Draft Noise and Vibration Assessment

Gazex Avalanche Mitigation System

Alpine Meadows, California

BAC Job # 2018-211

Prepared For:

Placer County Community Development Department

Attn: Ms. Leigh Chavez
3091 County Center Drive
Auburn, CA 95603

Prepared By:

Bollard Acoustical Consultants, Inc.

Paul Bollard, President

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Acoustical Consultants

Introduction

Project Background

Squaw Valley | Alpine Meadows (Squaw-Alpine) is owned by subsidiaries of Squaw Valley Ski Holdings, LLC, headquartered in the Olympic Valley area of Placer County, California. Squaw Valley Ski Holdings, LLC was formed in 2011 to be the parent company of Squaw Valley | Alpine Meadows' operating subsidiaries.

In 2015, Squaw-Alpine began installing Gazex avalanche mitigation systems as a safer alternative to the use of hand charges to trigger avalanches[1]. Gazex is a fixed location, remote avalanche control system based on exploding a propane/oxygen gas mixture inside an open metal tube. This system for preventive control consists of exploders (tubes) positioned in avalanche starting areas and connected by pipelines to a central gas unit (shelter containing oxygen and propane tanks). When the system is detonated it creates a pressure wave directed at the surface of the snow which is intended to trigger a controlled avalanche. Figure 1 shows photographs of the Gazex equipment. To date, 18 Gazex systems have been installed at the following locations:

- 4 within the resort boundaries at Alpine Meadows
- 6 within the resort boundaries at Squaw Valley
- 8 on Alpine Meadows Road

Following installation of the Gazex systems along Alpine Meadows Road, many local residents of the Alpine Meadows community expressed concerns regarding the noise and vibration generated by the Gazex systems. In response to the local concerns, Placer County retained the services of Bollard Acoustical Consultants, Inc. (BAC) to conduct Gazex system noise and vibration monitoring during a portion of the 2018-2019 ski season. Specifically, BAC was retained to monitor the noise and vibration generation of the 8 Gazex systems located along Alpine Meadows Road, and to compare the measurement results against industry standards for acceptable noise and vibration exposure.

This draft report contains the numeric results of BAC's surveys, research into acceptable noise and vibration exposure, and a comparison of the numeric data against those criteria.

[1] The use of hand charges for avalanche control resulted to two previous deaths and led the search for a safer alternative.

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Noise Fundamentals

Noise - General

Noise is often described as unwanted sound. Sound is defined as any pressure variation in air that the human ear can detect. If the pressure variations occur frequently enough (at least 20 times per second), they can be heard and hence are called sound. The number of pressure variations per second is called the frequency of sound, and is expressed as cycles per second, called Hertz (Hz).

Decibel Scale

Measuring sound directly in terms of pressure would require a very large and awkward range of numbers. To avoid this, the decibel scale was devised. The decibel scale uses the hearing threshold (20 micropascals), as a point of reference, defined as 0 dB. Other sound pressures are then compared to the reference pressure, and the logarithm is taken to keep the numbers in a practical range. The decibel scale allows a million-fold increase in pressure to be expressed as 120 dB. Another useful aspect of the decibel scale is that changes in levels (dB) correspond closely to human perception of relative loudness. Figure 2 provides examples of common noise sources and their related decibel values at the source location.

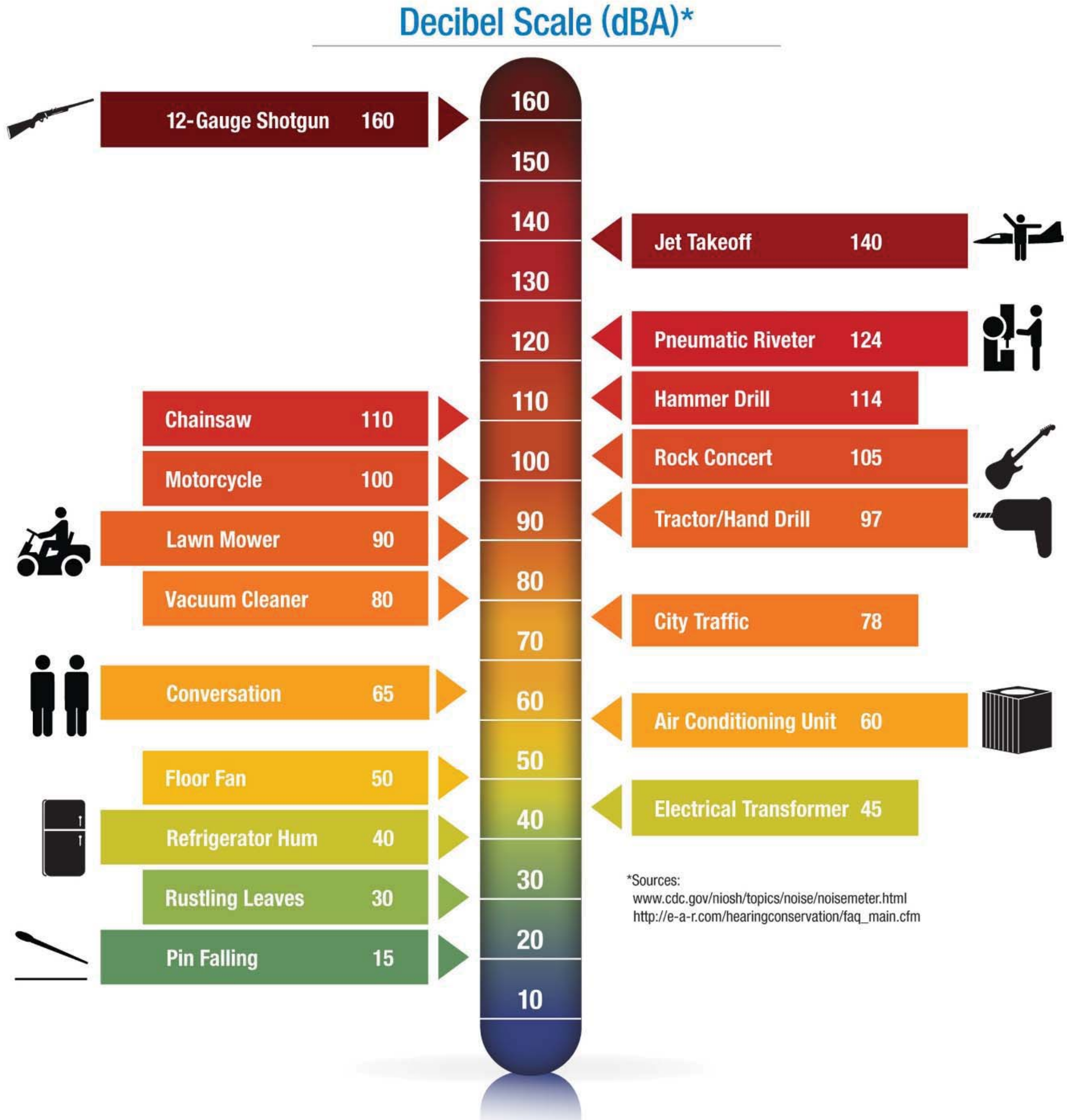
Perception

An individual's perception of the loudness of sounds is dependent upon many factors, including sound pressure level and frequency content. However, within the usual range of environmental noise levels, perception of loudness is relatively predictable, and can be approximated by weighting the frequency response of a sound level meter by means of the standardized A-weighting network. There is an established correlation between A-weighted sound levels (expressed as dBA) and community response to noise. For this reason, the A-weighted sound level has become the standard tool of environmental noise assessment. All noise levels reported in this section are in terms of A-weighted levels.

Noise Descriptors (Metrics)

Community noise is commonly described in terms of the ambient noise level, which is defined as the all-encompassing noise level associated with a given noise environment. A common statistical tool to measure the ambient noise level is the average, or equivalent, sound level (L_{eq}), which corresponds to a steady-state A-weighted sound level containing the same total energy as a time-varying signal over a given time period (usually one hour). The L_{eq} is the foundation of the composite noise descriptor, L_{dn}, and shows good correlation with community response to noise.

Figure 2
Noise Levels Attributable to a Variety of Sources



The Day-night Average Level (L_{dn}) is based upon the average noise level over a 24-hour day, with a +10 decibel weighing applied to noise occurring during nighttime (10:00 p.m. to 7:00 a.m.) hours. The nighttime penalty is based upon the assumption that people react to nighttime noise exposures as though they were twice as loud as daytime exposures. Because L_{dn} represents a 24-hour average, it tends to disguise short-term variations in the noise environment. L_{dn} based noise standards are commonly used to assess noise impacts associated with traffic, railroad and aircraft noise sources.

Descriptors for Quantifying Gazex System Noise

The noise generation of the Gazex systems is impulsive in nature, with elevated noise levels occurring for a very brief period of time after the systems are fired. As a result, the use of descriptors such as L_{eq} or L_{dn}, which depict average sound energy over a 1-hour or 24-hour period, would not provide a good correlation with expected public reaction to the noise levels generated by the Gazex system. As a result, this analysis utilizes two key noise descriptors which are better correlated with the effects of exposure to impulsive noise sources, such as that generated by the Gazex system. Specifically, this analysis focuses on quantifying the noise generation of the Gazex system in terms of A-weighted maximum noise levels (L_{max}, dBA), and Linear (unweighted) peak noise levels (L_{peak}, dB).

Sound Level Meter Response Time Settings

In addition to selecting the proper noise descriptors for use in assessing the noise effects of the Gazex systems, it is also important to utilize the appropriate response-time settings on the sound level meter. Most outdoor environmental noise level measurements are conducted using the “slow” meter response setting. The slow response setting is typically utilized for sources of noise which do not vary rapidly with time, and this setting was developed prior to the advent of digital sound level meters to slow down the needle (1 second) on the analog instrument to facilitate logging sound level data. The “fast” meter response provides a more rapid rise time of the sound level meter (125 milliseconds), and is more suitable for sources of noise which vary rapidly with time. Neither the slow nor the fast response time settings were used for the Gazex noise survey. Rather, the Impulsive response time setting was used to provide the most reliable and conservative assessment of the Gazex-generated noise.

Impulse Response Time Setting

Impulse is the least common of the Time Weightings. It’s about four times faster than Fast setting (35 milliseconds) and is usually used to measure quick bursts of impulsive noise, generated by pile drivers or explosions. Impulse Time Weighting has often been used for the measurement from, for example, clay pigeon shooting ranges where there is a need to assess the short, impulsive noise created when a shotgun is fired. All noise level measurements conducted for this survey utilized the impulsive response time setting to provide the most accurate means of quantifying the true noise generation of the Gazex System.

Peak Response Time Setting

The Impulse Time Weighting has a fast rise but a slower decay, which was designed to mimic the ear’s response to impulsive types of sound, such as that generated by the Gazex system. However, the Peak Time Weighting is used to measure the true Peak values of impulsive sounds. Peak is the maximum sound pressure reached at any instant during a measurement period.

Sound Propagation Characteristics

Important factors that affect sound propagation over distance are sound absorption in the air, presence of intervening topography or other types of barriers, vegetation, the effect of wind and temperature gradients, and the acoustic effect of the presence of the ground.

Effects of Distance on Sound Propagation

As a general rule, sound from a localized source spreads out as it travels away from the source and the sound pressure levels drop off with distance according to fundamental relationships. Sound from a localized source (i.e., point source) propagates uniformly outward in a spherical pattern. The sound level attenuates (i.e., decreases) at a rate of 6 dB for each doubling of distance from a point source. Because the Gazex units are located at a fixed point, the sound propagation away from the units is expected to behave similarly to a point source.

Atmospheric (Molecular) Absorption

Air absorbs sound energy. The amount of absorption is dependent on the temperature and humidity of the air, as well as the frequency of the sound. Families of curves have been developed which relate these variables to molecular absorption coefficients, frequently expressed in terms of dB per thousand feet. For the type of weather conditions present during avalanche control activities at Alpine Meadows (low temperatures and high relative humidity), the molecular absorption coefficients at the frequencies most prevalent with the Gazex usage (250-500 Hz), are 0.3 and 0.6 dB per thousand feet (SAE ARP 866A). These fairly low absorption coefficients indicate that sound propagation would normally be favorable during the cold temperatures and high humidity present during avalanche control operations (i.e. sound “travels” farther under favorable propagation conditions). However, if avalanche control operations occur during periods of snowfall (a common occurrence), the effects of new snow on the ground and in the air will increase the sound absorption and decrease sound propagation over distance.

Weather Conditions Present During Gazex Usage

BAC utilized local weather stations to identify the temperature and relative humidity conditions present during the periods during which the Gazex system was used. Atmospheric data for wind speeds was provided by Alpine Meadows.

During the Gazex usage period, average relative humidity was 96%, with maximum and minimum levels of 100% and 93%, respectively. As a result, the small variation in relative humidity during the periods of Gazex usage would not have contributed to measured variations in sound levels at the monitoring sites.

During the Gazex usage period, the average temperature was 18 degrees Fahrenheit at the summit, with overall levels ranging from 9 to 27 degrees Fahrenheit. At these low temperatures, there is very little variation in the molecular absorption coefficients. As a result, the relatively small variations in temperatures during the periods of Gazex usage would not have contributed to measured variations in sound levels at the monitoring sites.

During the Gazex usage period, the average wind speed at the summit was measured to be 46 mph, with overall levels ranging from 8 to 76 mph. The typical wind direction was from the southwest. The high registered wind speeds and variations in wind speeds likely did contribute to variations in measured noise levels at the survey positions. Additional analysis of the effects of wind speed on measured Gazex noise levels is ongoing.

Effects of Barriers and Ground Cover

A noise barrier is any impediment which intercepts the path of sound as it travels from source to receiver. Such impediments can be natural, such as a hill or other naturally occurring topographic feature which blocks the receiver's view of the source, vegetative, such as heavy tree cover which similarly blocks the source from view of the receiver, or man-made, such as a solid wall, earthen berm, or structure constructed between the noise source and receiver. Regardless of the type of impediment, the physical properties of sound are such that, at the point where the line-of-sight between the source and receiver is interrupted by a barrier, an approximate 5 dB reduction in sound can be expected to occur. As noted later in this report, the noise and vibration monitoring sites have direct line-of-sight to the eight (8) Gazex units located nearest to Alpine Meadows Road and the elevated position of those units reduces the effects of localized tree cover.

Effects of Wind Gradients on Sound Propagation

During windy conditions, wind gradients frequently form. This is due to the friction between the moving air and the ground. Due to these gradients, the speed of sound varies with height above ground. This condition tends to refract, or bend, sound waves upward or downward, depending on whether the receiver is upwind or downwind from the source.

At locations upwind from the sound source, wind gradients bend sound waves upward, thereby reducing sound levels at the receiver. Conversely, downwind locations will experience higher sound levels due to wind gradients bending sound waves downward.

In mountainous terrain like that present in the Alpine Meadows area, such gradients are less uniform and well-defined than over open, relatively level ground. As a result, the effects of wind on sound propagation is more variable in mountainous areas. Within the range of distances between the Gazex units and Alpine Meadows residences, measured to be as close as 850 feet and as far as approximately 7,500 feet, the effects of wind on sound propagation can vary considerably. Although the effects of wind on sound propagation increase with distance, sound is also decreasing with distance as a result of standard spherical spreading.

Vibration Fundamentals

Vibration is like noise in that it involves a source, a transmission path, and a receiver. While vibration is related to noise, it differs in that noise is generally considered to be pressure waves transmitted through air, while vibration is usually associated with transmission through the ground or structures. As with noise, vibration consists of an amplitude and frequency. A person's response to vibration will depend on their individual sensitivity as well as the amplitude and frequency of the source.

Vibration can be described in terms of acceleration, velocity, or displacement. A common practice is to monitor vibration measures in terms of peak particle velocities (PPV, inches/second), or Velocity Decibels in terms of root-mean-square levels (VdB RMS). Standards pertaining to perception as well as damage to structures have been developed for vibration in terms of peak particle velocity as well as root-mean-square.

As vibrations travel outward from the source, they excite the particles of rock and soil through which they pass and cause them to oscillate. Differences in subsurface geologic conditions and distance from the source of vibration will result in different vibration levels characterized by different frequencies and intensities. In all cases, vibration amplitudes will decrease with increasing distance. The maximum rate or velocity of particle movement is the commonly accepted descriptor of the vibration "strength."

Human response to vibration is difficult to quantify. Vibration can be felt or heard well below the levels that produce any damage to structures. The duration of the event has an effect on human response, as does frequency. Generally, as the duration and vibration frequency increase, the potential for adverse human response increases.

When structures shake or windows rattle following a blasting event, it is often thought to be due to ground vibration. However, this phenomenon may also be caused by the airborne pressure wave created by an impulsive event impacting the walls of the structure. This pressure wave is called peak overpressure. For this assessment, both groundborne vibration and peak overpressures were monitored and analyzed.

Noise & Vibration Criteria

General

The focus of this study is whether noise and vibration generated by the Gazex systems would be considered harmful to human health or result in damage to structures. As such, the following state and Federal criteria pertaining to hearing loss and damage to structures is presented.

Occupational Safety and Health Administration Noise Guidelines

The United States Department of Labor provides guidance and regulations pertaining to noise and hearing loss prevention. The Occupational Safety and Health Administration (OSHA) has developed a scale of acceptable workplace noise exposure which takes into consideration both the overall A-weighted sound level and duration of time of exposure to that level. Although the OSHA guidelines were developed to protect employees from exposure to excessive occupational noise exposure, they provide guidance to this evaluation as well. The OSHA section containing workplace noise criteria are reproduced below as follows:

1910.95(a) Protection against the effects of noise exposure shall be provided when the sound levels exceed those shown in Table G-16 (*Reproduced below as Table 1*), when measured on the A scale of a standard sound level meter at slow response.

Table 1
Permissible Noise Exposures
(Source: Table G-16 of OSHA Section 1910.95(a))

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

Footnotes to Table 1:
When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: C(1)/T(1) + C(2)/T(2) C(n)/T(n) exceeds unity, then, the mixed exposure should be considered to exceed the limit value. Cn indicates the total time of exposure at a specified noise level, and Tn indicates the total time of exposure permitted at that level. Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

The OSHA criteria shown in Table 1 indicate that noise levels should not exceed an A-weighted maximum of 115 dBA for 0.25 hours of the day or less (0 to 15 minutes). However, the OSHA criteria are specifically stated to be applicable to noise levels measured using the “slow” meter response. The use of slow meter response for the monitoring of impulsive noise, such as that generated by Gazex system operation, results in lower measured noise levels than does the use of the “impulsive” meter response, which was the response setting used for this evaluation. This likely accounts for the inclusion of the following statement in the footnotes of Table 1 which pertains to impulsive noise exposure:

"Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level."

Although not expressly stated in the OSHA criteria, it is assumed based on the "dB" rather than "dBA" suffix that the 140 dB peak sound level threshold is a linear peak, rather than an A-weighted peak.

Peak overpressures required to cause damage to structures are considerably higher than levels required to cause damage to hearing. Therefore, satisfaction with the OSHA 140 dB peak criteria for hearing loss would ensure that levels would be below those required to damage structures.

Federal Transit Administration Vibration Criteria

The Federal Transit Administration's publication, *Transit Noise and Vibration Impact Assessment Manual*, (FTA Report No. 0123 dated September 2018), includes criteria for assessing potential impacts related to groundborne vibration in terms of both annoyance and damage to structures. The FTA vibration impact criteria are based on maximum overall levels for a single event. Although developed primarily for vibration generated by heavy rail operations, the criteria have been widely used to assess annoyance impacts related other sources as well. The FTA vibration impact criteria for interference with human activity and annoyance are shown in Table 2. A discussion of FTA criteria related to damage to structures follows.

Table 2
Groundborne Vibration Impact Criteria for Annoyance Determinations

	Groundborne Vibration Impact Levels (VdB re 1 µinch/sec, RMS)		
Land Use Category	**Frequent Events[1]**	**Occasional Events[2]**	**Infrequent Events[3]**
Category 1: Buildings where vibration would interfere with interior operations.	65	65	65
Category 2: Residences and buildings where people normally sleep.	72	75	80
Category 3: Institutional land uses with primarily daytime use.	75	78	83

Notes:
1 "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
2 "Occasional Events" is defined as between 30 and 70 vibration events of the same kind per day. Most commuter trunk lines have this many operations.
3 "Infrequent Events" is defined by less than 30 vibration events of the same kind per day. This category includes most commuter rail branch lines.

There are eight (8) Gazex systems in close proximity to Alpine Meadows Road. Based on data collected in January and February of 2019, the systems are typically utilized only once per day. However, during a 24-hour period of very heavy snowfall spanning February 4-5, 2019, the system was utilized three (3) times. During this unusually heavy usage the total number of system discharges along Alpine Meadows Road was 24 (3 firings of each unit x 8 units). According to the Table 2 criteria, fewer than 30 events per day would be categorized as “infrequent”. The corresponding vibration impact criteria for residences and buildings where people sleep is 80 VdB.

It is important to note that the FTA criteria identified in Table 2 were developed to assess potential annoyance related to recurring daily passages of trains in the vicinity of the sensitive receptor. As a result, the use of the Table 2 criteria to assess impacts of considerably less frequent and far shorter duration avalanche mitigation activities is considered to be conservative.

Table 7-5 of the Federal Transit Administration’s publication, *Transit Noise and Vibration Impact Assessment Manual*, contains criteria for assessing damage to structures from vibration. That table is reproduced below as Table 3.

Table 3
FTA Vibration Damage Criteria

Building/ Structural Category	PPV, in/sec	Approximate L_V*
I. Reinforced-concrete, steel or timber (no plaster)	0.5	102
II. Engineered concrete and masonry (no plaster)	0.3	98
III. Non-engineered timber and masonry buildings	0.2	94
IV. Buildings extremely susceptible to vibration damage	0.12	90

*RMS velocity in decibels, VdB re I micro-in/sec

As indicated in Table 3, the intensity of vibration required to result in damage to structures depends on the construction of the structure. The specific construction types of the existing residences in Alpine Meadows undoubtedly varies, with a mix of older and newer homes. Newer residences are likely engineered, whereas older residences may not be. It is considered unlikely however, that the Alpine Meadows residences would fall into the category for buildings extremely susceptible to vibration damage (Category IV).

It is important to note that the Table 3 criteria do not differentiate between transient vibration and steady-state vibration. The importance of that distinction is presented in the following paragraphs of this report.

California Department of Transportation (Caltrans) Vibration Criteria

Damage criteria for transient vibration (i.e. impulsive sources such as Gazex system usage), are higher than criteria for continuous (steady-state) sources of vibration (i.e. the FTA criteria shown in Table 3). In the California Department of Transportation (Caltrans) publication, *Transportation and Construction Vibration Guidance Manual* (September 2013), the following information is presented with respect to the potential damage to structures associated with blasting activities (pages 37 and 38 of publication):

> **7.3 Evaluating Potential Vibration Impacts**
>
> *As shown in Chapter 6 (of the Caltrans publication), there is limited consistency between the categorization of effects and damage thresholds; however, it is apparent that* ***damage thresholds for continuous sources are less than those for single-event or transient sources****. It is also apparent that the vibration from traffic is continuous and that vibration from a single blasting event is a single transient event; however, many types of construction activities fall between a single event and a continuous source. An impact pile driver, for example, continuously generates single transient events. As a practical matter and based on the nature of available criteria, the criteria can only be reasonably separated into two categories: continuous and transient.*
>
> *To assess the damage potential from ground vibration induced by construction equipment, a synthesis of various vibration criteria presented in Chapter 6 has been developed.* ***This synthesis of criteria essentially assumes that the threshold for continuous sources is about half of the threshold for transient sources.*** *A vibration amplitude can be compared the criteria in Table 4* (Caltrans publication Table 19) *to evaluate the potential for damage to structures.*

Table 4
Guideline Vibration Damage Potential Threshold Criteria
Peak Particle Velocities (In/sec)

Structure and Condition	Transient Sources	Continuous or Frequent Intermittent Source
Extremely fragile historic buildings, ruins, ancient monuments	0.12	0.08
Fragile buildings	0.2	0.1
Historic and some old buildings	0.5	025
Older residential structures	0.5	0.3
New residential structures	1.0	0.5
Modern industrial/commercial buildings	2.0	0.5

Source: Caltrans Transportation and Construction Vibration Guidance Manual – Table 19

As indicated in Table 4, vibration thresholds for older and newer residential structures exposed to transient sources of vibration, such as that generated by the Gazex systems, are 0.5 and 1.0 inches per second, respectively. A vibration level of 0.5 inches/second is approximately equivalent to a level of 102 VdB (See Table 3). As a result, it could be concluded that a measured ground vibration level of less than 102 VdB resulting from Gazex usage would not be expected to result in damage to structures, according to the Caltrans and FTA criteria.

Because Gazex system usage could be considered a repetitive transient source if the units are fired between small time intervals, the use of 102 VdB as a damage-to-structures criteria may not be conservative enough. As a result, the use of vibration damage criteria of 94-102 for the transient events associated with the Gazex usage may be more appropriate for this evaluation.

Noise and Vibration Monitoring Program

Gazex System Locations

The eight (8) Gazex systems located in relatively close proximity to Alpine Meadows Road which are the focus of this study are shown in Figure 3. The Gazex Units are numbered 7 – 14 on Figure 3.

Noise and Vibration Monitoring Sites

Figure 3 also shows the locations of the five (5) selected noise and vibration survey locations used throughout the duration of the survey period. The noise monitoring sites were selected in cooperation with Placer County Public Works staff and Alpine Meadows Representatives. The sites were selected to meet the following criteria:

- To be representative of a range of residential exposures in Alpine Meadows, including a variety of distances and elevations relative to the Gazex units.
- To provide unobstructed line-of-sight between the monitoring sites and the 8 Gazex units.
- To be located within public right-of-way to allow BAC staff access at all hours for equipment maintenance without disturbing Alpine Meadows residents.
- To be located in areas where the sensitive monitoring equipment would not be subject to impact or damage from snow-removal equipment or, to the extent feasible, snow blown by such equipment.

Line-of-Sight Cross-Sections

BAC utilized Google Earth imagery to develop cross-sections between each of the eight (8) Gazex units and the five (5) noise and vibration monitoring sites. Figure 4 depicts the locations of those cross-sections. Although intervening vegetation (pine trees) did interrupt the visual line of sight between some of the Gazex units and monitoring locations, there were no locations where the line-of-sight was interrupted by intervening topography. It was not possible to satisfy the monitoring site selection objectives cited above without some intervening vegetation, but given the elevated positions of the Gazex units, that vegetation, where it occurred, was not expected to have an appreciable effect on the measured noise levels.

Appendix B contains representative cross-section details between the Gazex units and monitoring sites. Although only 9 of the 40 cross-sections are presented in Appendix B, each line-of-sight between the Gazex units and monitoring sites was verified to be uninterrupted by intervening topography.

ise/Vibration Survey Locations

: Noise & Vibration Survey Locations

: Gazex Locations

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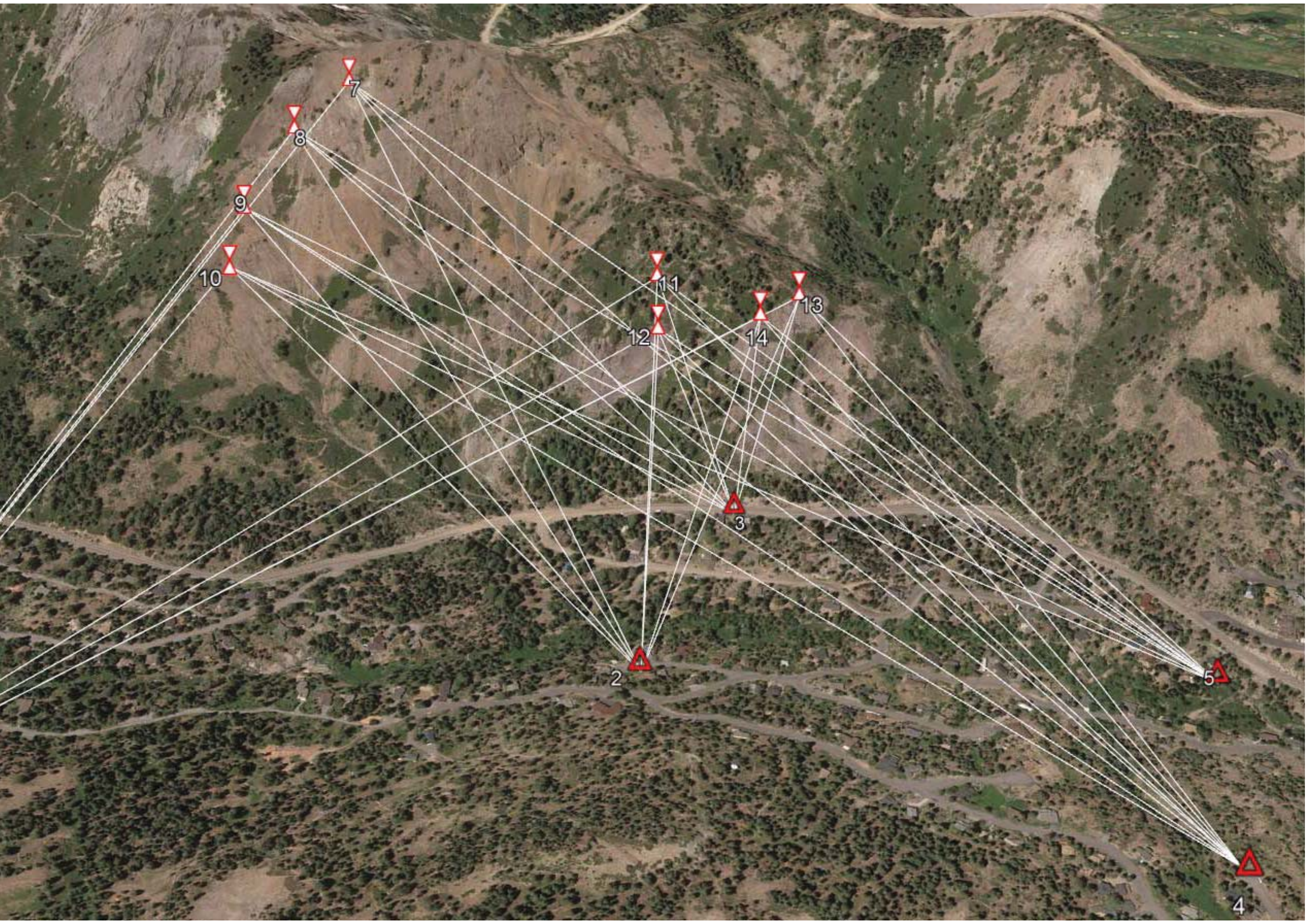
resentative cross-sections)



: **Noise & Vibration Survey Locations**

: **Gazex Cannon Locations**

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Monitoring Equipment & Parameters

Larson Davis Laboratories Model 831 and LxT precision (Type 1) integrating sound level meters were used for the noise and vibration surveys, respectively. The 831's were connected to ½ inch PCB Electronics microphones and preamplifiers via extension cables for the noise survey component of this evaluation. The microphones were fitted with manufacturer's windscreens and each system was calibrated during setup using a Larson Davis Laboratories CAL200 acoustic calibrator to ensure the accuracy of the measurements.

The LxT's used for the vibration monitoring were fitted with BRC Electronics SEN_Vel velocity transducers rated at 500 millivolts per inch per second (500 mv/ips), which were inserted firmly into the soil with ground spikes. The vibration transducer was placed within sprinkler boxes, open at the bottom, to prevent the buildup of snow at the transducer. Each vibration transducer was calibrated during system setup using an IMI Model 699A02 vibration calibrator to ensure the accuracy of the vibration measurements.

Both the 831 and LxT meters were located inside insulated pelican cases which were then locked inside metal contractor's boxes for security. Power to the noise and vibration monitoring systems was provided by Werker 33 amp-hour, deep-cycle, 12-volt batteries. The batteries maintained an operating capacity of 4-5 days between recharging, depending on air temperature.

Figure 5 shows representative photos of the noise and vibration equipment setups.

Both the noise and vibration meters were programmed to log data at one-second intervals in order to provide clear delineation of Gazex events. The noise meters were programmed to log maximum A-Weighted and Linear peak sound pressure levels (impulsive response setting), in addition to linear 1/3 octave band data and full-time wave file recording. The vibration meters were programmed to log maximum RMS velocity data (VdB rms), also with impulsive settings.

e/Vibration Monitoring Site Photos – Day of Equipment Setup

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Equipment Maintenance

Following initial equipment setup which occurred on December 9th, 2018, BAC staff returned to the monitoring sites on 3-5 day intervals to replace batteries, swap flash drives containing the logged data, and recalibrate both the noise and vibration measurement systems. During the initial part of the survey, an issue was identified with a memory-flash drive failure, as well as an underperforming battery. As a result, during some periods when the Gazex system was in operation, data was unavailable at limited monitoring locations. These conditions were rectified and overall system performance was considered excellent for the majority of the remaining test dates despite extensive snowfall at the monitoring sites and very low operating temperatures.

Figure 6 shows photos taken during regular equipment maintenance periods.

Gazex Usage Notification

BAC signed up for the Gazex usage notifications and received texts, email and phone calls notifying of impending Gazex system usage during the survey periods. Following Gazex system usage, Alpine Meadows staff (Goldstone) emailed BAC the usage logs identifying the specific dates and times the various units were fired, as well as the fill levels of each unit. Table 5 shows the Gazex system usage log for the duration of the noise survey period.

The Table 5 data indicate that only Gazex units 7-10 were fired on January 7, 2019, and that a misfire occurred at Unit 13 on January 21, 2019. Otherwise, all 8 Gazex units were fired during each of the other periods.

The fill values shown in Table 5 relate to the duration of time the Gazex tubes are filled with the mixture of oxygen and propane prior to firing. Longer fill times equate to a larger volume of gas and would be expected to result in a stronger detonation, thereby creating higher pressure waves and correspondingly higher noise levels.

From review of the Table 5 data, it appears that the Gazex units located furthest from the residences in Alpine Meadows (Units 7 and 8) utilized longer fill times than the units located closer to Alpine Meadows Road. An analysis of the relationship of fill times to measured noise levels is presented later in this report.

The Table 5 data were used to identify the specific times within the extensive noise and vibration database during which the Gazex system was used. In addition, audio files and graphs of second-by-second time histories were also employed to identify Gazex events at each of the monitoring sites.

e/Vibration Monitoring Site Photos – Site Maintenance

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Table 5
Gazex System Usage Log

#8 West Gully High		#9 West Gully		#10 West Gully		#13 Cliffs		#14 Van E		#11 HAH House Pro		HAH House	
Time	**Fill**	**Time**	**Fill**	**Time**	**Fill**	**Time**	**Fill**	**Time**	**Fill**	**Time**	**Fill**	**Time**	**Fill**
8:28:18am	8	8:15:18am	8	8:11:03am	8	Not Used		Not Used		Not Used		Not Used	
8:06:55am	13	8:08:45am	10	8:05:08am	10	8:22:36am	8	8:19:22am	8	8:16:05am	8	8:12:48am	8
4:06:25pm	13	4:04:52pm	10	4:03:12pm	10	4:19:54pm	8	4:16:40pm	8	4:10:09pm	8	4:13:25pm	8
7:55:36am	13	7:53:08am	10	7:49:47am	10	Misfire	4	8:08:17am	4	8:01:31am	4	8:04:58am	4
9:10:54am	13	9:09:22am	10	9:05:10am	10	9:26:26am	8	9:23:10am	8	9:19:54am	8	9:16:37am	8
8:33:37am	13	8:31:Xxam	10	8:28:15am	10	8:48:39am	8	8:45:21am	8	8:42:06am	8	8:38:53am	8
4:20:04pm	13	4:23:04pm	10	4:19:56pm	10	4:34:51pm	8	4:31:30pm	8	4:28:16pm	8	4:25:03pm	8
12:56:35am	13	12:58:31am	10	12:55:23am	10	1:11:33am	8	1:08:11am	8	1:04:55am	8	1:01:42am	8
5:49:39pm	13	5:52:39pm	10	5:49:31pm	10	6:04:26pm	8	6:01:13pm	8	5:57:58pm	8	5:54:44pm	8
5:01:49am	13	5:04:49am	10	5:01:41am	10	5:16:30am	8	5:13:16am	8	5:09:59am	8	5:06:46am	8

Monitoring Duration

A primary objective of this analysis was to obtain a statistically representative sample of noise and vibration data under varying conditions such that the range of data could be considered representative of noise and vibration levels resulting from ongoing usage of the Gazex systems in subsequent seasons.

The monitoring program commenced on December 12, 2018. During the first 26 days of the monitoring program no Gazex system usage was warranted due to the lack of appreciable snowfall. Over the course of the next 14 days, the Gazex systems were utilized four (4) times. During the period of February 3-10, 2019, the systems were utilized an additional six (6) times.

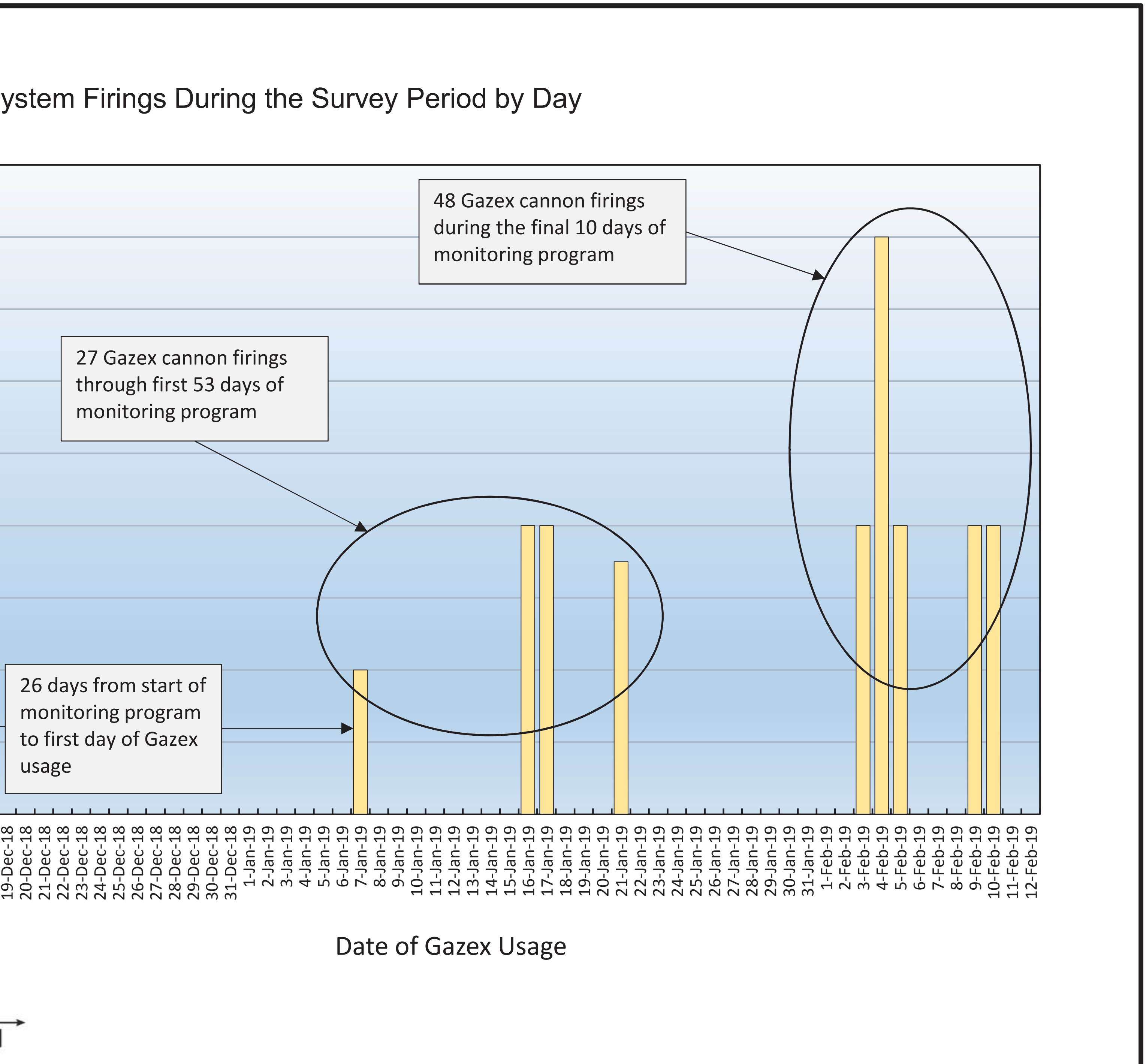
During each system usage, 3 separate data points were attempted to be logged at each monitoring site, (A-weighted maximum sound level, linear peak sound level, and maximum ground vibration), for a total of 15 data points for each Gazex Unit discharge. Due to limited issues with monitoring equipment related to the extremely cold operating conditions, some data was not logged. Nonetheless, the volume of data increased with each Gazex firing cycle.

At the end of the survey, the noise monitoring equipment captured 352 of the possible 375 data points, or 94% of the possible data. For the vibration surveys, 366 of the possible 375 data points were captured, or 98% of the possible data.

By February 10, 2019, it was determined that sufficient data had been collected to achieve the objectives of this evaluation. Specifically, by the end of the survey period a total of 352 separate maximum A-weighted noise level readings and 352 separate linear peak noise level readings directly correlated with Gazex system usage were logged. In addition, 366 separate vibration readings associated with Gazex system usage were logged. See Figures 7 and 8 for the log of Gazex usage over time and the corresponding number of samples collected per use.

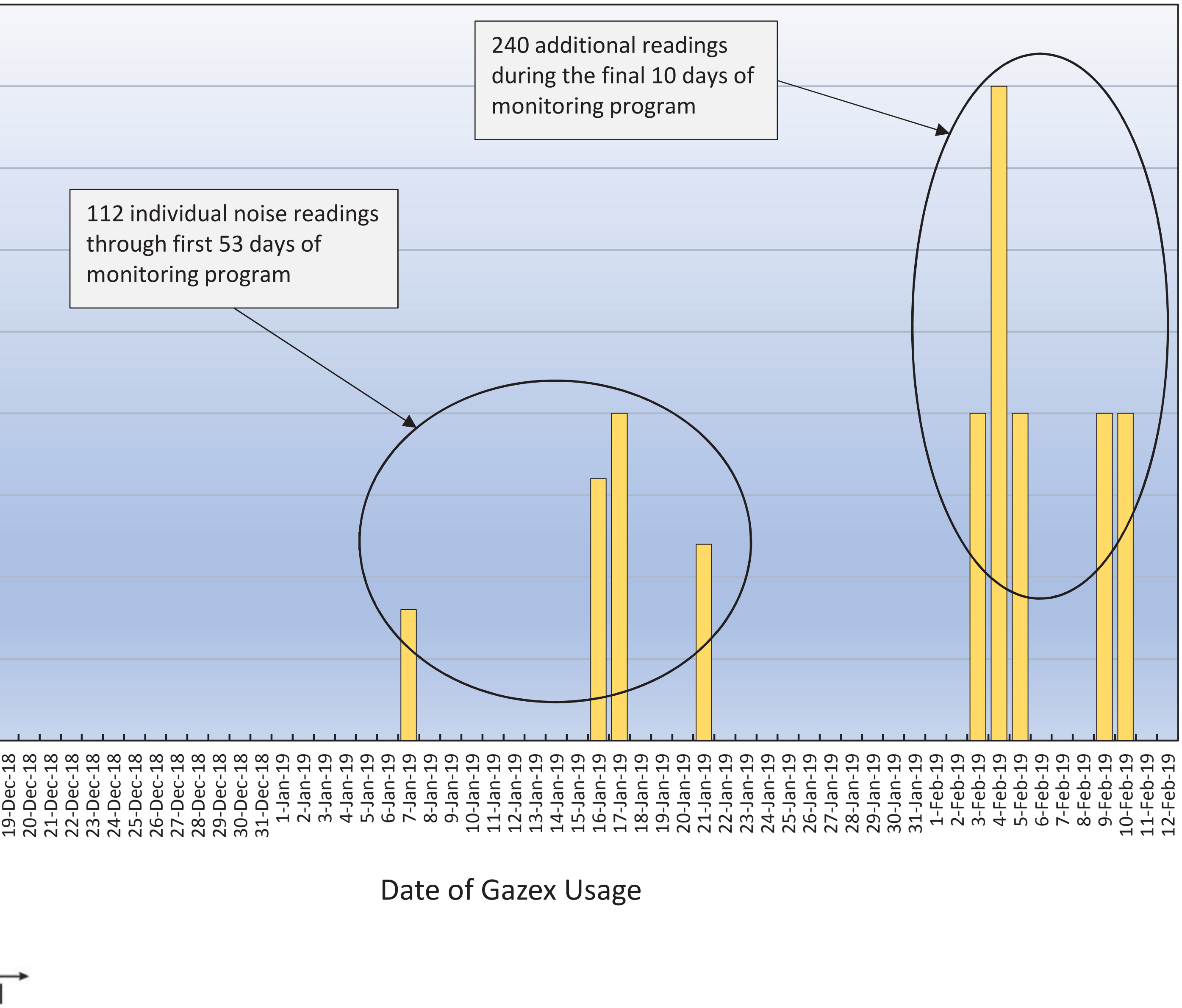
An ongoing statistical analysis of the data was maintained with each subsequent Gazex system usage. At the time it was determined that sufficient data had been collected to satisfy the objective of the evaluation, the standard deviation of the sample population ranged from 3.2 to 7.4 dB and the 90% confidence intervals for the entire data set ranged from 0.6 to 1.4 dB. The smaller the confidence interval, the greater the probability that the data set includes the true average of the noise generation of the Gazex system. As a result of the narrow confidence intervals derived from the 352 to 366 data points, the population sample was considered to be statistically representative and the survey was ended.

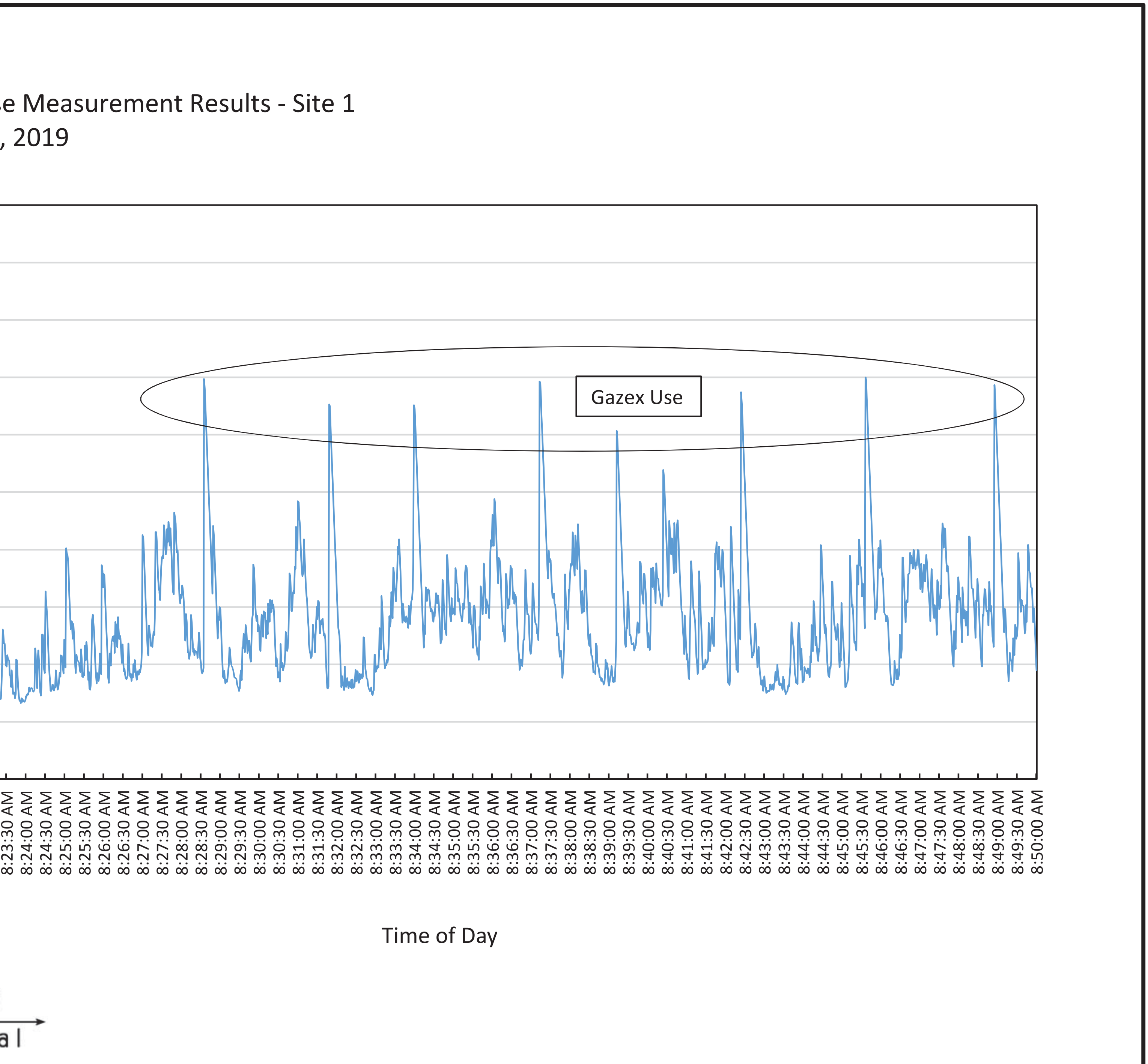
To specifically identify and isolate the Gazex events from other sources of local noise (i.e. traffic, snow plows, snow falling from trees and impacting the microphones, etc.), second-by-second time histories were reviewed at each location for each Gazex system usage. Figures 9, 10 and 11 show representative examples of these time-history graphs at three of the five monitoring sites. Similar graphs were prepared for each event and monitoring site, but for presentation purposes it was concluded that depicting the data for three events would be adequate. A complete listing of noise and vibration monitoring results is provided later in this report.



ystem Firings During the Survey Period by Day
48 Gazex cannon firings during the final 10 days of monitoring program
27 Gazex cannon firings through first 53 days of monitoring program
26 days from start of monitoring program to first day of Gazex usage
19-Dec-18
20-Dec-18
21-Dec-18
22-Dec-18
23-Dec-18
24-Dec-18
25-Dec-18
26-Dec-18
27-Dec-18
28-Dec-18
29-Dec-18
30-Dec-18
31-Dec-18
1-Jan-19
2-Jan-19
3-Jan-19
4-Jan-19
5-Jan-19
6-Jan-19
7-Jan-19
8-Jan-19
9-Jan-19
10-Jan-19
11-Jan-19
12-Jan-19
13-Jan-19
14-Jan-19
15-Jan-19
16-Jan-19
17-Jan-19
18-Jan-19
19-Jan-19
20-Jan-19
21-Jan-19
22-Jan-19
23-Jan-19
24-Jan-19
25-Jan-19
26-Jan-19
27-Jan-19
28-Jan-19
29-Jan-19
30-Jan-19
31-Jan-19
1-Feb-19
2-Feb-19
3-Feb-19
4-Feb-19
5-Feb-19
6-Feb-19
7-Feb-19
8-Feb-19
9-Feb-19
10-Feb-19
11-Feb-19
12-Feb-19
Date of Gazex Usage

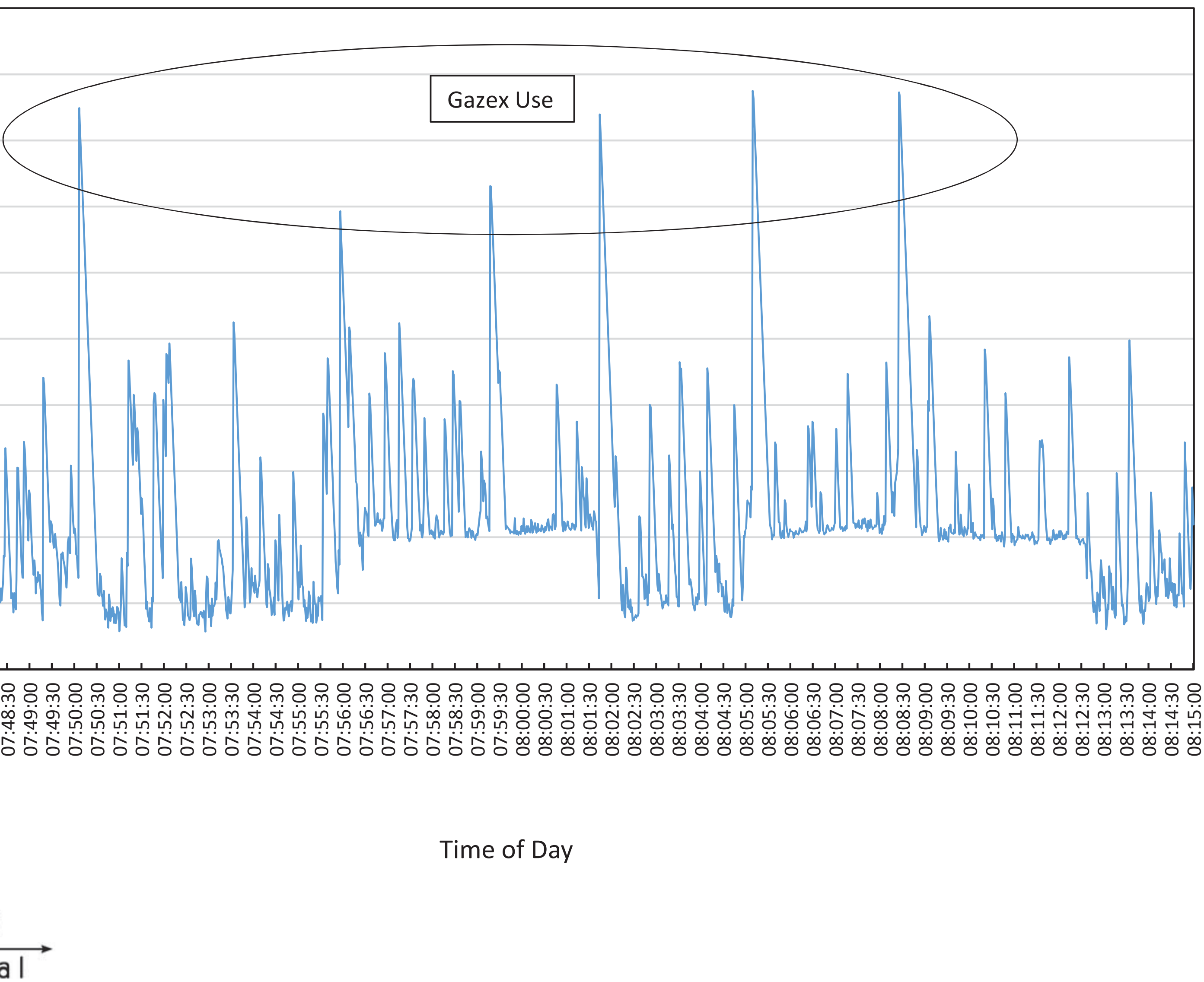
ta Readings Collected During the Survey Period by Day
comparable)



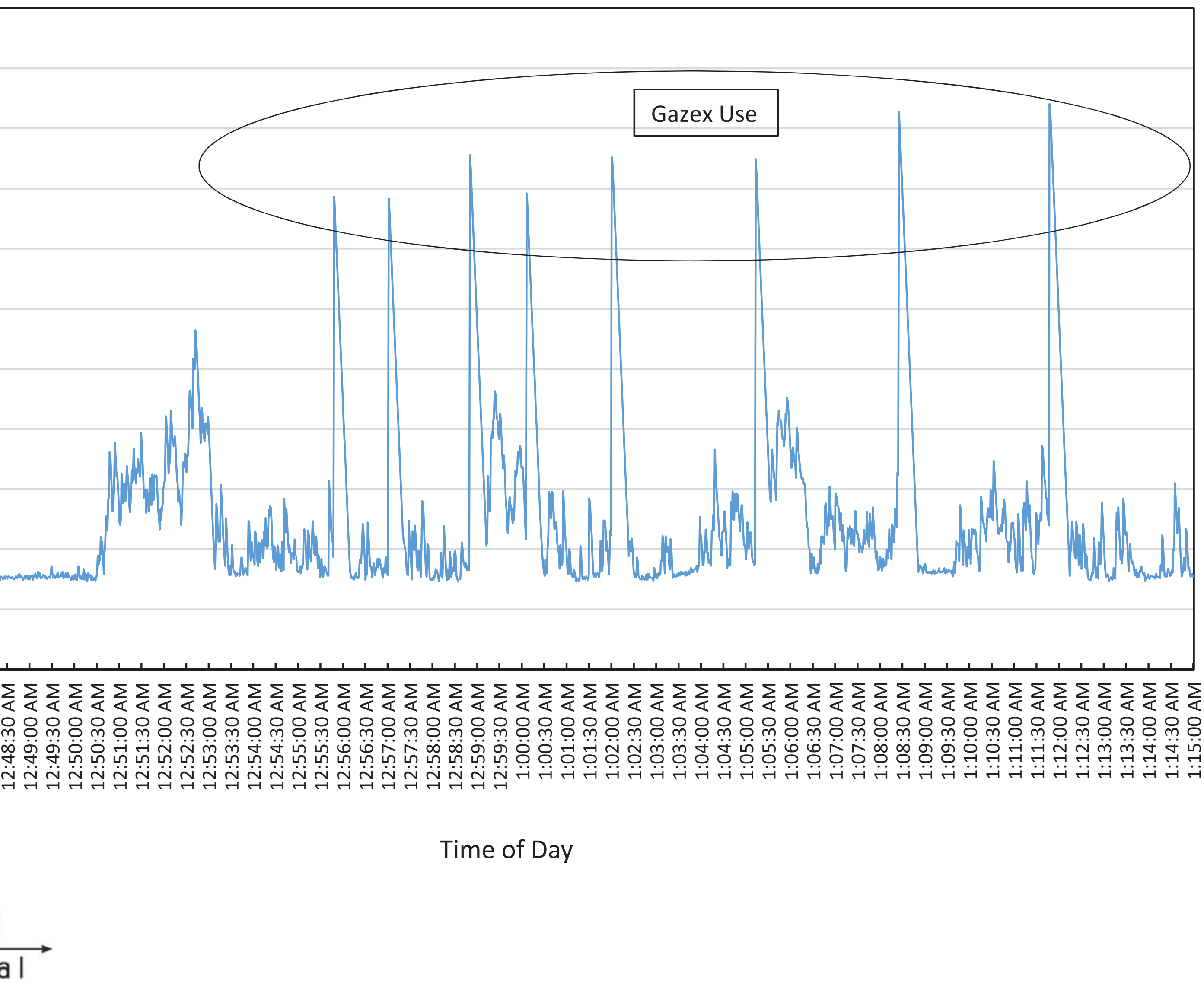


e Measurement Results - Site 1
, 2019
Gazex Use
8:23:30 AM
8:24:00 AM
8:24:30 AM
8:25:00 AM
8:25:30 AM
8:26:00 AM
8:26:30 AM
8:27:00 AM
8:27:30 AM
8:28:00 AM
8:28:30 AM
8:29:00 AM
8:29:30 AM
8:30:00 AM
8:30:30 AM
8:31:00 AM
8:31:30 AM
8:32:00 AM
8:32:30 AM
8:33:00 AM
8:33:30 AM
8:34:00 AM
8:34:30 AM
8:35:00 AM
8:35:30 AM
8:36:00 AM
8:36:30 AM
8:37:00 AM
8:37:30 AM
8:38:00 AM
8:38:30 AM
8:39:00 AM
8:39:30 AM
8:40:00 AM
8:40:30 AM
8:41:00 AM
8:41:30 AM
8:42:00 AM
8:42:30 AM
8:43:00 AM
8:43:30 AM
8:44:00 AM
8:44:30 AM
8:45:00 AM
8:45:30 AM
8:46:00 AM
8:46:30 AM
8:47:00 AM
8:47:30 AM
8:48:00 AM
8:48:30 AM
8:49:00 AM
8:49:30 AM
8:50:00 AM
Time of Day

e Measurement Results - Site 3
, 2019



e Measurement Results - Site 5
, 2019



Noise & Vibration Survey Results

The complete results of the noise and vibration data collection program are provided graphically in Appendices C, D & E in terms of A-weighted maximum noise levels, Linear peak noise levels, and Linear vibration levels, respectively. Appendix F shows the complete data set. Appendix G contains the statistical analysis conducted on the complete data set.

The columns of Appendices C, D & E where no data is provided represents data points that were not captured due to equipment (primarily flashdrive) malfunctions. As noted previously, the missing data represents a very small percentage (approximately 5%) of the total possible data points which could have been collected.

Analysis of Measured A-Weighted Maximum Noise Levels (Appendix C)

The Appendix C data indicate that maximum A-weighted noise levels varied by site and Gazex unit. The general consistency of the measured noise levels is believed to be due to the fact that the Gazex units located further from the residences had higher fill times whereas the units located closer to the residences had the lower fill times.

Relative to the OSHA criteria of 115 dBA, 350 of the 352 data samples were below that criteria, with two samples collected at measurement Site 3 slightly above that limit (116 and 117 dBA). It is unclear if the two highest data points were anomalous but the level of 117 did exceed two standard deviations from the mean of the sample, which tends to identify that data point as an outlier.

Because the OSHA criteria of 115 is based on “slow” meter response, it is certain that the two levels measured slightly above the 115 criteria would have been lower than 115 had they been measured using the slow meter response setting. As a result, comparing the level of 116 and 117 measured using the “impulsive” response setting against the criteria which are based on “slow” response setting yields a conservative assessment of the potential harm associated with the elevated levels. After accounting for the differences in levels measured using the “slow” versus “impulsive” response times, this analysis concludes that the measured maximum noise levels measured at each location were within compliance with the OSHA recommended 115 dBA maximum noise level criteria.

It should also be noted that persons located inside their residences with windows closed during the Gazex usage would experience noise levels typically at least 20 dB lower than those shown in Appendix C, which represent outdoor noise exposure. Within residences with windows closed, the Gazex noise levels would be at levels not considered harmful to hearing.

Subjectively, the Gazex system usage noise generation is considered to be loud, as is required for the effective triggering of avalanches. As a result, despite this evaluation’s conclusion that measured noise levels were below thresholds for damage to hearing, there remains a high probability for annoyance during the system usage, particularly if the resident is unaware of the impending usage and is outside.

Analysis of Measured Linear Peak Noise Levels (Appendix D)

The Appendix D data indicate that linear peak noise levels also varied by site and Gazex unit. Relative to the OSHA criteria of 140 dB, all 352 data samples were below that criteria. As a result, this analysis concludes that the measured linear peak noise levels would not result in damage to hearing. Furthermore, the measured peak overpressures are at levels which would not be expected to result in damage to structures.

It should also be noted that persons located inside of their residences with windows closed during the Gazex usage would experience noise levels typically at least 20 dB lower than those shown in Appendix D, which represent outdoor noise exposure. Within residences, the Gazex noise levels would be well below levels considered harmful to hearing.

Analysis of Measured Ground Vibration Levels (Appendix E)

The Appendix E data indicate that measured ground vibration levels also varied by site and Gazex unit. Relative to the FTA criteria of 94 to 102 VdB conservatively applied to this assessment for evaluating possible damage to structures, all 366 data samples were below that criteria. Even buildings considered non-engineered, which may incur vibration damage at levels above 94 VdB according to FTA damage criteria, all recorded vibration levels were below 94 VdB. As a result, this analysis concludes that the measured vibration levels would not result in damage to residential structures in Alpine Meadows.

The Appendix E data does indicate, however, that vibration levels exceeded the FTA criteria for annoyance during several of the Gazex operations. As a result, it is probable that ground vibration resulting from Gazex usage will still be considered annoying to residents of the Alpine Meadows community during certain conditions. In fact, the recorded vibration levels may have caused shaking of structures or items within the structure, but not at levels which would cause damage to structures

Conclusions

This evaluation concludes that noise and vibration levels generated by the Gazex avalanche control systems located near Alpine Meadows Road during the survey period were below state and federal criteria for assessing damage to structures and hearing.

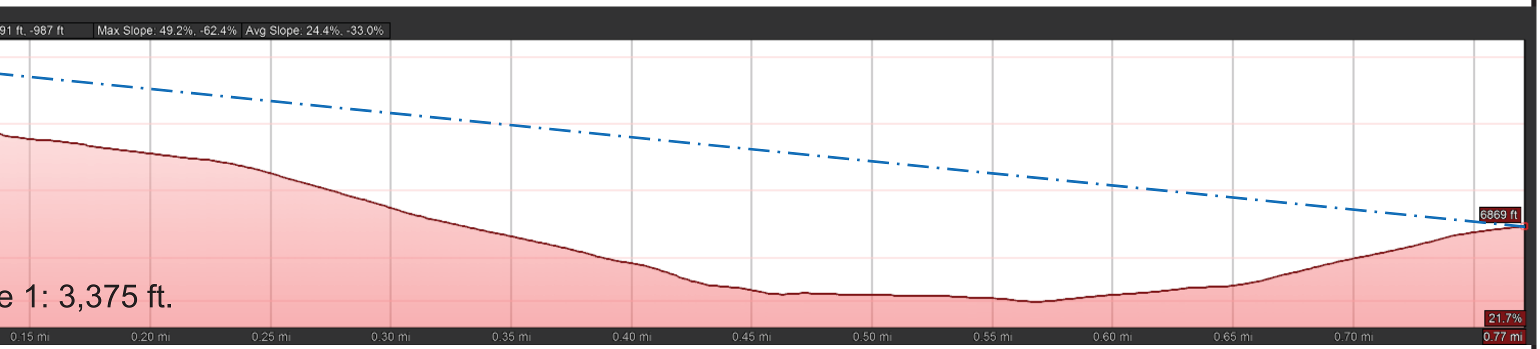
This concludes BAC's evaluation of Gazex system noise and vibration generation. Please contact BAC at (916) 663-0500 or PaulB@bacnoise.com with any questions regarding this evaluation.

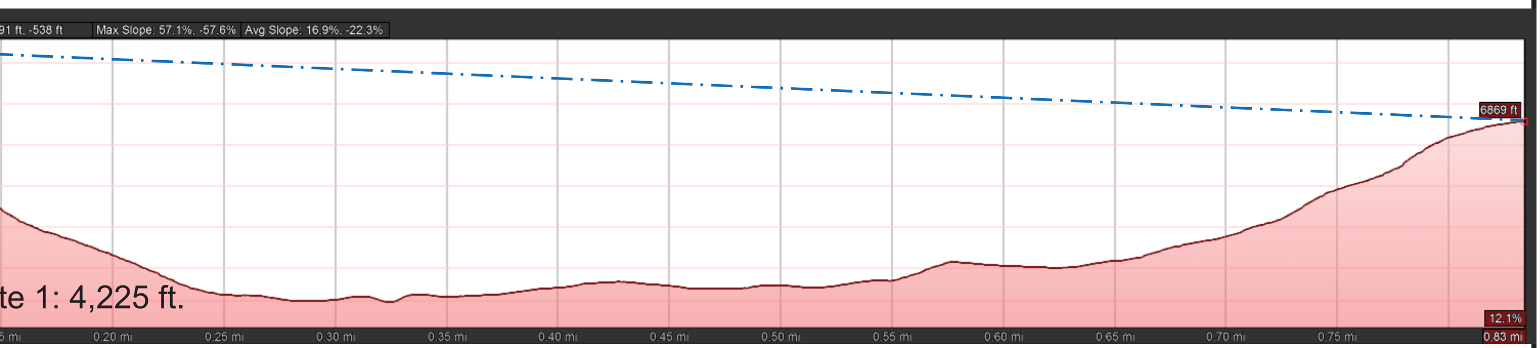
Appendix A

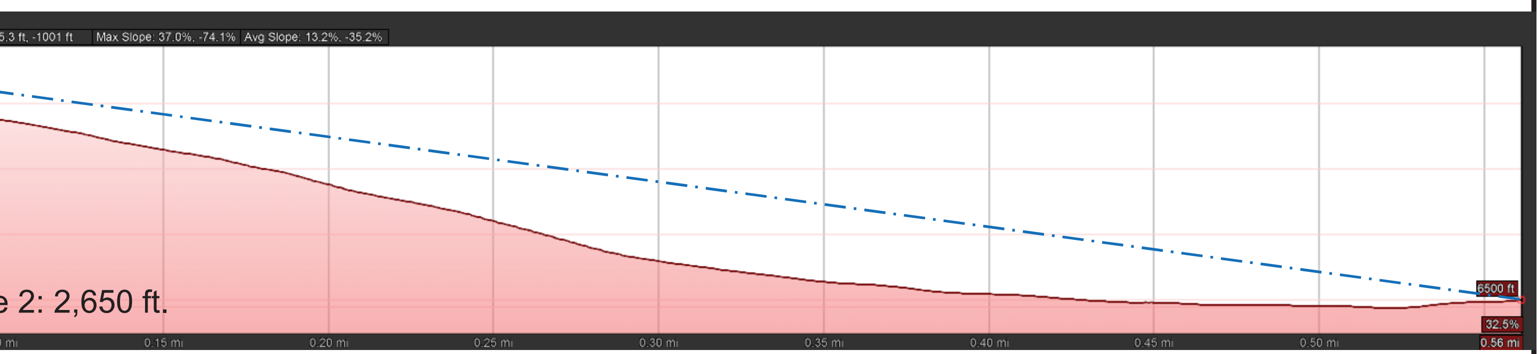
Acoustical Terminology

Acoustics	The science of sound.
Ambient Noise	The distinctive acoustical characteristics of a given space consisting of all noise sources audible at that location. In many cases, the term ambient is used to describe an existing or pre-project condition such as the setting in an environmental noise study.
Attenuation	The reduction of an acoustic signal.
A-Weighting	A frequency-response adjustment of a sound level meter that conditions the output signal to approximate human response.
Decibel or dB	Fundamental unit of sound, A Bell is defined as the logarithm of the ratio of the sound pressure squared over the reference pressure squared. A Decibel is one-tenth of a Bell.
CNEL	Community Noise Equivalent Level. Defined as the 24-hour average noise level with noise occurring during evening hours (7 - 10 p.m.) weighted by a factor of three and nighttime hours weighted by a factor of 10 prior to averaging.
Frequency	The measure of the rapidity of alterations of a periodic signal, expressed in cycles per second or hertz.
L_{dn}	Day/Night Average Sound Level. Similar to CNEL but with no evening weighting.
L_{eq}	Equivalent or energy-averaged sound level.
L_{max}	The highest root-mean-square (RMS) sound level measured over a given period of time.
Loudness	A subjective term for the sensation of the magnitude of sound.
Masking	The amount (or the process) by which the threshold of audibility is for one sound is raised by the presence of another (masking) sound.
Noise	Unwanted sound.
Peak Noise	The level corresponding to the highest (not RMS) sound pressure measured over a given period of time. This term is often confused with the Maximum level, which is the highest RMS level.
RT_{60}	The time it takes reverberant sound to decay by 60 dB once the source has been removed.
Sabin	The unit of sound absorption. One square foot of material absorbing 100% of incident sound has an absorption of 1 sabin.
SEL	A rating, in decibels, of a discrete event, such as an aircraft flyover or train passby, that compresses the total sound energy of the event into a 1-s time period.
Threshold of Hearing	The lowest sound that can be perceived by the human auditory system, generally considered to be 0 dB for persons with perfect hearing.
Threshold of Pain	Approximately 120 dB above the threshold of hearing.

s-Sections between Gazex Units & Noise/Vibration Survey Locations

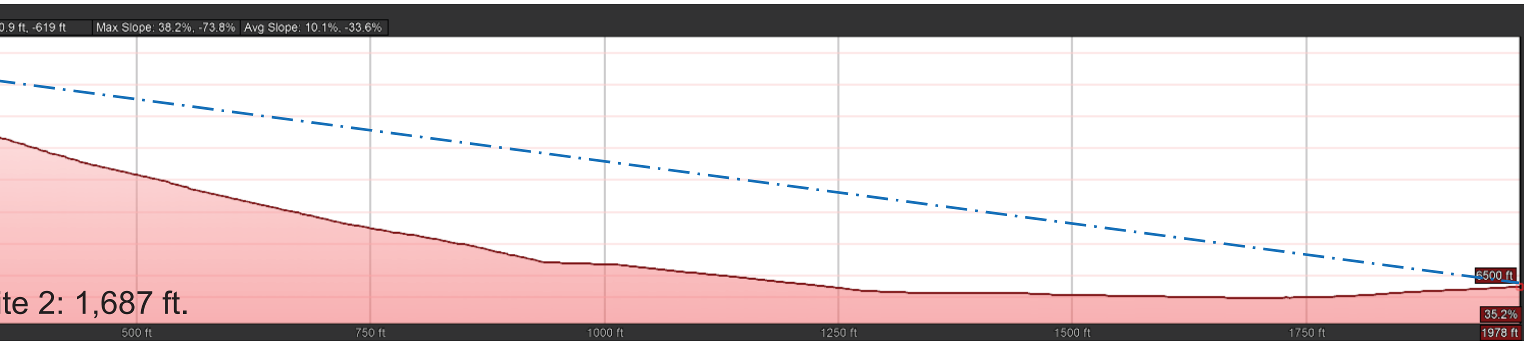


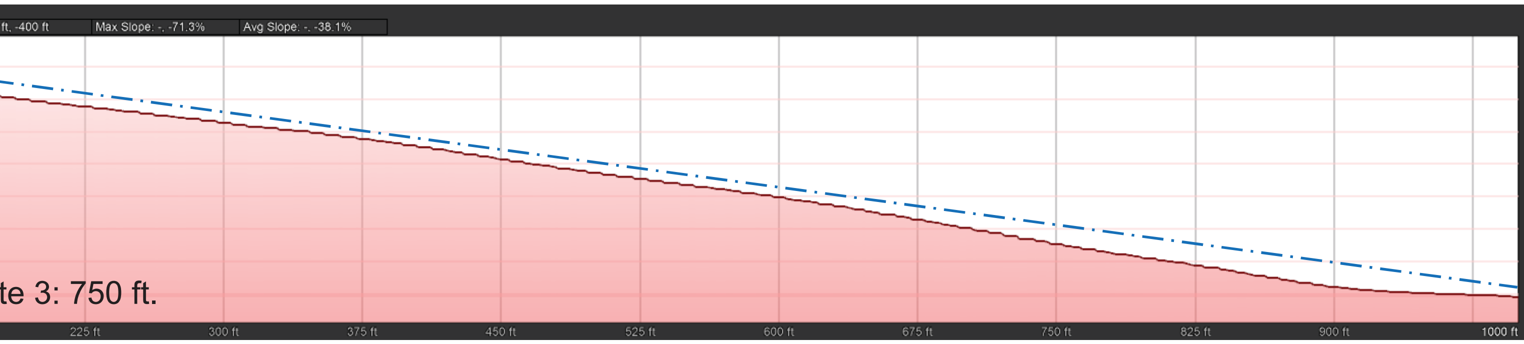


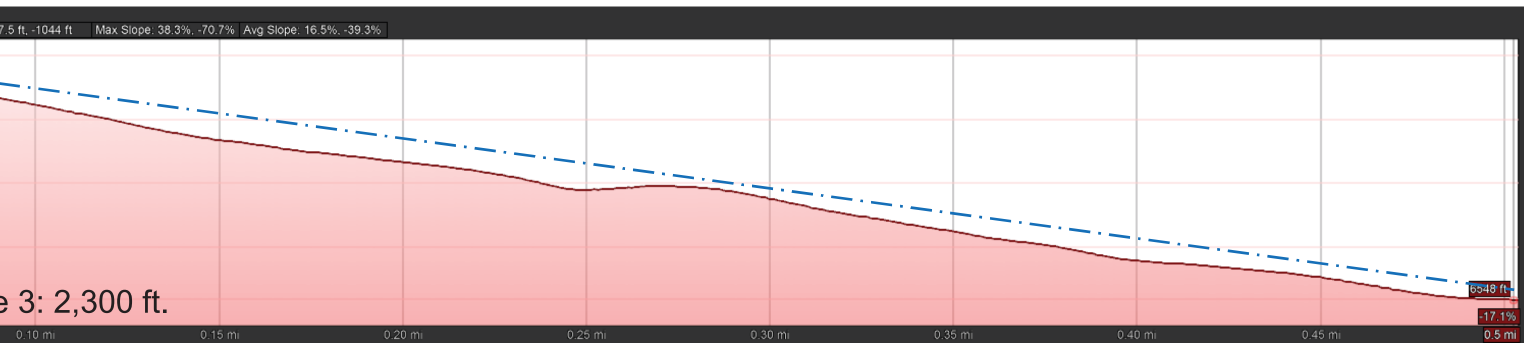


Note: It is recognized that the aspect ratios for these cross-sections vary, as the X and Y scales are not consistent. The intent of these graphics is to illustrate that uninterrupted line-of-sight exists between the Gazex units and the monitoring sites.

s-Sections between Gazex Units & Noise/Vibration Survey Locations



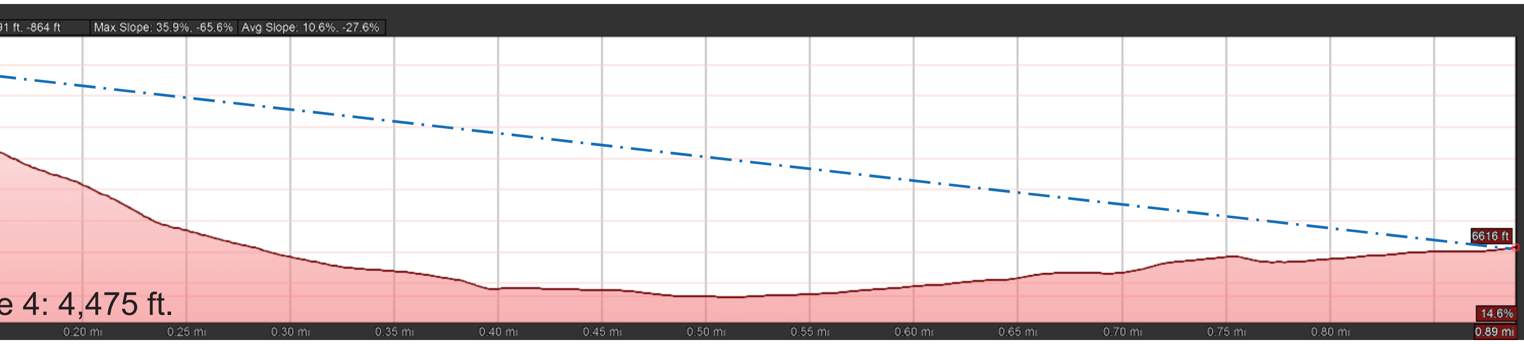


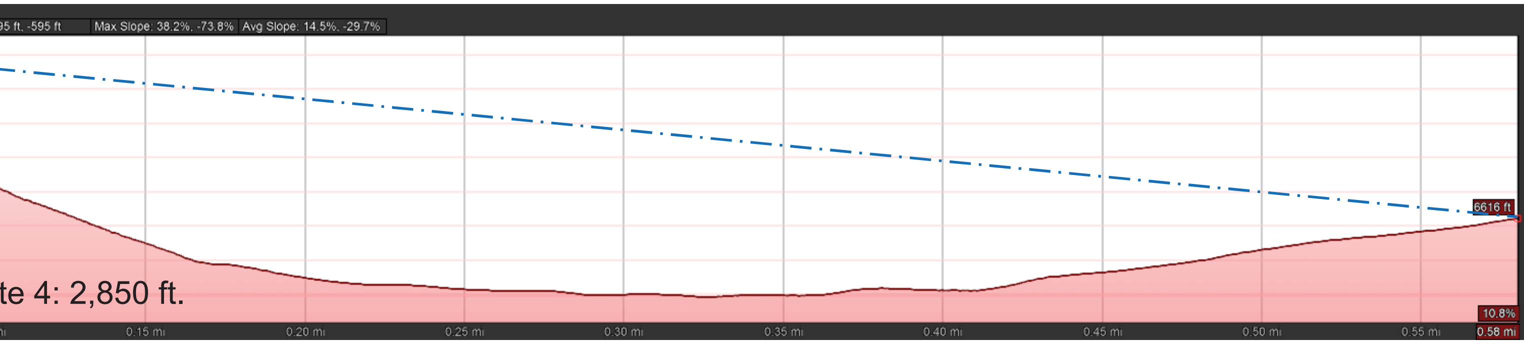


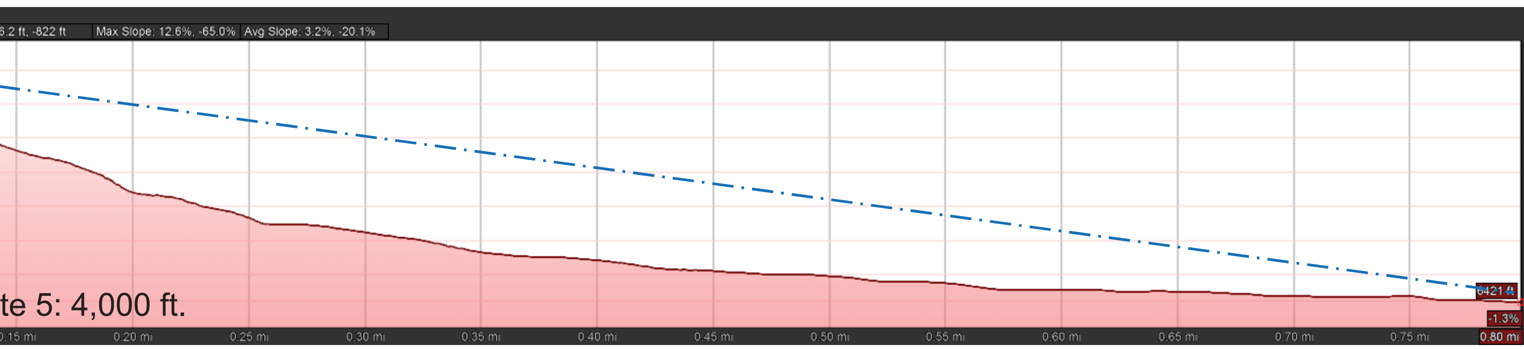
a l

Note: It is recognized that the aspect ratios for these cross-sections vary, as the X and Y scales are not consistent. The intent of these graphics is to illustrate that uninterrupted line-of-sight exists between the Gazex units and the monitoring sites.

s-Sections between Gazex Units & Noise/Vibration Survey Locations



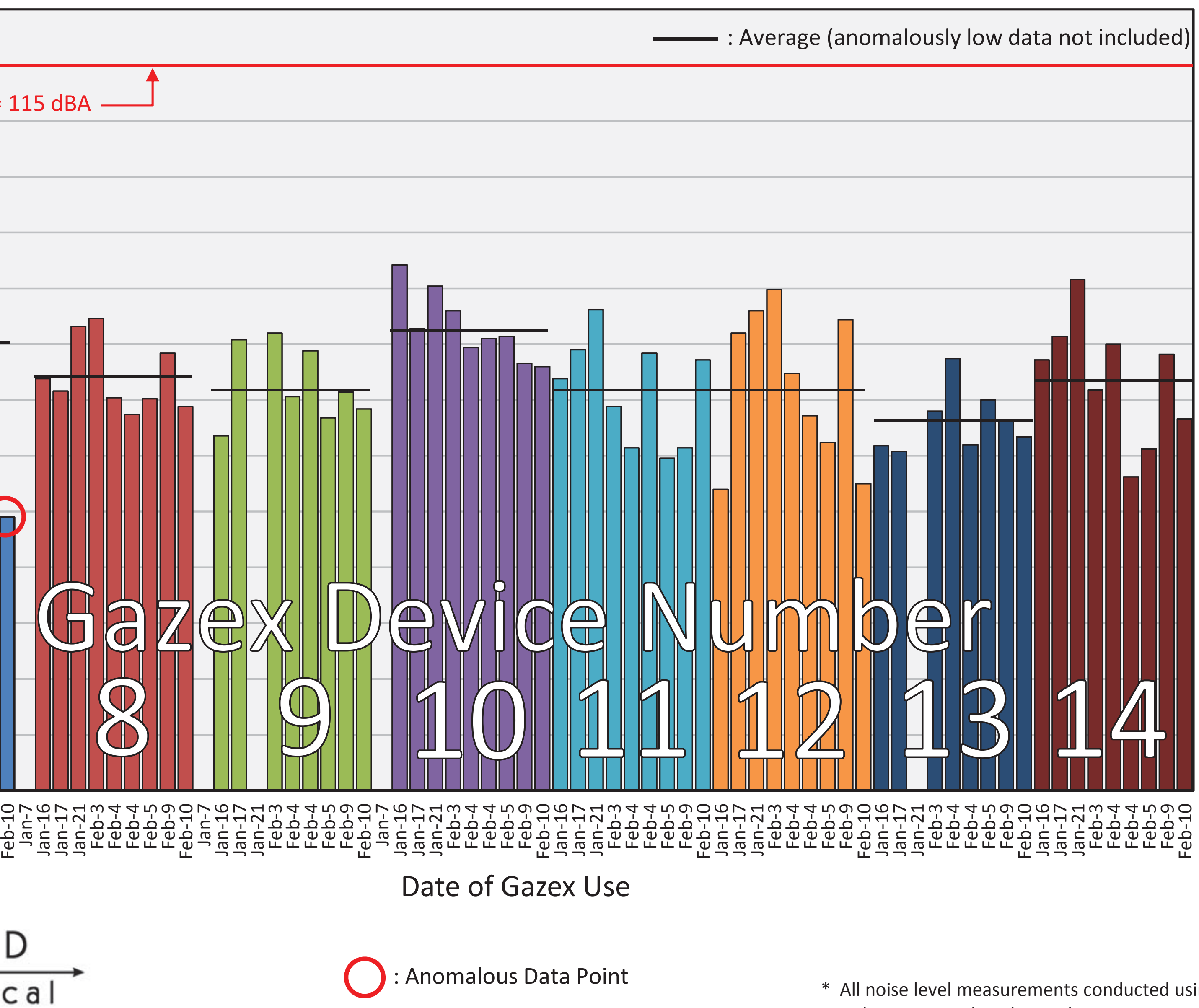




a l

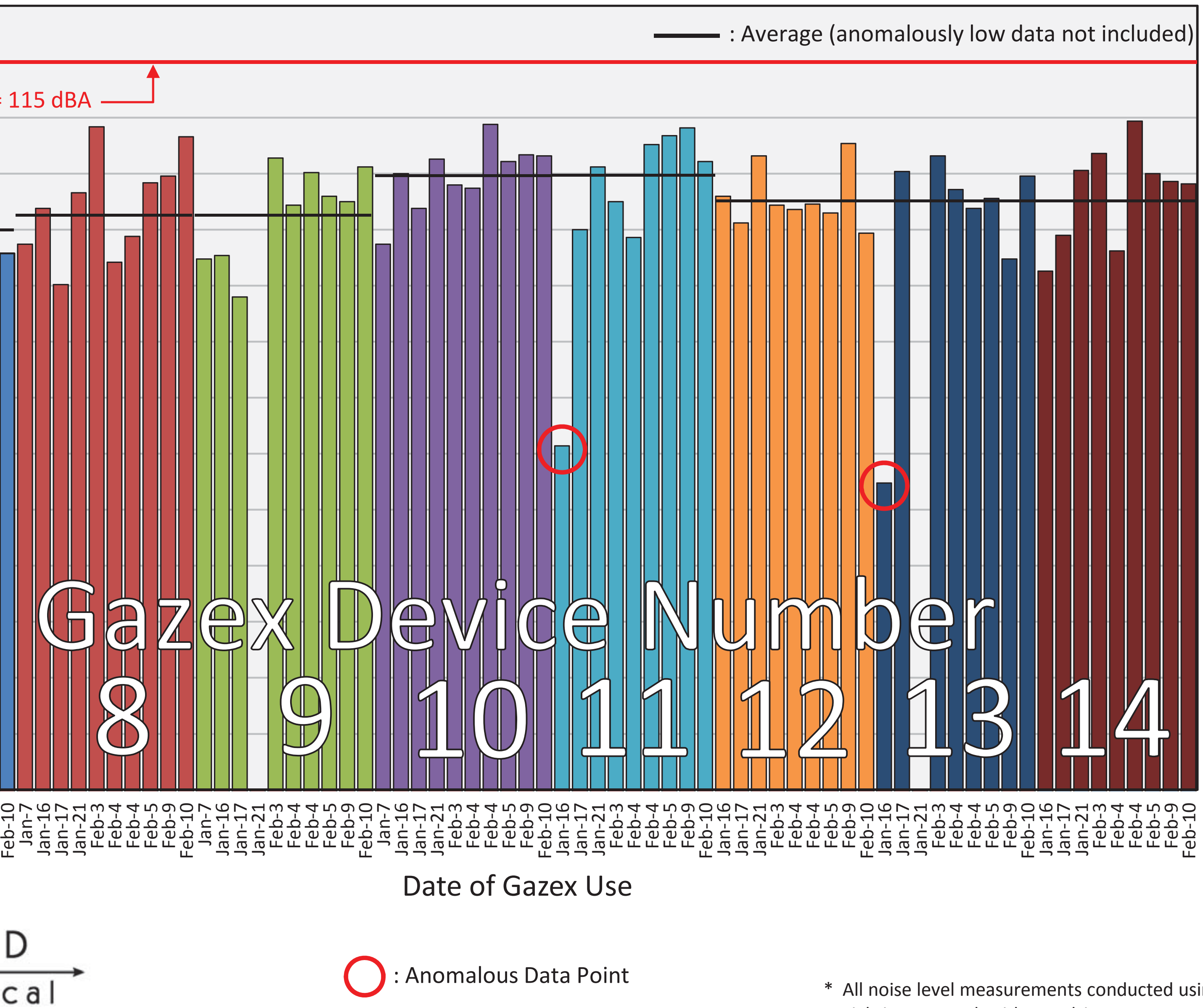
Note: It is recognized that the aspect ratios for these cross-sections vary, as the X and Y scales are not consistent. The intent of these graphics is to illustrate that uninterrupted line-of-sight exists between the Gazex units and the monitoring sites.

Appendix C-1
Measured Gazex System Maximum Noise Levels
Monitoring Site 1 - Chalet Road



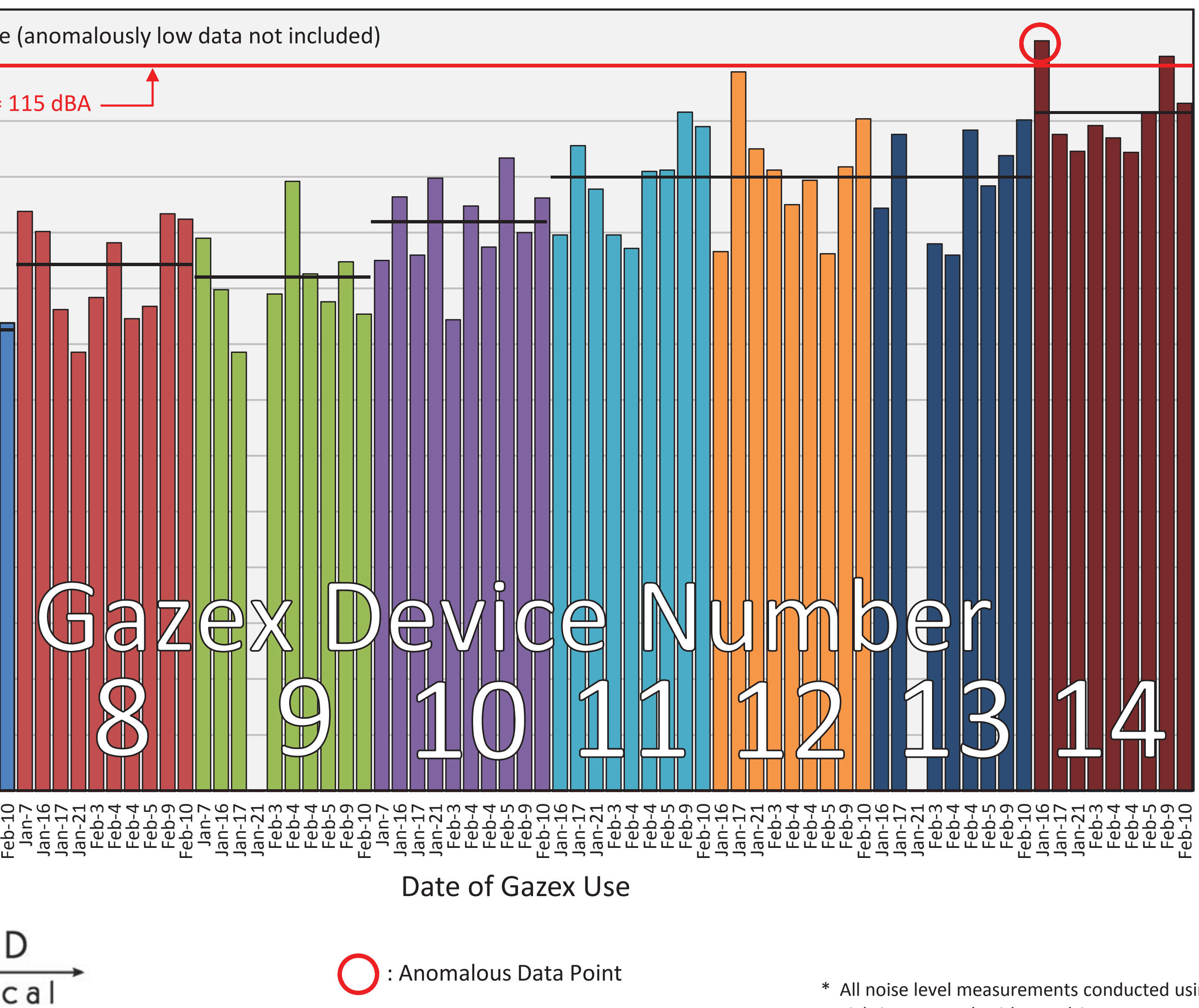
* All noise level measurements conducted using A-Weighting Network with Impulsive Response Time.

Appendix C-2
Measured Gazex System Maximum Noise Levels
Monitoring Site 2 - Trapper Place



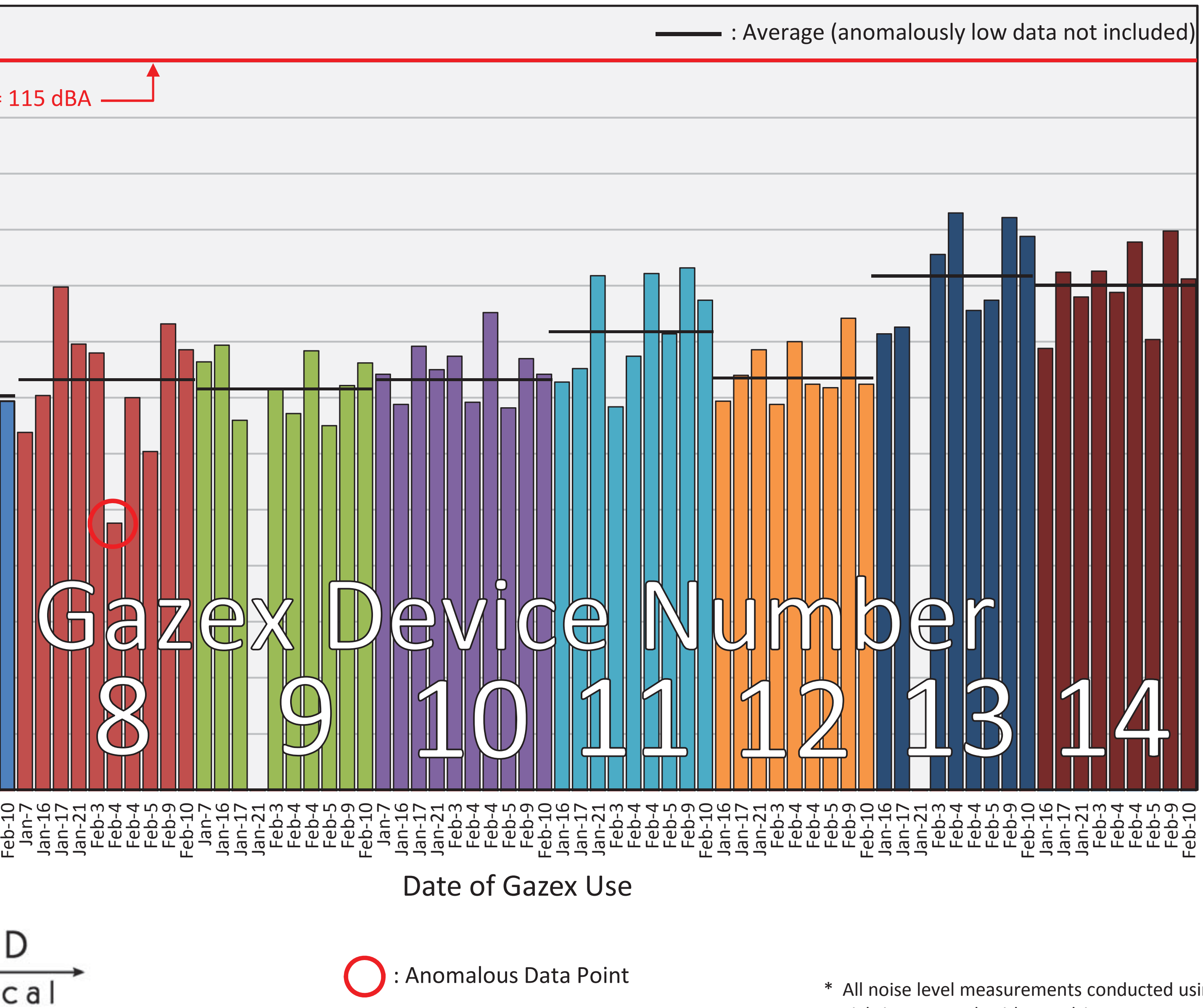
* All noise level measurements conducted using A-Weighting Network with Impulsive Response Time.

Appendix C-3
Measured Gazex System Maximum Noise Levels
Monitoring Site 3 - Alpine Meadows Road



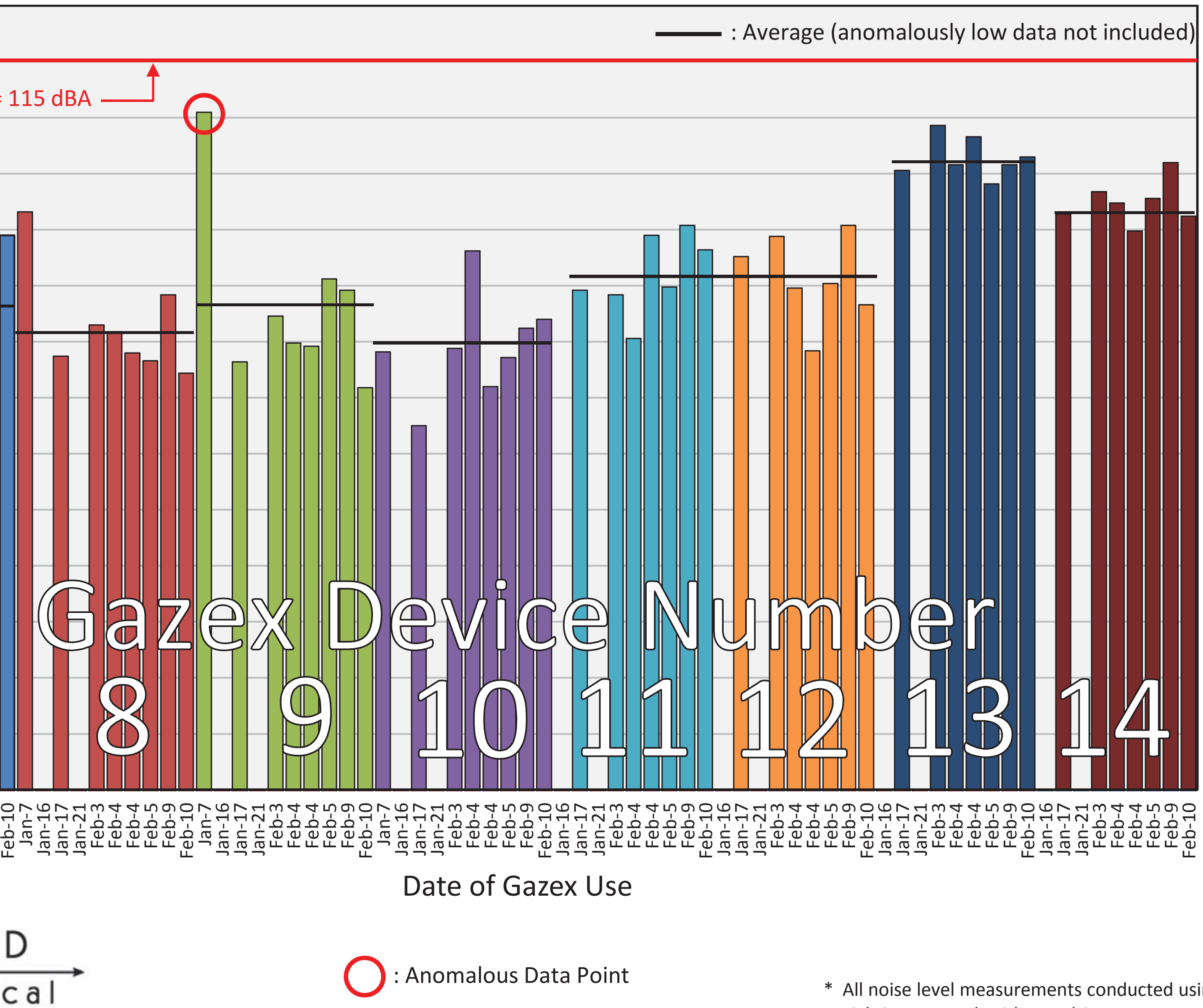
* All noise level measurements conducted using A-Weighting Network with Impulsive Response Time.

Appendix C-4
Measured Gazex System Maximum Noise Levels
Monitoring Site 4 - Chateau Place



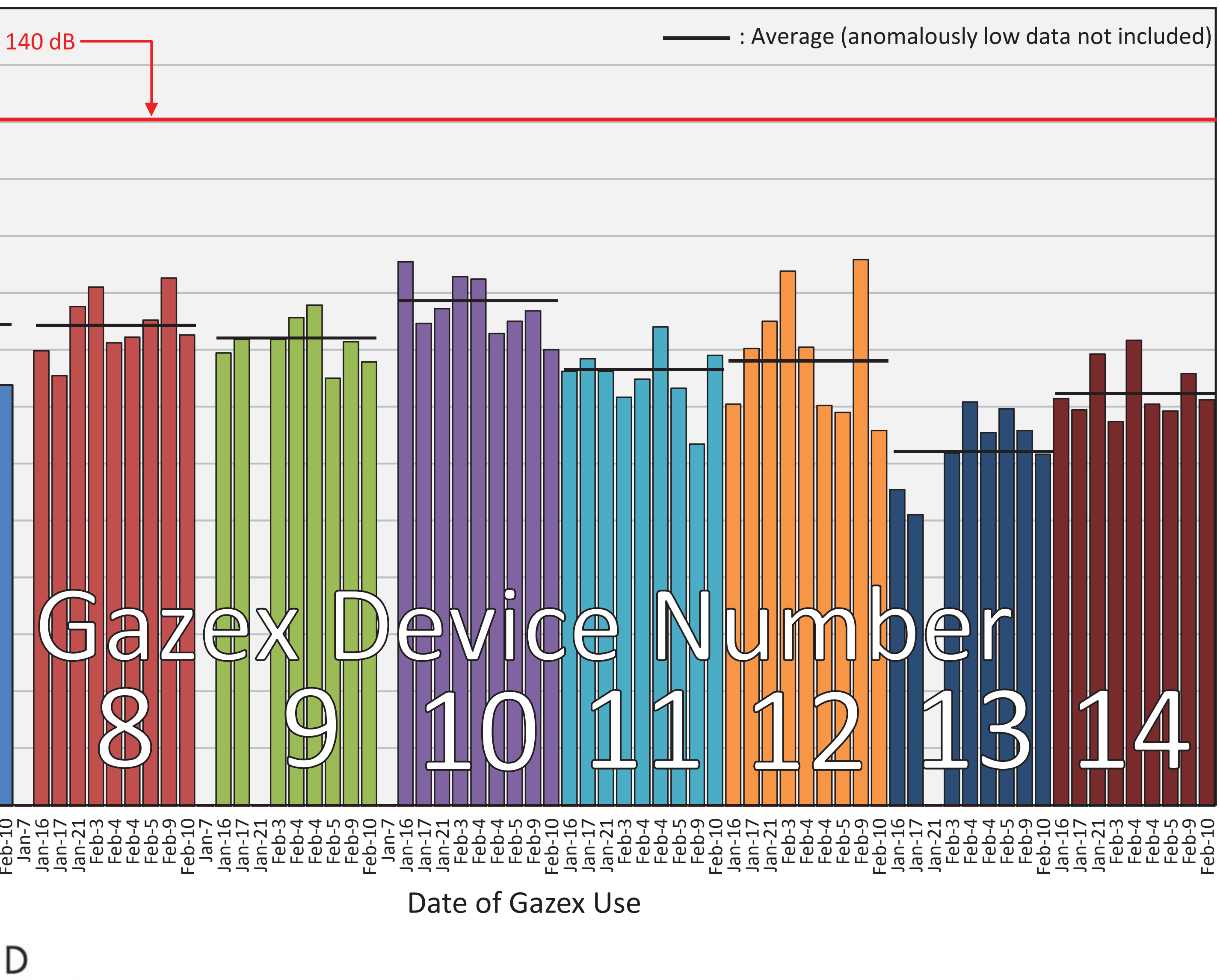
* All noise level measurements conducted using A-Weighting Network with Impulsive Response Time.

Appendix C-5
Measured Gazex System Maximum Noise Levels
Monitoring Site 5 - Beaver Dam Trail



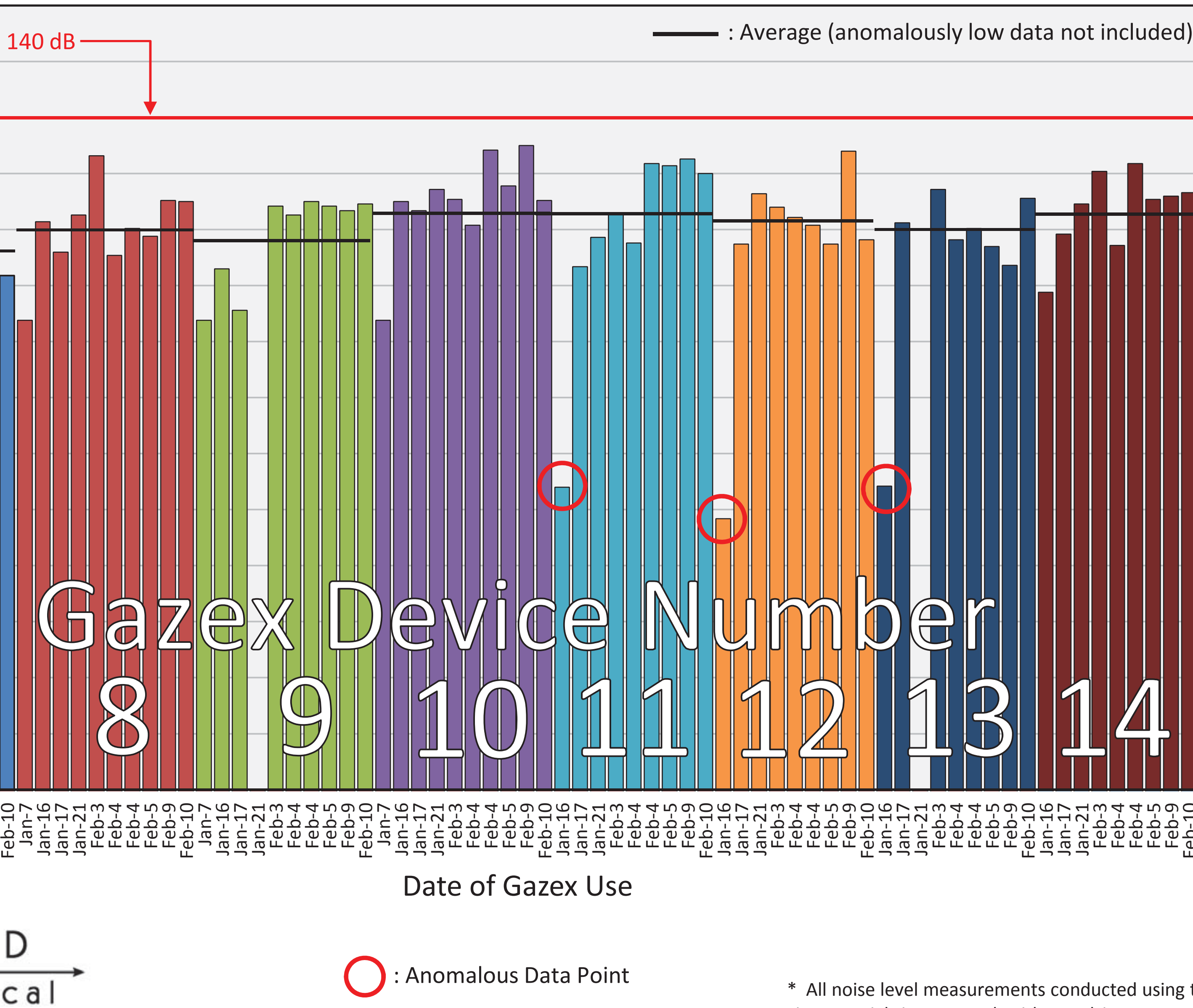
* All noise level measurements conducted using A-Weighting Network with Impulsive Response Time.

Appendix D-1
Measured Gazex System Linear Peak Noise Levels
Monitoring Site 1 - Chalet Road



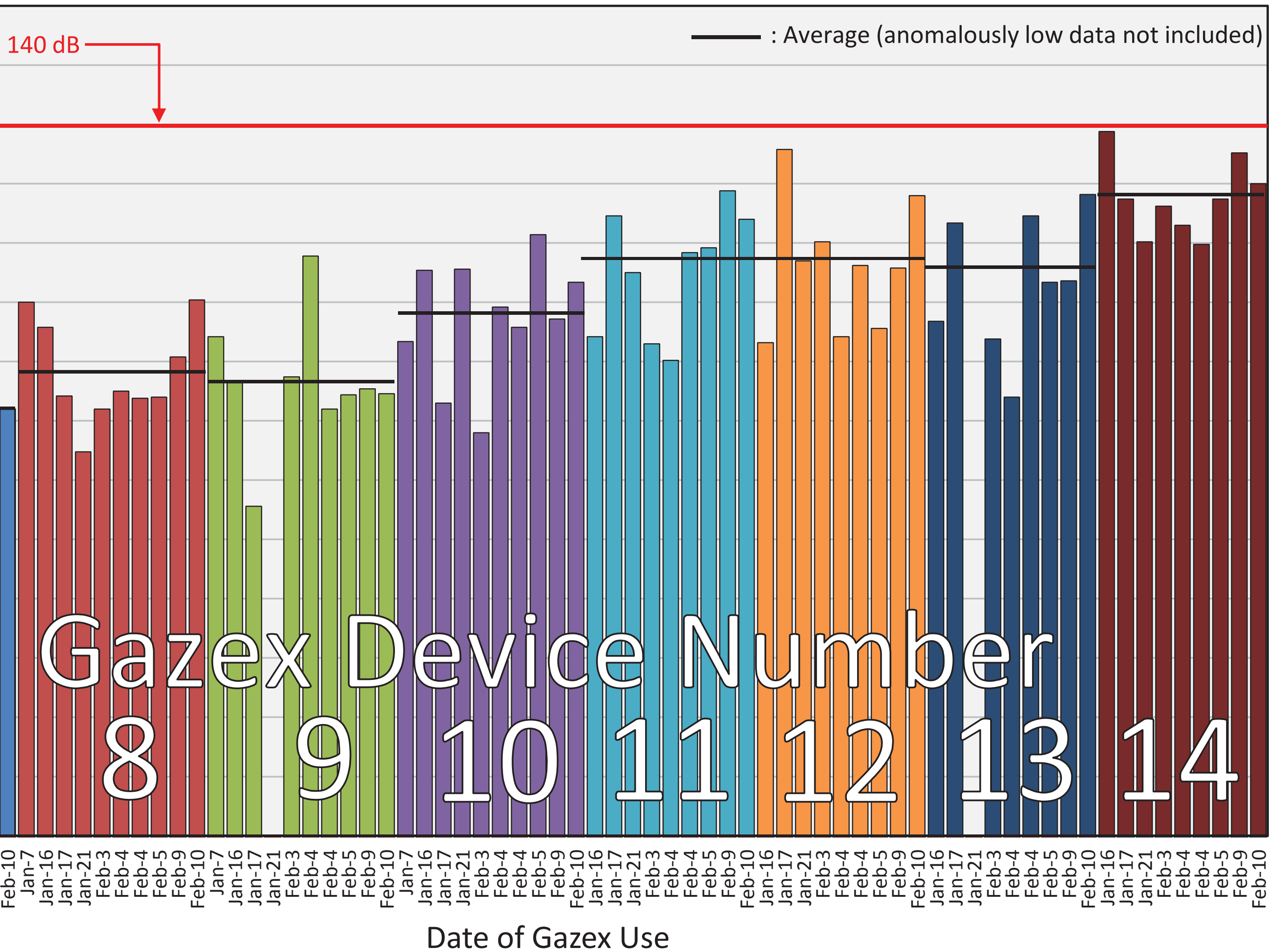
* All noise level measurements conducted using the Linear Weighting Network with Impulsive Response Time.

Appendix D-2
Measured Gazex System Linear Peak Noise Levels
Monitoring Site 2 - Trapper Place



* All noise level measurements conducted using the Linear Weighting Network with Impulsive Response Time.

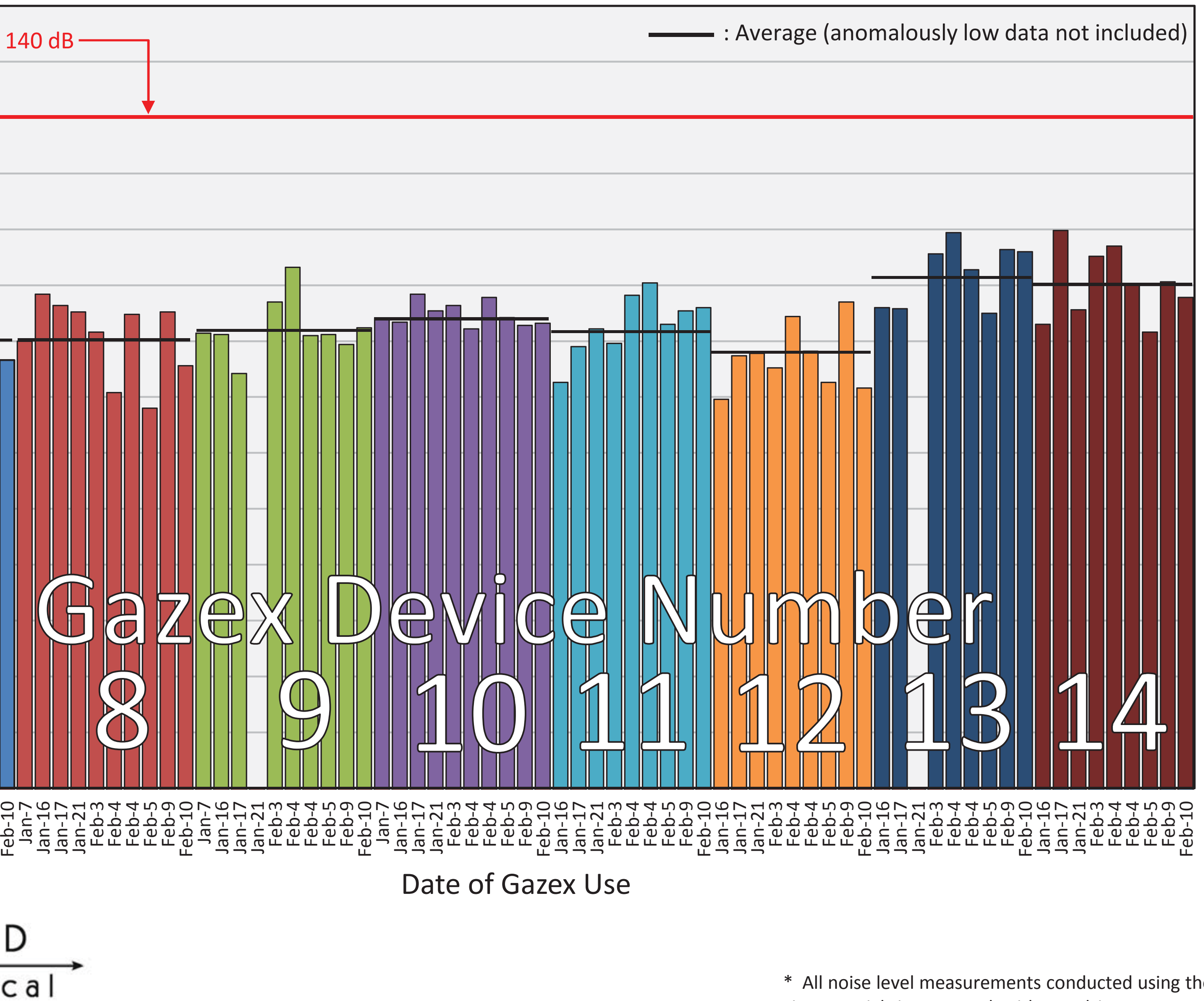
Appendix D-3
Measured Gazex System Linear Peak Noise Levels
Monitoring Site 3 - Alpine Meadows Road



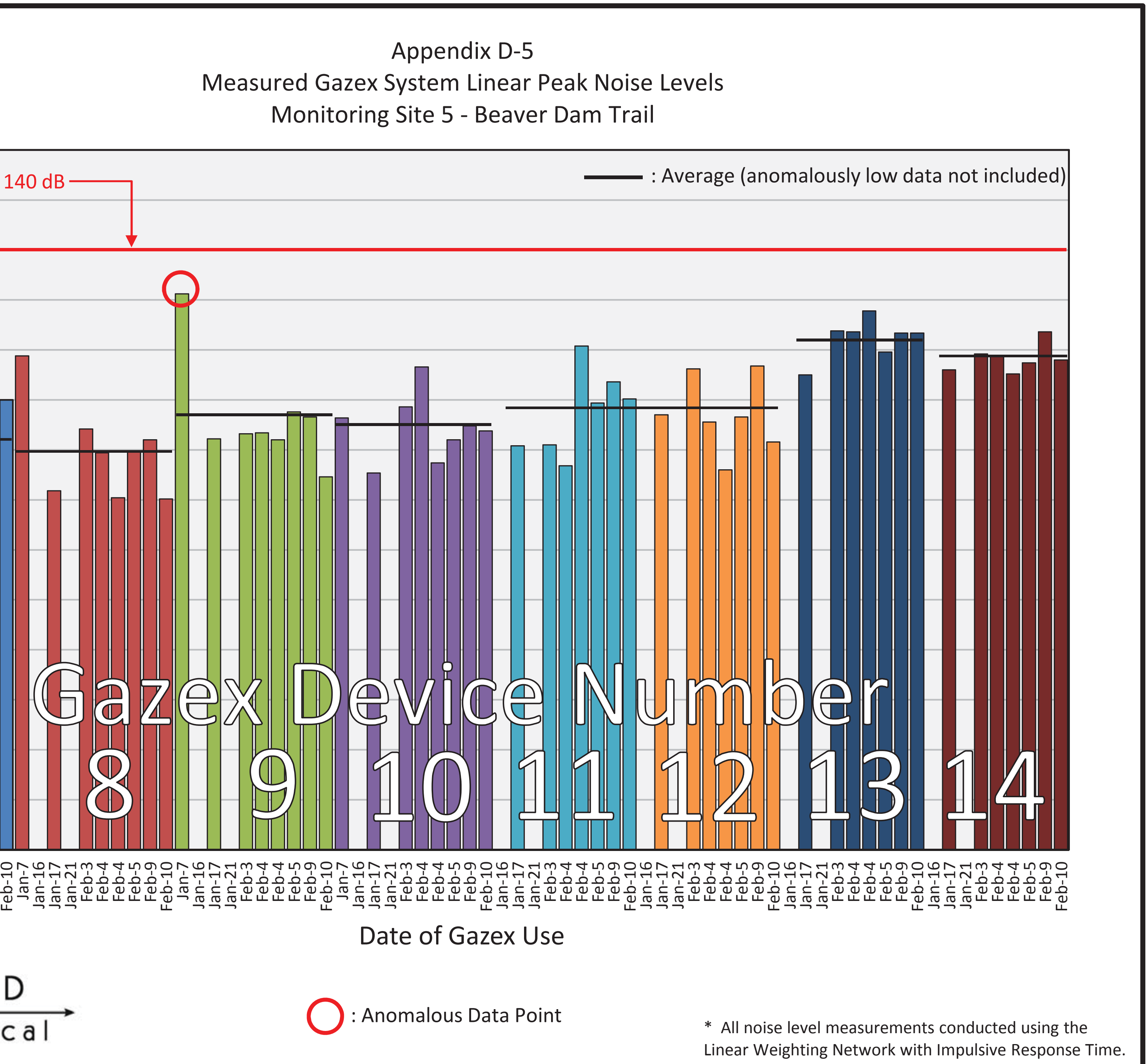
: Anomalous Data Point

* All noise level measurements conducted using the Linear Weighting Network with Impulsive Response Time.

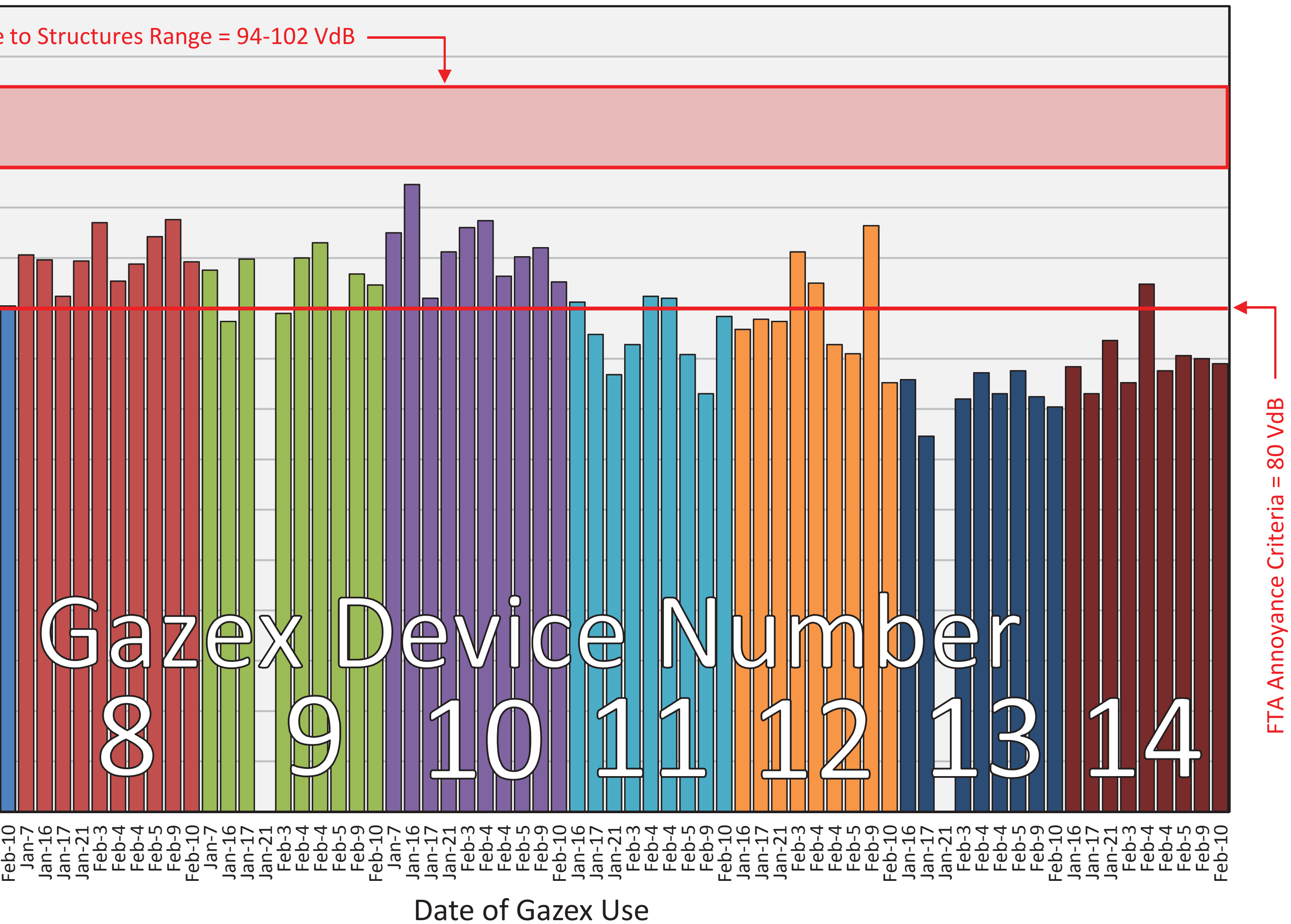
Appendix D-4
Measured Gazex System Linear Peak Noise Levels
Monitoring Site 4 - Chateau Place



* All noise level measurements conducted using the Linear Weighting Network with Impulsive Response Time.

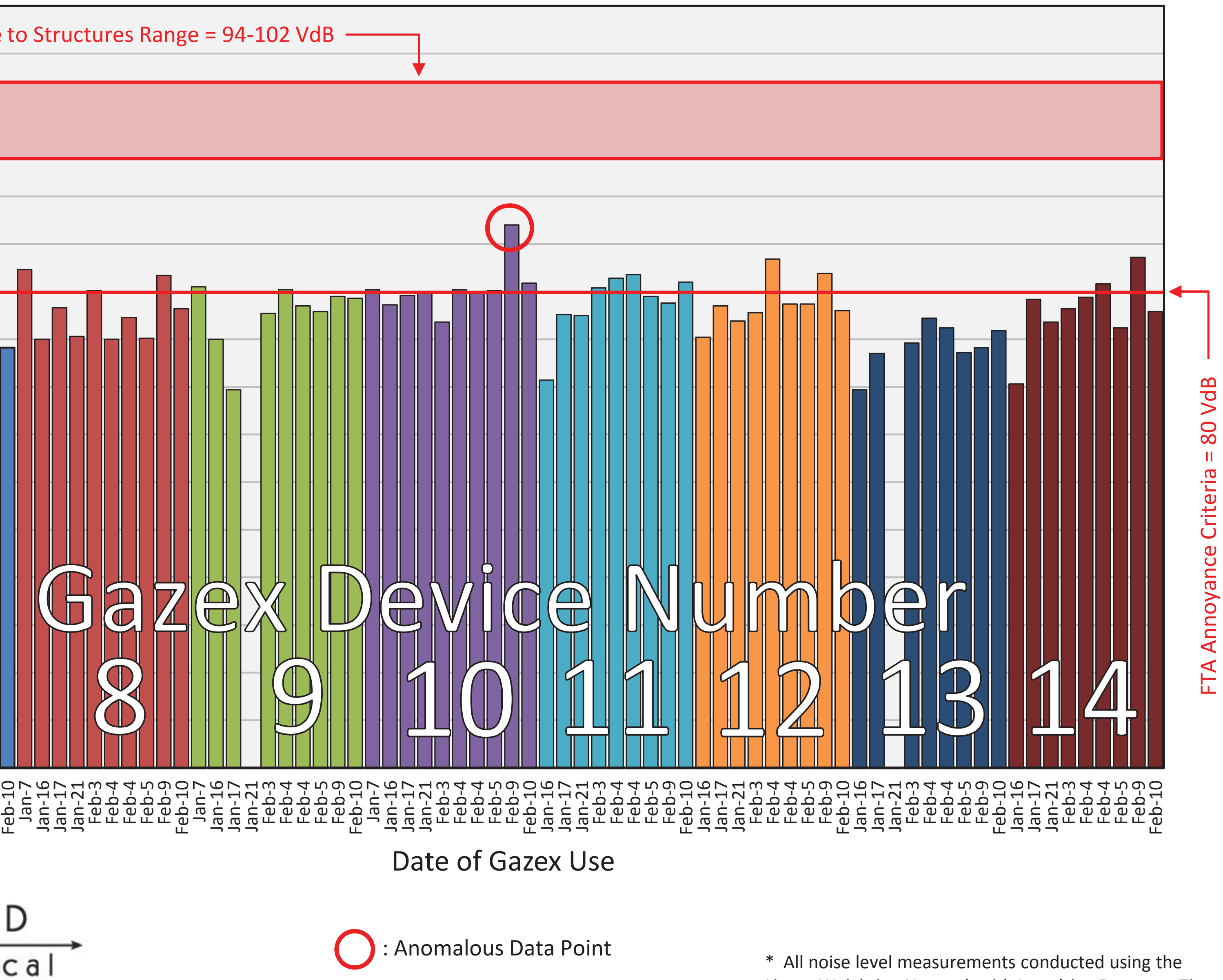

Appendix D-5
Measured Gazex System Linear Peak Noise Levels
Monitoring Site 5 - Beaver Dam Trail
140 dB
: Average (anomalously low data not included)
Gazex Device Number
8
9
10
11
12
13
14
Date of Gazex Use
D
cal
: Anomalous Data Point
* All noise level measurements conducted using the Linear Weighting Network with Impulsive Response Time.

Appendix E-1
Measured Gazex System Ground Vibration Levels
Monitoring Site 1 - Chalet Road



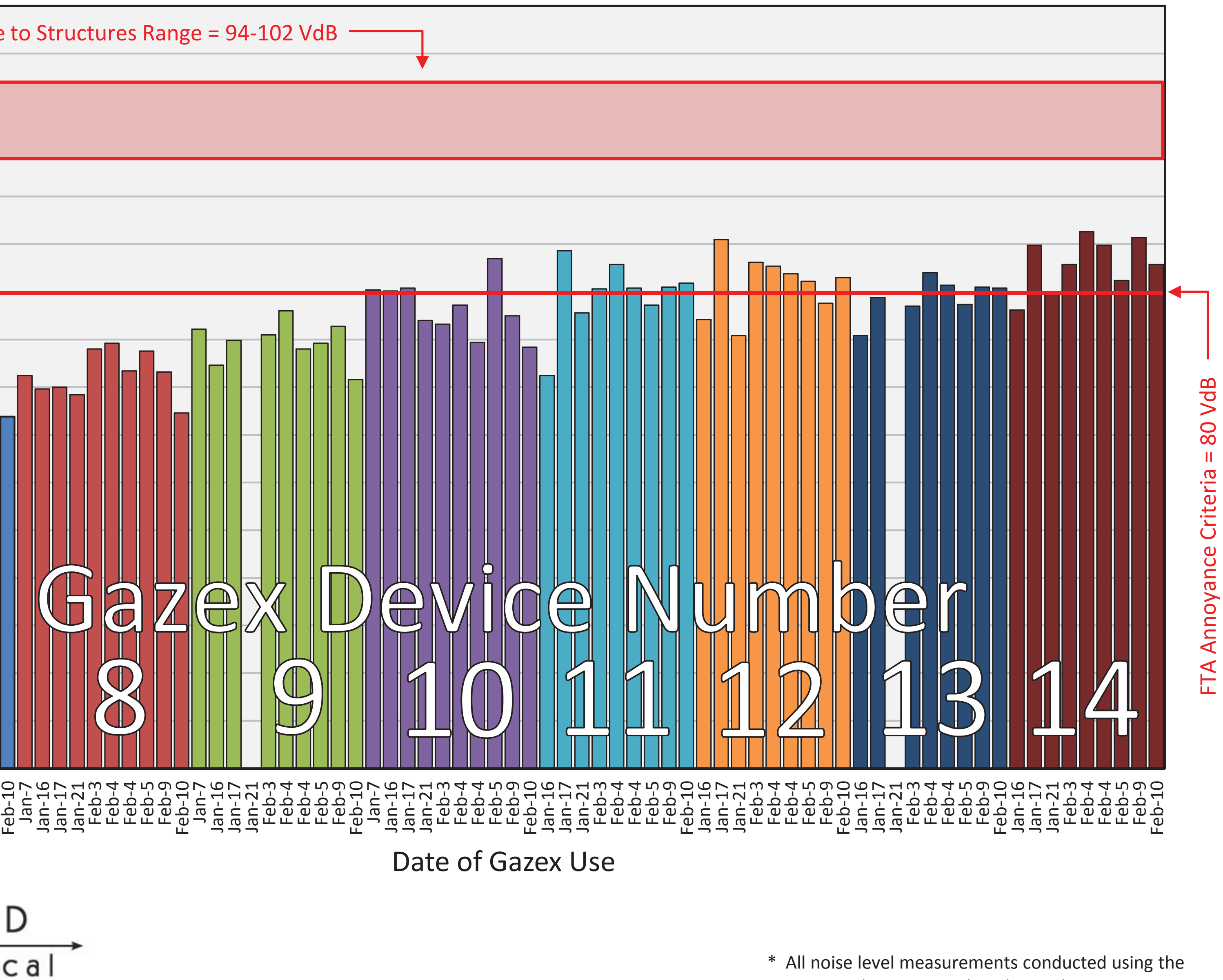
* All vibration level measurements conducted using the Linear Weighting Network with Impulsive Response Time.

Appendix E-2
Measured Gazex System Ground Vibration Levels
Monitoring Site 2 - Trapper Place



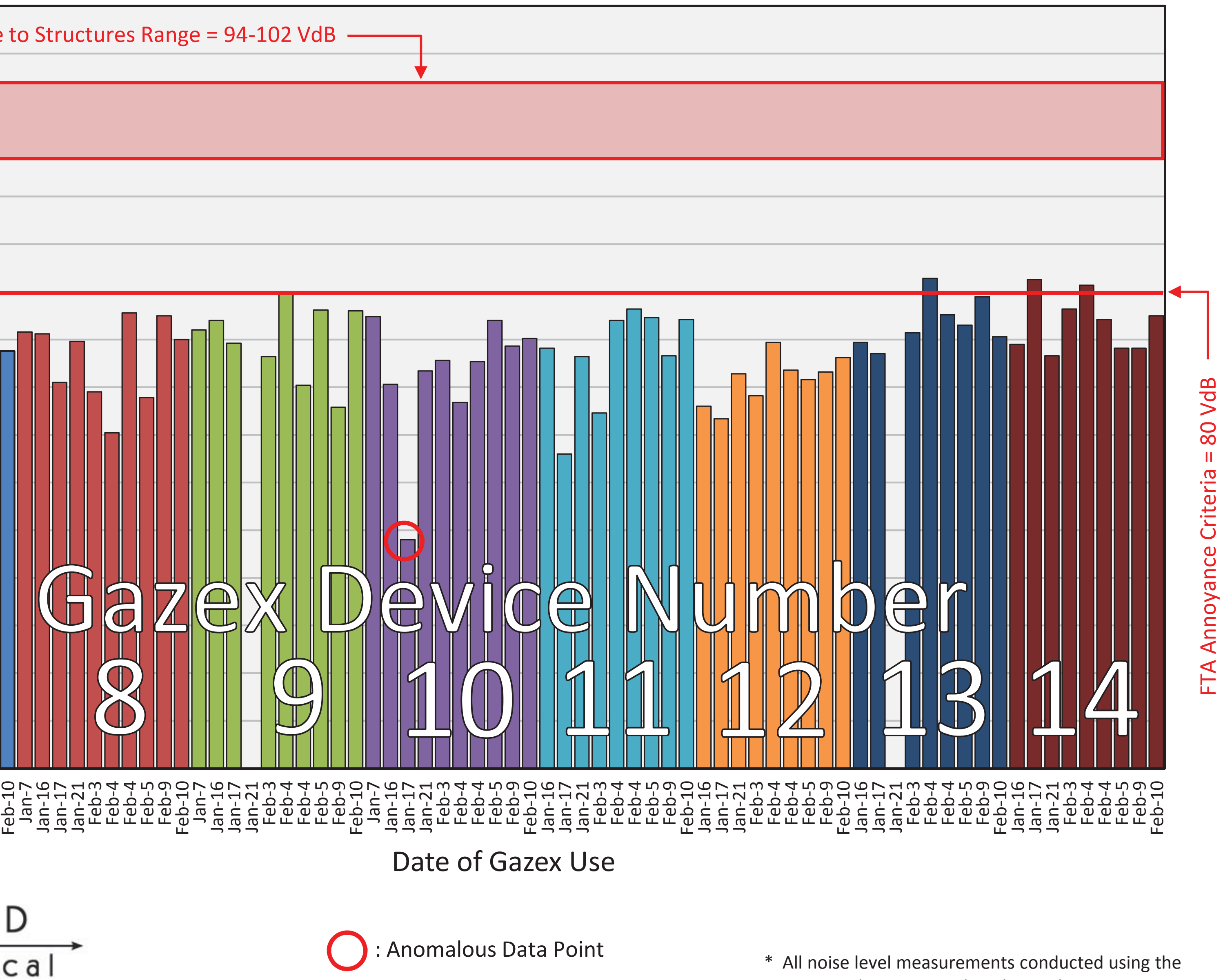
* All noise level measurements conducted using the Linear Weighting Network with Impulsive Response Time.

Appendix E-3
Measured Gazex System Ground Vibration Levels
Monitoring Site 3 - Alpine Meadows Road



* All noise level measurements conducted using the Linear Weighting Network with Impulsive Response Time.

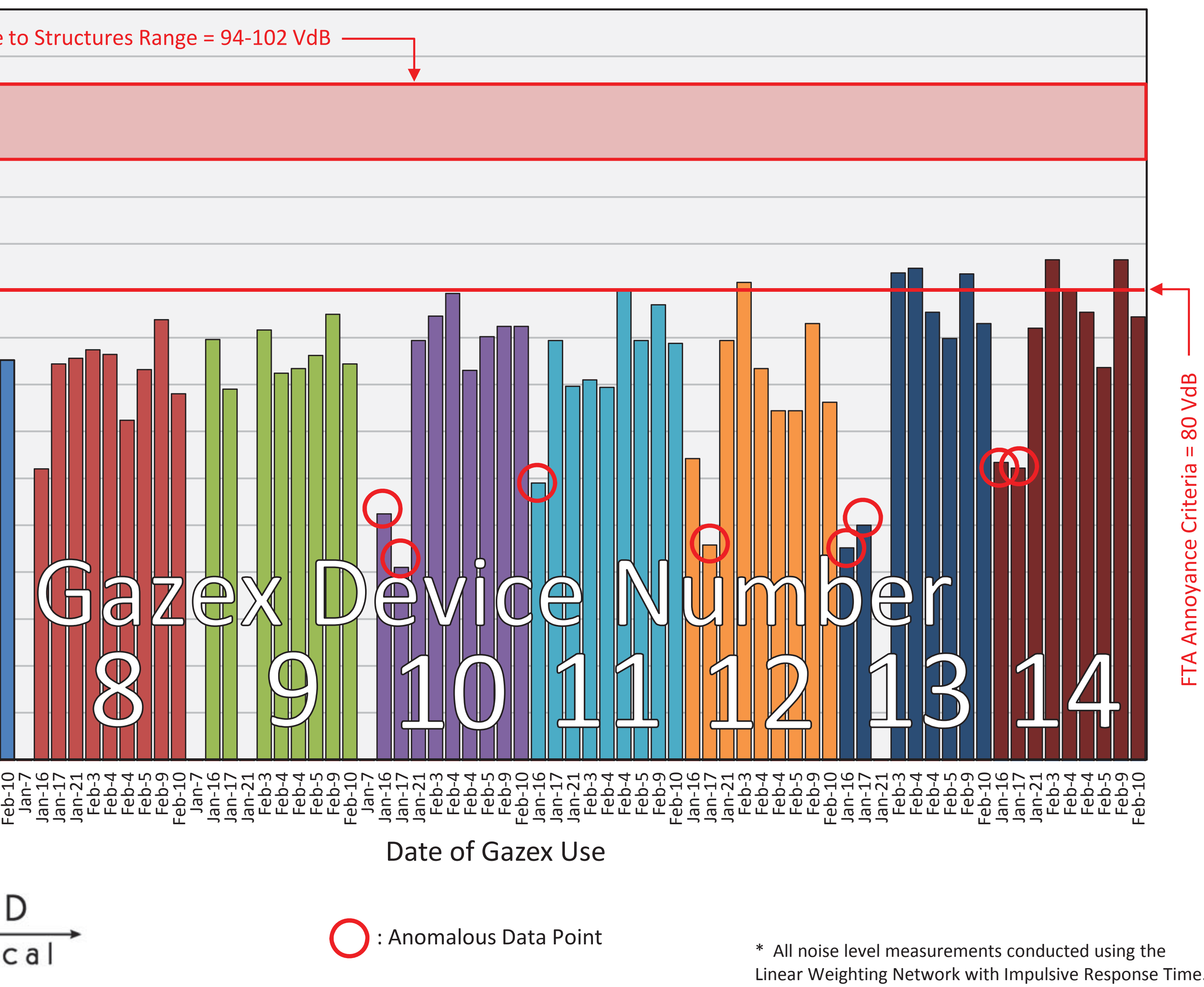
Appendix E-4
Measured Gazex System Ground Vibration Levels
Monitoring Site 4 - Chateau Place



: Anomalous Data Point

* All noise level measurements conducted using the Linear Weighting Network with Impulsive Response Time.

Appendix E-5
Measured Gazex System Ground Vibration Levels
Monitoring Site 5 - Beaver Dam Trail



* All noise level measurements conducted using the Linear Weighting Network with Impulsive Response Time.

n System Monitoring Results

Maximum Sound Level, Lmax dBA					Peak Sound Level, Lpeak dB					Maximum Vibration Level, VdB				
Site 1	Site 2	Site 3	Site 4	Site 5	Site 1	Site 2	Site 3	Site 4	Site 5	Site 1	Site 2	Site 3	Site 4	Site 5
n/a	99	98	87	89	n/a	122	122	122	123	88	80	80	77	n/a
n/a	97	100	88	111	n/a	122	122	121	136	84	81	76	76	n/a
n/a	95	94	84	99	n/a	122	111	122	124	91	81	75	75	n/a
n/a	99	102	82	102	n/a	122	125	120	129	85	82	71	76	n/a
97	105	103	84	n/a	128	133	128	122	n/a	92	79	80	70	56
87	102	100	85	n/a	120	131	123	124	n/a	85	75	70	76	61
82	98	95	90	n/a	120	127	118	121	n/a	79	75	72	77	75
96	102	98	83	n/a	129	130	118	122	n/a	93	79	75	75	72
77	103	98	85	n/a	115	104	122	115	n/a	78	75	77	68	62
87	81	100	86	n/a	118	107	122	116	n/a	81	71	71	74	60
89	96	117	89	n/a	116	124	139	122	n/a	74	70	78	75	62
81	77	102	91	n/a	108	107	123	123	n/a	73	70	75	75	53
91	102	98	90	83	122	132	117	124	118	81	80	80	54	51
90	94	89	83	88	121	123	108	117	121	85	70	75	75	70
86	95	93	95	89	118	128	117	123	116	81	78	70	71	72
96	97	99	90	94	124	125	122	118	122	87	73	74	75	71
90	100	108	88	95	119	127	132	120	120	77	78	84	63	75
91	101	114	87	98	120	129	138	119	124	79	79	86	67	53
91	100	109	96	101	115	130	134	130	128	72	79	85	81	61
80	105	109	91	105	106	131	132	123	128	67	74	79	74	55
95	106	105	88	n/a	124	134	128	123	n/a	86	80	77	72	75
n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
92	103	89	90	n/a	124	131	112	123	n/a	85	75	69	75	73
94	102	93	81	n/a	124	129	118	122	n/a	85	76	71	74	73
93	106	104	96	n/a	118	129	128	121	n/a	73	78	78	73	70
93	107	108	89	n/a	123	133	129	119	n/a	79	77	75	71	75
96	105	107	94	n/a	120	132	130	123	n/a	77	77	80	73	76
n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
93	104	92	89	89	126	133	114	123	124	88	77	77	73	77
91	106	95	86	92	121	132	119	124	122	80	78	76	73	76
92	109	94	89	92	126	137	116	121	122	89	80	74	70	74
91	103	86	90	93	122	131	103	121	121	84	75	67	74	79
84	103	100	84	94	116	131	122	120	121	76	80	80	67	71
95	102	106	84	99	127	132	130	118	128	86	78	83	69	81
86	107	110	96	103	114	135	133	128	130	73	78	83	78	83
84	107	99	98	109	111	134	122	128	132	71	75	79	76	82
90	104	102	85	98	126	130	125	121	128	89	80	79	68	80
85	102	105	84	90	123	131	129	127	122	85	80	78	80	71
85	97	99	74	91	121	128	118	115	120	83	75	75	65	73

n System Monitoring Results

Maximum Sound Level, Lmax dBA					Peak Sound Level, Lpeak dB					Maximum Vibration Level, VdB				
Site 1	Site 2	Site 3	Site 4	Site 5	Site 1	Site 2	Site 3	Site 4	Site 5	Site 1	Site 2	Site 3	Site 4	Site 5
89	107	89	82	96	124	134	103	122	127	89	81	70	74	82
81	99	99	89	90	117	129	120	124	118	81	81	83	77	70
87	102	103	90	95	120	131	122	122	123	83	83	83	75	72
90	98	109	94	102	121	129	132	129	129	82	79	86	81	80
89	104	98	102	106	115	129	117	130	132	74	77	82	81	82
91	109	99	93	86	121	137	123	124	119	83	80	75	73	72
84	99	92	85	89	121	130	117	122	115	84	77	72	78	66
89	105	96	89	90	124	133	116	121	121	87	79	74	70	72
92	94	86	79	85	123	127	108	116	117	82	78	69	70	69
84	102	105	86	89	115	130	128	119	118	76	79	82	72	67
89	108	106	96	100	122	136	129	125	130	81	82	80	78	80
78	110	107	99	100	115	136	130	125	128	74	81	85	77	78
81	102	109	93	108	113	130	132	126	134	72	76	81	78	78
91	106	107	84	89	123	134	131	122	121	85	80	84	77	75
85	104	93	80	88	123	129	117	114	120	87	75	74	69	72
83	103	94	83	96	118	132	117	121	124	80	78	75	78	73
81	100	95	84	89	117	128	120	117	117	80	75	72	70	69
81	102	98	86	95	115	129	123	116	123	76	79	81	71	67
80	108	106	91	95	117	136	130	122	125	75	80	79	77	75
81	105	111	90	103	115	133	134	121	129	75	76	81	74	72
85	103	104	94	104	115	129	127	123	130	74	74	79	77	75
88	107	100	89	91	123	138	124	121	122	86	87	78	74	76
89	105	102	92	94	126	133	120	123	121	89	82	72	78	77
86	103	97	86	95	121	132	118	120	123	83	80	76	68	78
83	102	92	90	91	118	132	113	123	118	81	81	69	79	73
92	108	106	92	100	128	137	128	124	128	88	82	79	72	77
81	109	111	97	100	112	136	134	123	127	72	79	81	73	79
89	104	116	100	106	118	133	138	125	132	75	84	86	74	83
83	97	107	101	106	113	127	127	128	132	71	74	81	80	82
88	107	103	87	92	120	133	127	122	122	83	81	74	75	76
84	108	101	89	87	121	133	125	118	115	85	78	67	75	69
84	106	93	88	86	119	132	117	121	117	82	79	71	78	72
75	98	92	85	100	117	126	116	118	125	80	74	67	74	73
78	100	110	86	93	113	129	134	116	121	73	78	82	73	68
89	106	110	94	98	120	135	132	123	125	79	81	81	77	74
83	104	112	96	101	116	133	135	124	129	75	78	83	78	77
82	105	110	99	107	111	133	134	128	132	70	76	80	75	77

n System Monitoring Results

	Maximum Sound Level, Lmax dBA					Peak Sound Level, Lpeak dB					Maximum Vibration Level, VdB				
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 1	Site 2	Site 3	Site 4	Site 5	Site 1	Site 2	Site 3	Site 4	Site 5
ge:	87	102	101	89	96	119	130	124	122	124	81	78	77	74	72
an:	87	103	100	89	95	120	131	123	122	123	81	78	78	74	73
m:	75	77	86	74	83	106	104	103	114	115	67	70	67	54	51
m:	97	107	117	96	111	129	134	139	130	136	93	82	86	81	76
es:	70	74	74	74	60	70	74	74	74	60	74	74	74	74	70
le:	5	5	7	6	7	5	6	8	3	5	6	3	5	4	7
on:	5	5	7	5	7	5	6	8	3	5	6	3	5	4	7
al:	**1.0**	**1.0**	**1.4**	**1.0**	**1.4**	**0.9**	**1.2**	**1.5**	**0.7**	**1.1**	**1.1**	**0.6**	**1.0**	**0.8**	**1.5**
ge:	88	103	102	90	97	120	131	125	122	125	82	79	78	75	74
ge:	86	101	100	88	94	118	128	122	121	123	80	77	76	73	71