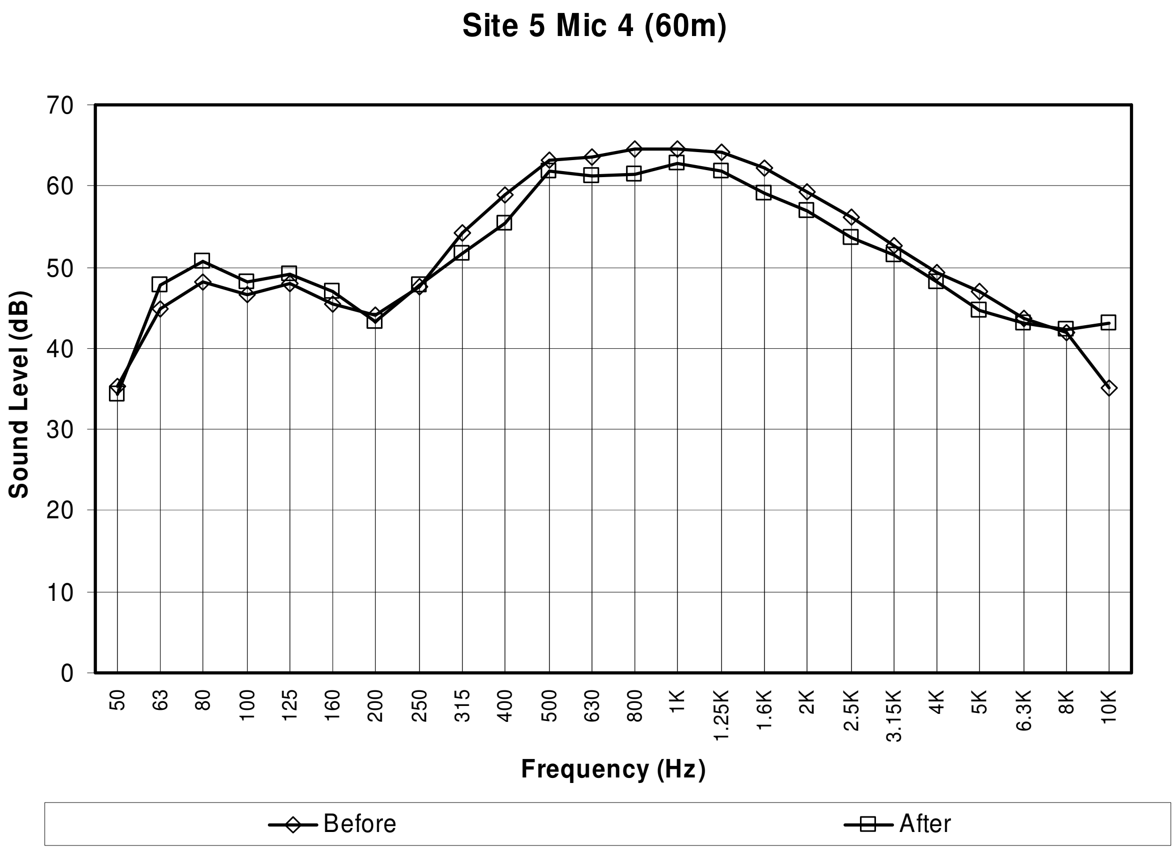

Figure 47: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 196.9 ft (60 m) microphone location at Site 5.

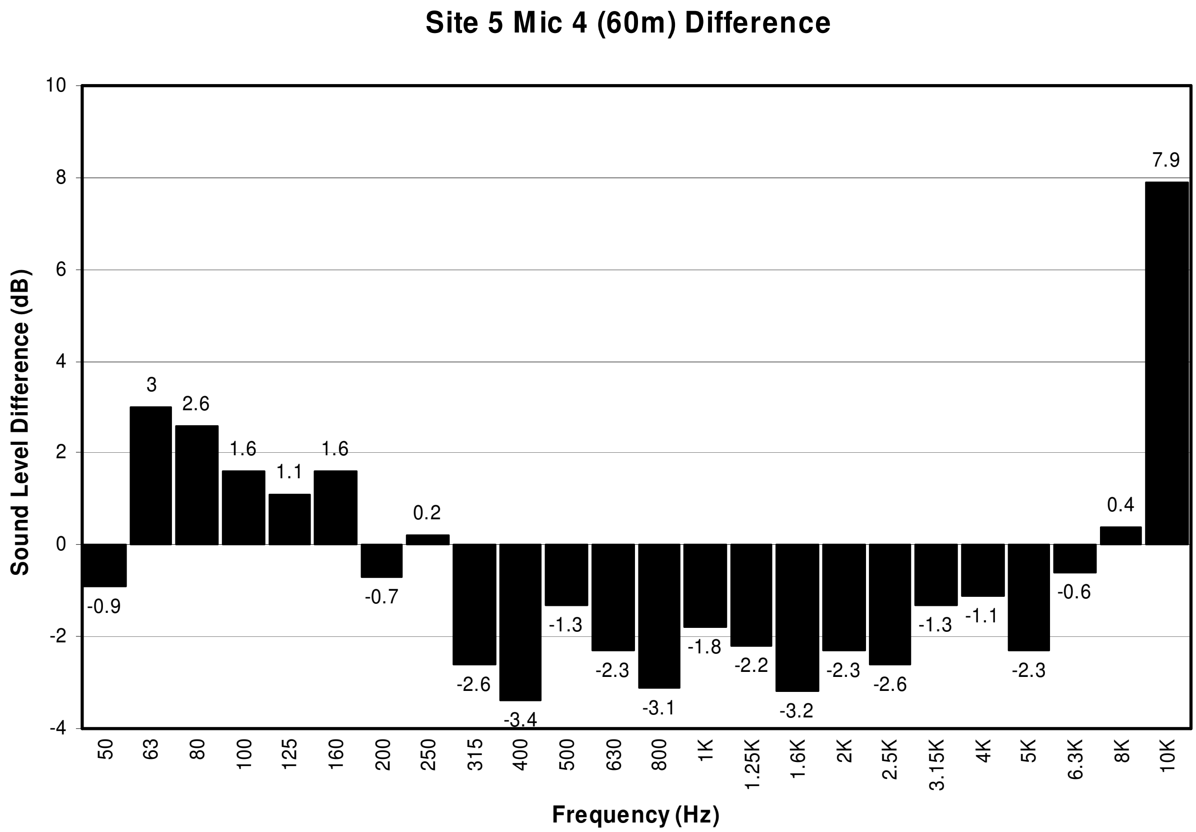

Figure 48: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 196.9 ft (60 m) microphone location at Site 5.

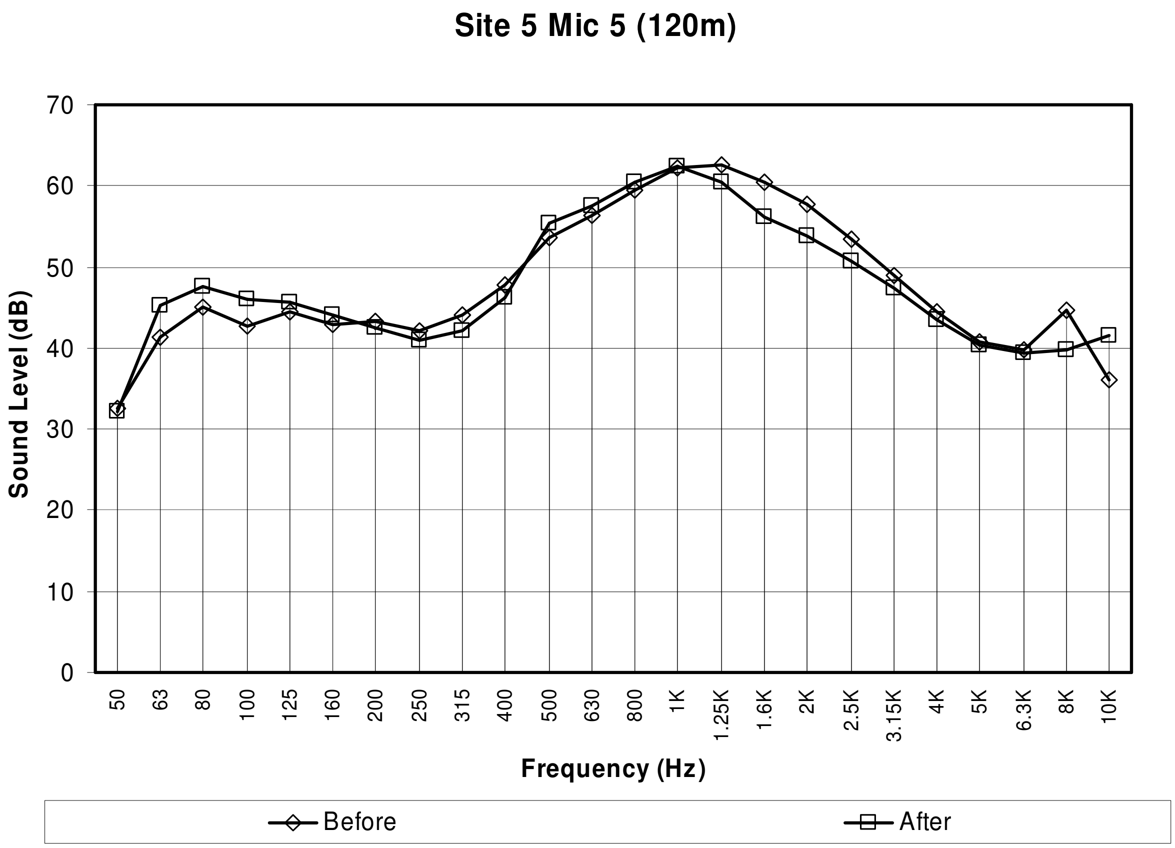

Figure 49: The equivalent continuous sound level, A-weighted by 1/3 octave frequency band, measured before and after diamond grinding for the 393.7 ft (120 m) microphone location at Site 5.

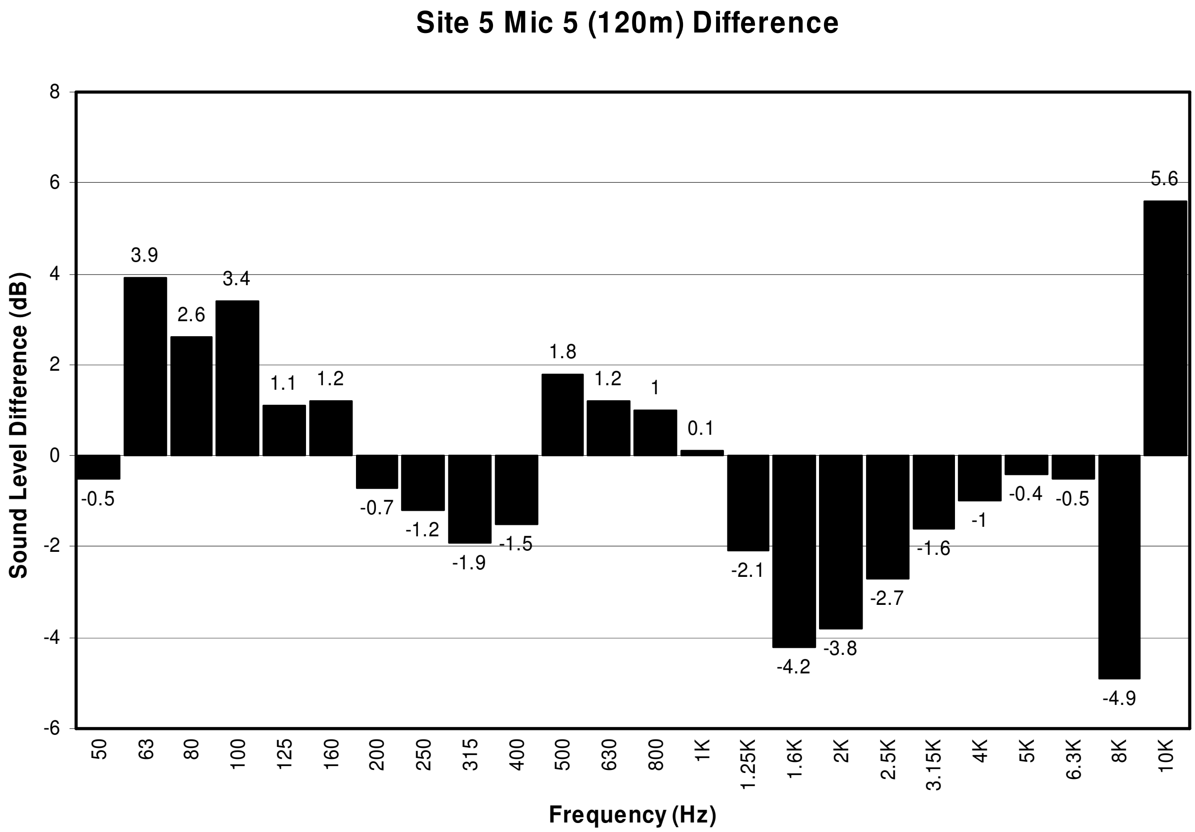

Figure 50: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the 393.7 ft (120 m) microphone location at Site 5.

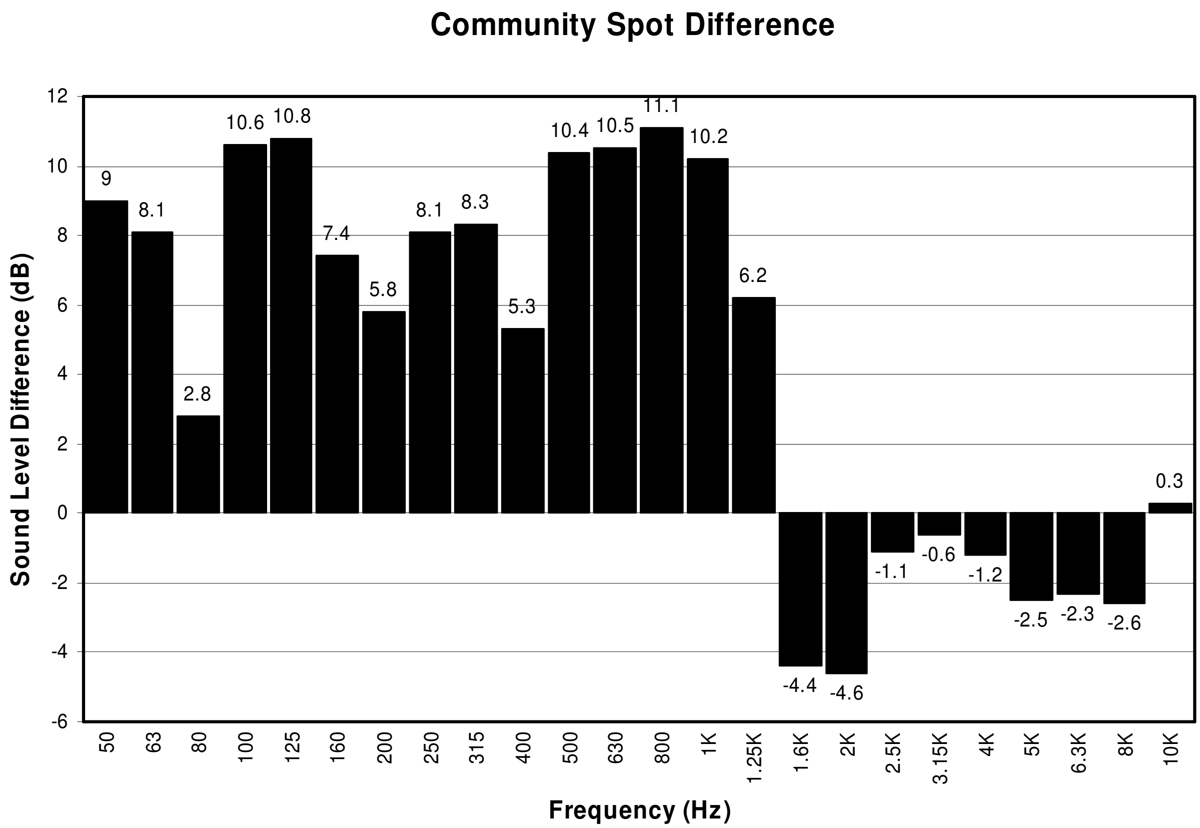

Figure 51: The difference in the equivalent continuous sound level due to diamond grinding, A-weighted by 1/3 octave frequency band, for the Community Spot microphone location at 290 Hanna Dr.