SOUND ANALYSIS

for

SNOHOMISH COUNTY PUD
SMOKEY POINT SUBSTATION
ARLINGTON, WASHINGTON

Submitted to:

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1. INTRODUCTION

This report is a sound analysis of proposed upgrades at the existing Snohomish County Public Utility District No. 1 (PUD) Smokey Point Substation located in Arlington, Washington. The scope of this report is to present existing sound levels measured at and near the existing substation, to evaluate sound levels from one existing and one added electrical transformer at the site with respect to State of Washington noise regulations, and to recommend noise-mitigation measures as necessary.

2. PROJECT SITE AND NEARBY LAND USES

Figure 2-1 shows a vicinity aerial photograph of the project site, surrounding properties, and sound measurement and calculation locations. The project site's north boundary adjoins 166th Pl. NE. Directly across to the north is a Les Schwab Tire Center. A business park is located to the northeast, also across 166th Pl. NE. The adjacent properties to the west and south are occupied by the Autos Only dealership. Adjacent to the east of the substation is the Kids 'N Us Early-Learning Academy. One residence is located 100 feet southwest of the substation.

The substation site and adjacent properties in all directions (including the residence to the southwest) are zoned HC (Highway Commercial) by the City of Arlington. The nearest residential zone is approximately 1000 feet to the east, fronting on 40th Ave. NE; the properties are zoned RMD (Moderate-Density Residential). Properties farther to the south are zoned General Commercial by the City of Marysville.

The Smokey Point Substation houses one 28-MVA RTE-ASEA power transformer (K-198). The proposed site improvements consist of relocating the existing transformer to a new equipment pad (Phase I) and adding a second 28-MVA Waukesha transformer (Phase II).

3. SOUND LEVEL DESCRIPTORS

Sound is measured as sound level in units of decibels, dB. Environmental sound is often measured as A-weighted sound level in dBA. The A-weighting is a specific weighting filter in a sound level meter that corresponds to human hearing sensitivity at the various sound frequencies. People normally experience sound levels between about 30 and 90 dBA, depending on their activity. For example, a loud nearby vehicle, radio or power tool may produce 80 to 90 dBA, normal conversation is about 50 to 60 dBA, and a bedroom or quiet office is about 30 to 40 dBA.

Each 10-dB increase in sound level corresponds to a tenfold increase of sound energy, but is judged by a listener as only a doubling of loudness. The smallest changes in sound level considered clearly noticeable are about 3 to 5 dBA.

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		Figure 2-1
		Snohomish PUD Smokey Point Substation Sound Analysis
		Sound Measurement and Analysis Locations
		BRC Acoustics & Audiovisual Design

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Sound levels from two or more sources are combined using logarithms, not by adding the levels. When two levels are combined, the louder level predominates, and the combined level is the louder level plus 0 to 3 dBA. Some examples: 50 dBA combined with 50 dBA is 53 dBA, and 50 dBA combined with 40 dBA results in 50.4 dBA.

Because sound levels fluctuate over time, several sound-level descriptors are used to characterize the sound. In this report, the following descriptors are used:

Leq	**Equivalent sound level, Leq**, is the most commonly used descriptor for measuring fluctuating sound. The Leq is the level of a constant sound that, over a given time period, contains the same amount of sound energy as the measured fluctuating sound.
Ldn	**Day-night average sound level, Ldn**, is the Leq over 24 hours with a 10 dBA penalty added during the nighttime hours of 10 p.m. to 7 a.m. The Ldn is often used to measure the overall 24-hour sound to determine land-use compatibility and overall impacts. The Ldn is usually close to the same level as the daytime Leq.
Lmax	**Maximum sound level, Lmax**, is the highest instantaneous sound level for a given sound source, event or time period. Because the Lmax in a neighborhood will, unlike Leq, typically have large fluctuations from hour to hour and day to day, Lmax is seldom used to measure noise impact, except in cases where brief high-level sound is causing an impact such as sleep disturbance.
Lmin	**Minimum sound level, Lmin**, is the lowest sound level during the measurement period. The Lmin is an effective descriptor for quantifying the relatively steady level of sound that is present in the absence of local noise events. If a continuous sound source such as a transformer is operating, the Lmin may be caused by that source.
Sound Spectrum	For a sound comprising energy over a range of frequencies, the distribution of sound energy by frequency. When considering sounds with a frequency spectrum such as the hum of a transformer, which is characterized by a large portion of the sound energy being concentrated in the 60-Hz and 120-Hz bands, the sound spectrum is also measured. The sound pressure levels are usually measured in frequency bands of one octave centered at frequencies of 31, 63, 125, 250, 500, 1000 (1k), 2000 (2k), 4000 (4k), and 8000 (8k) Hz. The most important of these octave bands

in terms of potential annoyance is the 125 Hz octave band, because transformer hum occurs primarily at 120 Hz.

4. EXISTING SOUND LEVELS

4.1 Measured Sound Levels at Receiver Property Lines

Existing sound levels were measured at five locations near the substation site, shown in Figure 2-1 as Locations AL1-1 to AL5-1. Two types of measurements were performed. Continuous measurements for 26 to 30 hours were conducted at Locations AL1-1 and AL4-1, using a RION NL-32 and a Bruel & Kjaer 2238 Integrating Sound Level Meter, respectively. Short-term (ten-minute), attended measurements were made at all five locations, using a Bruel & Kjaer 2250 Real-Time Spectrum Analyzer. All instruments conform to ANSI S1.4 requirements for Type I measurement systems. All measurements were conducted at the first-story elevation of five feet above the ground elevation. The locations and times of the measurements were as follows:

Location	Description
AL1-1	At the south property line of the substation property. A-weighted sound levels were measured continuously for 26 hours beginning at 10 a.m. on Thursday, June 2, 2016. A 10-minute measurement of A-weighted and octave-band sound pressure levels was made on Thursday, June 2, 2016 beginning at 11:26 a.m.
AL2-1	At the west property line of the substation, directly west of the proposed relocated transformer K-198. A 10-minute measurement of A-weighted and octave-band sound pressure levels was made on Thursday, June 2, 2016 beginning at 10:50 a.m.
AL3-1	At the southwest corner of the commercial office property northeast of the substation, across 166th Pl. NE. A 10-minute measurement of A-weighted and octave-band sound pressure levels was made on Thursday, June 2, 2016 beginning at 11:53 a.m.
AL4-1	At the east property line of the substation, directly east of the proposed added transformer. A-weighted sound levels were measured continuously for 30 hours beginning at 10 a.m. on Thursday, June 2, 2016. A 10-minute measurement of A-weighted and octave-band sound pressure levels was made on Thursday, June 2, 2016 beginning at 11:38 a.m.

AL5-1 At the west property line of the residence at 16514 40th Ave. NE, representing the nearest residential properties east of the substation.

A 10-minute measurement of A-weighted and octave-band sound pressure levels was made on Thursday, June 2, 2016 beginning at 12:28 p.m.

Three additional locations were considered in the analysis and are shown in Figure 2-1 and listed in Table 4-1.

TABLE 4-1
SOUND ANALYSIS LOCATIONS

AL #	Description
3-2	Second-story, south-facing window of office building northeast of substation
5-2	Second-story, west-facing window of residence at 16514 40th Ave. NE
6-1	Northeast corner of residence at 16507 Smokey Pt. Blvd., southwest of substation

The weather during the measurements ranged from overcast to sunny during the day, with temperatures in the high 50s to mid-60s degrees Fahrenheit and north winds of 5 to 7 mph. The weather was within the range allowed by Washington Administrative Code (WAC) 173-58 for the measurement of environmental sound.

Results of the long-term measurements are shown in Figures A-1 and A-2 in Appendix A. The A-weighted sound levels are shown as Leq, Lmax, and Lmin over one-hour intervals, and 24-hour Ldn.

The results of the 10-minute measurements are shown in Table 4-2.

TABLE 4-2
TEN-MINUTE DAYTIME SOUND MEASUREMENTS
(Leq, dBA)

	MEASUREMENT LOCATION				
	AL1-1	AL2-1	AL3-1	AL4-1	AL5-1
Date and time of measurement	6/2/16 11:25 a.m. (10 minutes)	6/2/16 10:44 a.m. (10 minutes)	6/2/16 11:53 a.m. (10 minutes)	6/2/16 11:38 a.m. (10 minutes)	6/2/16 12:28 p.m. (10 minutes)
Leq	54	53	56	57	49

Existing sound levels at Locations AL1-1, 2-1, 3-1, and 4-1 are caused primarily by traffic on Smokey Point Blvd. and by power and pneumatic tools at the Les Schwab Tire Center to the north. Other noise sources include occasional outdoor play activities at the Early-Learning Academy to the east, an air compressor at the truck dealership to the west, across Smokey Point Blvd., and occasional vehicle pass-bys on 166th Pl. NE. Existing sound levels at Analysis

Location 6-1 are dominated by traffic noise from Smokey Point Blvd. Existing sound levels at Location AL5-1 are due to distant traffic, commercial activities, and occasional aircraft flyovers. Under mid-morning conditions, the existing transformer was audible at Location AL2-1 and not audible at the remaining Analysis Locations.

The hourly Leq sound levels at the long-term measurement locations range from the upper 40s to upper 50s dBA during the daytime and nighttime, with one hourly Leq exceeding 60 dBA at Location AL4-1.

Existing sound levels at Location 5-1 are consistent with an urban residential community.

4.2 Sound Levels from the Existing Transformer

The existing transformer (K-198) at Smokey Point Substation is a 28-MVA RTE-ASEA model. In order to quantify the noise emissions of the existing unit, sound levels produced by the transformer were measured in one-octave bands at reference distances of 15 to 25 feet from the center of the transformer in four directions surrounding the unit.

The measurement results were normalized to sound power levels, presented in Table 4-3. The sound levels shown in the table include the noise from all six cooling fans operating. The current through each of the three phases ranged from 345 to 360 amperes. The four directions are defined with respect to the principal features of the transformer and also to the existing orientation at the Smokey Point site.

The measurements of transformer sound levels were conducted in close proximity to the unit in order to minimize the effect of other environmental noise sources. Furthermore, the transformer sound levels reported in Table 4-3 are based on the measured Lmin, which is not affected by intermittent ambient noise.

TABLE 4-3 SOUND POWER LEVELS OF EXISTING 28-MVA RTE-ASEA TRANSFORMER										
DIRECTION		**dBA**	**OCTAVE-BAND CENTER FREQUENCY, Hz**							
			31.5	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
I	115 kV bushings and radiators (S)	**84**	79	80	85	86	84	78	71	62	53
II	(W)	**81**	82	81	89	74	79	78	69	60	49
III	12-kV bushings (N)	**85**	81	83	86	80	84	80	74	65	56
IV	(E)	**88**	86	83	89	85	88	81	75	68	59

The sound levels received at surrounding properties strictly from the existing 28-MVA RTE-ASEA transformer (K-198) in its current location at Smokey Point Substation were computed using the CadnaA program, which is based on International Standard ISO 9613 for the prediction of environmental noise. The model takes into account the sound power level, directivity, location, and height of the noise sources, distance, ground cover and topography between the noise source and receiver, atmospheric conditions, and location and height of the receiver.

The sound calculations were executed for the five Monitoring Locations and additional three Analysis Locations listed in Section 4 and shown in Figure 2-1. The calculated A-weighted sound levels at the Analysis Locations from the existing transformer are shown in Table 4-4. The table also shows State of Washington noise limits, which are presented in detail in Section 5, and existing measured Leq.

The calculated sound levels from the existing transformer are lower than the measured sound levels at all Analysis Locations, indicating that the daytime measured sound levels contain substantial contributions from other noise source, such as traffic and commercial activities. At Location AL5-1, which is more than 1000 feet east-southeast of the project site, the measured Leq sound levels were higher than the sound levels attributable to the existing transformer by at least 25 dBA, which is consistent with the observation that the transformer does not contribute measurably to the overall sound levels at this location.

TABLE 4-4
CALCULATED SOUND LEVELS FROM EXISTING K-198 TRANSFORMER
A-WEIGHTED DECIBELS (dBA)

	Analysis Location							
	AL1-1	**AL2-1**	**AL3-1**	**AL3-2**	**AL4-1**	**AL5-1**	**AL5-2**	**AL6-1**
RTE-ASEA Transformer (K-198) at existing location	41	45	35	35	42	20	23	34
Washington State Permitted Sound Level	60	60	60	60	60	57	57	60
Measured Leq Sound Level	54	53	56	56	57	49	49	--

The calculated sound levels from the existing transformer are well below the Washington State daytime and nighttime permitted sound levels of 57 or 60 dBA (discussed in Section 5) at all Analysis Locations.

5. PERMITTED SOUND LEVELS

The Arlington Municipal Code Section 9.20.060, *Nuisance noise originating from private property or premises not open to the public,* adopts by reference the noise limits contained in Chapter 173-60, *Maximum Environmental Noise Levels,* of the Washington Administrative Code (WAC). Noise limits under WAC 173-60 are based on the Environmental Designation for Noise Abatement (EDNA) of source and receiver properties. Where a local Zoning Code is in effect, the EDNA classification is made according to the zoning designation of source and receiver properties, with residential zones generally being Class A EDNA, commercial zones Class B, and industrial zones Class C.

The maximum permissible sound levels according to WAC Chapter 173-60 are listed in Table 5-1.

TABLE 5-1
STATE OF WASHINGTON PERMITTED SOUND LEVELS (dBA)

EDNA of Sound Source	EDNA of Receiver		
	A	**B**	**C**
A	55	57	60
B	57	60	65
C	60	65	70

The Smokey Point Substation site and neighboring properties are zoned Commercial by the City of Arlington and are therefore categorized as EDNA Class B. The residences to the east, represented by Locations AL5-1 and AL5-2, are categorized as Class A EDNA.

Between the hours of 10 p.m. and 7 a.m., the permitted sound levels listed in Table 5-1 are reduced by 10 dBA for Class A EDNA receivers. Electrical substations are exempt from the reduction in noise limits for nighttime conditions; therefore the noise limit pertaining to sound produced by the transformers and received at residences to the east is 57 dBA. The noise limit at all other receiver locations is 60 dBA.

For sound sources of short duration, the noise limits are increased as follows:

- By 5 dBA for a total of fifteen minutes in any one-hour period; or,
- By 10 dBA for a total of five minutes in any one-hour period; or,
- By 15 dBA for a total of 1.5 minutes in any one-hour period.

For steady-state sound sources such as transformers, the limits of 60 dBA and 57 dBA are primarily relevant. The permitted exceedances for short-duration noises ensure that momentary noise from equipment start-up will not exceed State of Washington noise limits.

The noise limits apply to equipment within the substation. The limits do not apply to traffic on public roads or aircraft flyovers.

6. CALCULATED SOUND LEVELS FROM THE PROPOSED UPGRADES

The proposed upgrades to Smokey Point Substation would occur in two phases. In Phase I, the existing transformer K-198 would be relocated approximately 40 feet to the south-southwest and reoriented 180 degrees. In Phase II, a second 28-MVA Waukesha transformer would be installed approximately 60 feet east of transformer K-198.

A 20-foot high, 24-foot long fire wall would be placed approximately 2 feet east of the relocated transformer K-198 in order to provide the required separation between the two transformers.

The proposed added transformer is similar to the 28-MVA Waukesha transformer (Snohomish PUD K-355) currently located at the Snohomish PUD Maplewood Substation. The sound spectrum of Transformer K-355 was measured by BRC Acoustics on December 30, 2013, using a Bruel & Kjaer 2270 spectrum analyzer.

In order to quantify the noise emissions of the Waukesha transformer at Maplewood Substation, sound levels produced by the transformer were measured in octave bands at reference distances of 8 to 13 feet from the nearest surface of the transformer (or nearest fan) in four directions surrounding the unit.

The sound emissions of the 28-MVA Waukesha transformer (PUD K-355), normalized to sound power levels, are presented in Table 6-1. The sound levels shown in the table include the noise of eight cooling fans operating. The four directions are defined with respect to the principal features of the transformer and also to the proposed orientation at the Smokey Point Substation.

TABLE 6-1
SOUND POWER LEVELS
OF 28-MVA WAUKESHA TRANSFORMER PUD K-355

DIRECTION		dBA	OCTAVE-BAND CENTER FREQUENCY, Hz								
			31.5	63	125	250	500	1k	2k	4k	8k
I	115 kV bushings and radiators (N)	**84**	76	78	84	87	84	77	71	67	62
II	(E)	**85**	75	81	95	87	83	77	72	68	64
III	12-kV bushings (S)	**84**	76	81	90	84	79	78	73	71	64
IV	(W)	**83**	79	83	90	81	82	76	69	64	58

The measurements of transformer sound levels were conducted in close proximity to the unit in order to minimize the effect of other environmental noise sources. Furthermore, the transformer sound levels reported in Table 6-1 are based on the measured Lmin, which is not affected by intermittent ambient noise. However, these precautions did not completely eliminate the effect of background noise sources such as continuous traffic. For this reason, the source levels given in Table 6-1 are considered worst-case (high) estimates of the transformer emissions.

The sound levels received at surrounding properties from the proposed Phase-I and Phase-2 transformer configurations were computed using the CadnaA program, which is based on International Standard ISO 9613 for the prediction of environmental noise. The model takes into account the sound power level, directivity, location, and height of the noise sources, distance, ground cover and topography between the noise source and receiver, atmospheric conditions, and location and height of the receiver.

The computational model took into account sound reflections off the firewall proposed for Phase II of the substation upgrades. However, for a conservative (worst-case) sound analysis, the sound-shielding (barrier) effect of the firewall was not included. Furthermore, barrier effects of off-site structures, such as buildings and fences, were not included in the model.

The sound calculations were executed for the eight Analysis Locations listed in Section 4.1 and shown in Figure 2-1. The calculated A-weighted sound levels at the Analysis Locations from the proposed transformers without additional noise mitigation are shown in Table 6-2.

The table also shows the Snohomish County noise limits and the existing measured Leq at the Analysis Locations.

The calculations indicate that, without noise mitigation, A-weighted sound levels produced by the proposed transformer would be considerably below the Snohomish County daytime and nighttime noise limits of 57 or 60 dBA at all Analysis Locations. The calculated sound levels at the residential locations AL5-1 and AL5-2 shown in Table 6-2 are also below the nighttime noise limit of 47 dBA that applies to commercial source and residential receiver properties. As stated previously, electrical substations are exempt from the nighttime reduction in the noise limits.

7. SOUND MITIGATION MEASURES

The calculated sound levels presented in Table 6-2 indicate that the upgrades proposed for the Smokey Point Substation would comply with applicable noise limits at all Analysis Locations. Therefore, no additional noise mitigation measures are required.

TABLE 6-2
CALCULATED SOUND LEVELS FROM PROPOSED UPGRADES
A-WEIGHTED DECIBELS (dBA)

Phase	Sound Source	Analysis Location							
		AL1-1	AL2-1	AL3-1	AL3-2	AL4-1	AL5-1	AL5-2	AL 6-1
I	Relocated RTE-ASEA Transformer (K-198)	45	49	33	34	42	20	23	36
II	Existing Relocated K-198	45	50	33	34	42	20	23	36
	Proposed added Waukesha Transformer	44	40	33	33	46	20	22	32
	Combined Phase-II Transformers	48	50	36	37	47	23	26	37
Washington State Permitted Sound Level		60	60	60	60	60	57	57	60
Measured Leq Sound Level		54	53	56	56	57	49	49	--

APPENDIX A
Graphs of Measured Hourly Sound Levels

Figure A-1
Existing Sound Levels, Location AL1-1
June 2-3, 2016

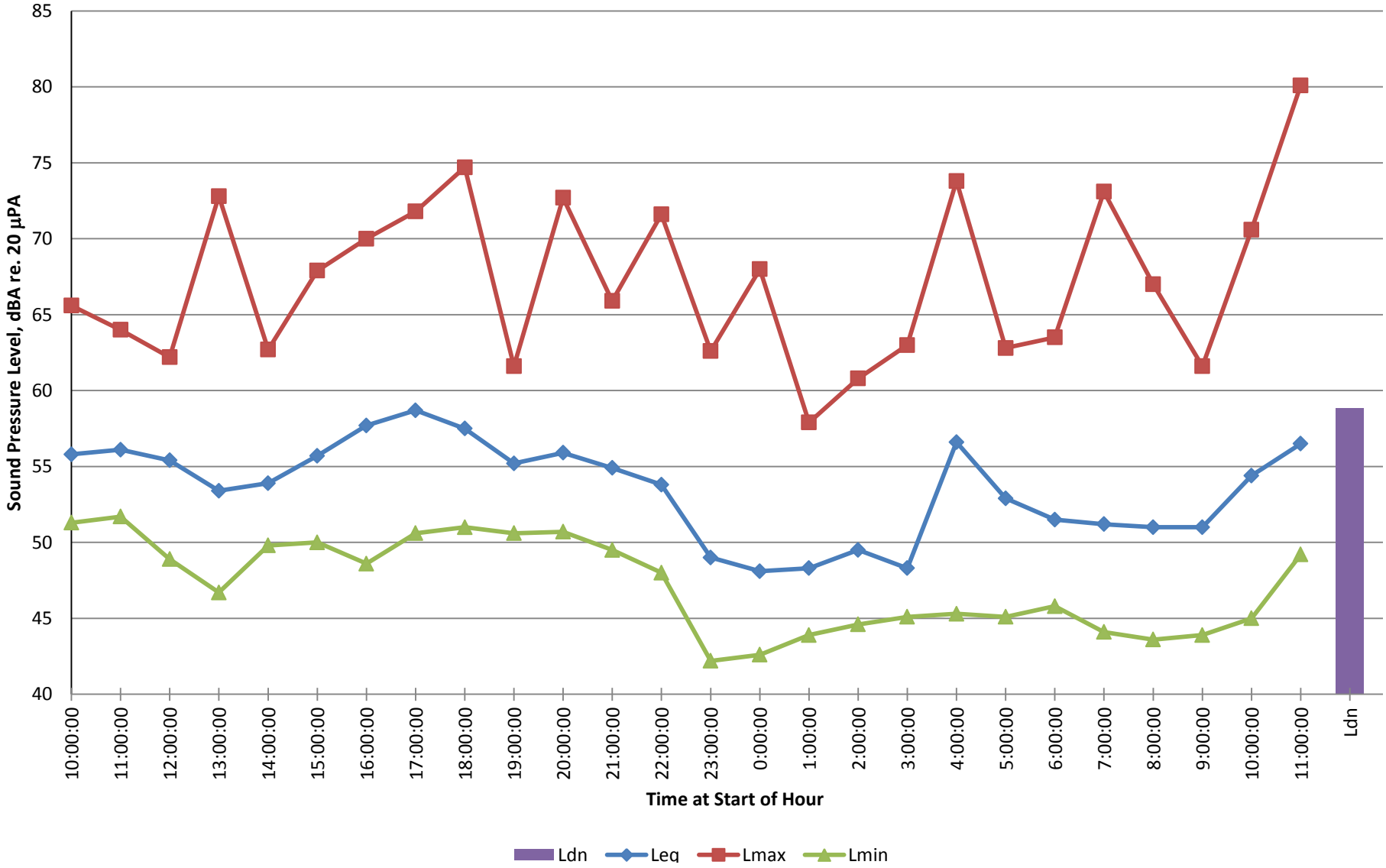

Figure A-2
Existing Sound Levels, Location AL4-1
June 2-3, 2016